Original Article

Dietary fiber intake, dietary glycemic load, and the risk of gestational diabetes mellitus during the second trimester: A nested case-control study

Qing Xu PhD†, Yang Tao MSc†, Yong Zhang PhD, Xinsheng Zhang PhD, Changyong Xue MD, Yinghua Liu PhD

Department of Nutrition, the First Medical Center of PLA General Hospital, Beijing, China
†Both authors contributed equally to this manuscript

Background and Objectives: The effect of fiber, especially the effect of specific fiber in different food groups, on gestational diabetes mellitus (GDM) has seldomly been investigated. This study aimed to examine the association between GDM risk and consumption of total fiber, fiber in specific food groups, and glycemic load (GL) in the second trimester in Chinese women. **Methods and Study Design:** A total 162 GDM cases were matched to 324 controls on women's age and pre-pregnancy BMI. Dietary survey was conducted twice to evaluate dietary factors between 13-16 gestational weeks (GW) and 21-24 GW respectively. Multivariable logistic regression analysis was used to compute the odds ratios (ORs) and 95% confidence intervals (CIs). **Results:** Intake of total fiber and fruit fiber in both 13-16 GW and in 21-24 GW were significantly correlated with decreased risk of GDM, with adjusted ORs (95% CIs): 0.06 (0.03-0.13) and 0.03 (0.01-0.08) for total fiber in the highest quartile, 0.003 (0.0002-0.02) and 0.01 (0.001-0.02) for fruit fiber in the highest quartile, respectively. In contrast, consumption of cereal fiber in 21-24 GW and daily average GL in 13-16 GW were positively associated with GDM risk, with adjusted ORs (95% CIs) of the highest quartile: 3.34 (1.45-7.92) and 3.88 (1.43-10.89) respectively. **Conclusions:** Our findings suggested consumption of dietary fiber in various food groups in the second trimester might be associated with GDM risk. Particularly, diet rich in total fiber and fruit fiber may play a protective role.

Key Words: gestational diabetes mellitus, dietary fiber, glycemic load, total fiber, fruit fiber

INTRODUCTION

Gestational diabetes mellitus (GDM) is a common complication during pregnancy that brings a wide range of significant short-term and long-term effects on mother and offspring. It comprises 5.8%-12.9% of all pregnancies worldwide.[1] Surprisingly, the prevalence of GDM in mainland China has sharply increased to 14.8% according to a meta-analysis of research published between 2010-2017.[2] GDM poses adverse effects on both mother and children. Women with GDM had an increased risk of preeclampsia, cesarean delivery, and type 2 diabetes (T2DM) in later years after pregnancy.[3] Children from GDM pregnancy are more likely to develop hypoglycemia after birth, become obese and develop diabetes in their adulthood.[3] Substantial evidence from observational studies and interventional studies supports that lifestyle and diet are modifiable factors for preventing and treating GDM. For instance, a systematic review of intervention and observational studies has shown that consumption of fiber-rich foods - fruits, vegetables, nuts and legumes - was protective factor for populations at the risk of GDM in North America, Europe, Australia, Malaysia, Korea and Iran.[4,5] Although some large observational studies in the U.S. have identified that dietary fiber is adversely associated with T2DM risk in middle-aged and older men and women,[6-10] the evidence for population at the risk of GDM is limited. Particularly, the effect of specific fiber from different food groups on GDM risk in Chinese population has seldom been investigated.

In addition, studies have also emphasized on the beneficial effects of a low glycemic index (GI) diet.[5] Glycemic load (GL), which represents overall glycemic response of an individual food with specific amount of carbohydrate,[11] covers more comprehensive effects of glycemia. It measures not only the GI of each food but also the amount of carbohydrate in each food. Research have shown that high GL was a risk factor for diabetes mellitus (DM) in non-pregnant populations.[12,13] The association between GL and the risk of GDM has also been examined in some observational studies;[14-16] however, findings of these studies were controversial. A large cohort study investigated the habitual fruit intake prior GDM revealed that GL was positively related to GDM risk, while two

Corresponding Author: Dr Yinghua Liu, Department of Nutrition, the First Medical Center of PLA General Hospital, Beijing 100853, China.
Tel: +86-10-66937619
Email: liuyinghua77@163.com
Manuscript received 23 March 2021. Initial review completed 22 April 2021. Revision accepted 22 August 2021.
doi: 10.6133/apjcn.202109_30(3).0014

studies indicated that GL was not associated with GDM. Meanwhile, researchers have suggested that dietary fiber and its source, such as whole grains, fruits, and vegetables, also play a role in the associations between GL and glucose homeostasis.[17]

For most women, the second trimester is more comfortable, compared with the first trimester when the gastrointestinal symptoms frequently happened and the third trimester when there was only limited space left for the digestive system after the fetus growing bigger. Therefore, dietary intake in the second trimester is relatively stable for most women. Accordingly, the present study aimed to investigate the relationship among fiber and its sources, GL and GDM in a sample of Chinese pregnant women in their second trimester.

METHODS

Study design and population

A 1:2 nested case-control analysis matched by age and pre-pregnancy BMI was conducted from a cohort of 1261 Chinese women. Participants were recruited at 11 hospitals from May 20th, 2012 to Dec 31st, 2013. The primary purpose of the cohort study was to investigate the relationship of dietary intake and maternal body composition with the risk of GDM, which was described in our previous paper.[18]

Pregnant women were recruited when they established their obstetric records for the regular prenatal examination. The inclusion criteria were: 1) age between 18 to 45 years old; 2) conceive a singleton fetus; 3) 12-18 gestational weeks (GW); 4) plan to deliver in the current maternity units. Exclusion criteria were a history of GDM or any types of diabetes mellitus, or any concomitant disease. Written informed consent was acquired by each subject before participation. The study was approved by the Human Subjects Committees of the PLA General Hospital and written informed consent was acquired by each enrolled subject before participation.

Assessment of dietary intakes

The method of 24-hour dietary recall on 3 consecutive days was used to evaluate the intakes of energy, protein, fat, carbohydrate, and dietary fibers in all subjects twice during the second-trimester (13-16 GW and 21-24 GW) before the screening of GDM. The quantization of dietary fiber was based on the China Food Composition Table and Food Nutrition Composition Database from U.S. Department of Agriculture.

GL value of each food item by one serving size was searched in International Table of Glycemic Index and Glycemic Load Values (International Table)[19] and University of Sydney online databases (http://www.glycemicindex.com). The daily total GL was calculated by the following formula:

total GL (g)=∑ [(daily consumption of food item i (g)) / (serving size in International Table for food i) × GL of food i]

The final daily average GL was the average of total GL values of three surveyed days.

Assessment of outcomes

The primary outcome was GDM which was diagnosed as one or more abnormal values from a 2h, 75g oral glucose tolerance test (OGTT) between 24 and 28 GW according to the criteria of The International Association of Diabetes and Pregnancy Study Groups (IADPSG) standard protocols. Threshold glucose values were as follows: fasting: 5.1 mmol/L, 1 h: 10.0 mmol/L, 2 h: 8.5 mmol/L.

Assessment of covariates

Sociodemographic characteristics, lifestyle, and pregnancy-relating medical information were collected by questionnaire during the first visit. Covariates were selected based on clinical relevance or previously reported as risk factors for GDM in other studies,[20-22] including education level, cigarette smoking status, passive smoking status, alcohol intake, gravidity, and parity. Pre-pregnancy body mass index (BMI) was calculated with self-reported height and pre-pregnancy body weight. Baseline clinical characteristics, such as albumin, triglycerides, and cholesterol were tested routinely before they established the obstetric records and were retrieved as baseline information.

Statistical analysis

To calculate the sample size, there are six factors to consider:[23] 1) number of controls per case which is 2; 2) the estimated odds ratio being 0.41 when comparing the highest versus the lowest quartile of the primary independent variable (fruit consumption), according to a previous study;[24] 3) a two-sided test with $\alpha= 0.05$; 4) a power=0.8; 5) probability that a control is exposed to the primary independent variable (adequate fruit fiber) which we chose 0.55, representing 55% of the control group who consumed more than 200g fruits (the lower level of recommended fruit consumption for pregnant women) based on our previous work;[18] 6) correlation between case and control which is 0.2. The calculated sample size with PASS11.0 (NCSS) for the case group is at least 73. Actually, we have included all the pregnant women who have developed GDM (n=162) in our multicenter cohort of 1123 women which we have described in the results part.

For the baseline data, continuous variables were presented as mean ± standard deviation and Student t-test was performed to test differences between two groups; while discrete variables were presented as frequencies (%) and Pearson's χ^2 test/ Fisher's exact test was used to analyze group differences.

Multivariable logistic analysis was used to examine the association between GDM risk and dietary factors adjusting nondietary and dietary covariates. Each dietary factor was analyzed separately to estimate odds ratios (ORs) and 95% confidence intervals (CIs). Three models were established to adjust for different covariates. In Model 1, education level (junior high or less, middle school and vocational school, college, university or higher), cigarette smoking status (never, less than 1 cigarette per day, 1-5 cigarettes per day, or more than 6 cigarettes per day), passive smoking status (None, sometimes, or often), alcohol intake (none or sometimes), gravidity (0 or ≥1), and parity (0 or ≥1) were adjusted. In Model 2, we adjusted for variables in Model 1, energy(quartile), protein intake (quartile), fat intake (quartile), and gestational weight gain (GWG). In the stage of 13-16 GW, GWG was weight change before 13 GW; whereas in the stage of 21-24 GW, GWG was weight change between 13 to 24 GW. In Model 3, we adjusted for variables in Model 2 and other fiber types (cereal, fruit, vegetable, and legume in quartile).

All statistical analysis was performed with SPSS 22.0 for windows (SPSS, Chicago, IL) and R version 3.6.3 (R Foundation for Statistical Computing). A two-sided *p* value <0.05 was considered statistically significant.

RESULTS

Sociological and clinical characteristics of study population

Within the original cohort of 1261 women, 138 subjects were excluded for the following reasons: not singleton pregnancy (n=69), had more than 15% blanks in their questionnaires (n=26), had apparent mistake in their dietary recall (n=23), underwent miscarriage (n=12), and lost to follow-up (n=8). Therefore, 1123 women finished the observation after they completed their OGTT, among which 162 subjects developed GDM. For the 162 GDM cases, each was matched two controls on maternal age and pre-pregnancy BMI.

Sociological and clinical characteristics are given in Table 1. All sociodemographic and medical characteristics were comparable between two groups except the use of alcohol. Women in GDM group had significantly higher frequency of alcohol use than the control group ($p<0.05$). No significances were seen in education, smoking habits/environment, gravidity, and parity. Among those who consumed alcohol in two groups, there were no difference in wine category, drinking frequency, or consumption amount.

Baseline clinical characteristics and weight (BMI) change

Women with GDM had significant higher weight gain between 13 GW and OGTT (medians: 9.3 kg vs 8.5 kg, $p<0.05$; Table 2) and BMI gain between 13 GW and OGTT (medians: 3.5 kg/m^2 vs 3.2 kg/m^2, $p<0.05$; Table 2) than controls. Other baseline clinical characteristics were comparable between the two groups.

Dietary intake in 13-16 GW and association with gestational diabetes

Dietary intakes between GDM group and control group in 13-16 GW were significantly different except seafood, eggs, soybean and legume fiber, with higher total energy, protein, fat, carbohydrate, cereal fiber, and daily average GL in GDM group and higher total dietary fiber, fruit fiber, and vegetable fiber in control group (Table 3).

The effects of dietary fiber intakes and GL in 13-16 GW on GDM risks are shown in Table 4. The likelihood of GDM decreased as the consumption of total fiber and fruit fiber increased in quartiles. Compared with the lowest quartile, higher total fiber consumption was associated with lower likelihood of GDM (highest vs. lowest quartile in Model 2: OR, 0.06; 95% CI 0.03 to 0.13). Likewise, as the consumption of fruit fiber increased in quartiles, the likelihood of GDM decreased in gradient. The adjusted ORs in Model 3 across the lowest to highest quartiles of fruit fiber consumption were 1.00 (reference), 0.03 (95% CI 0.01 to 0.08), 0.01 (95% CI 0.001 to 0.02), and 0.003 (95% CI 0.0002 to 0.02), respectively. Vegetable fiber consumption was initially negatively associated with GDM after adjusting energy, protein, fat, weight change, and other non-dietary covariables, but this association was attenuated to null in Model 3 after adjusting other types of fiber (highest vs. lowest quartile in Model 3: OR, 0.45; 95% CI 0.18 to 1.11).

On the contrary, greater consumption of GL was associated with higher likelihood of GDM. Compared with the lowest quartile, the highest quartile for daily average GL consumption was associated with a higher likelihood of GDM (adjusted OR in Model 3, 3.88; 95% CI 1.43 to 10.89). At first, cereal fiber consumption shown positive association with GDM after adjusting energy, protein, fat, weight change, and other non-dietary covariables, but this association was attenuated to null in Model 3 (highest vs. lowest quartile in Model 3: OR, 1.21; 95% CI 0.47 to 3.07). Additionally, no significant association was observed between GDM and legume fiber consumption.

Dietary intake in 21-24 GW and association with gestational diabetes

In 21-24 GW, GDM group still consumed higher total energy, protein, carbohydrate, cereal fiber, and high GL food with significance compared with control group, while control group ate significantly more vegetables and fruits which result in higher total dietary fiber and fruit fiber consumption. Meanwhile, GDM group consumed more legume fiber in a similar manner to 13-16 GW, but with statistical significance. There was no difference in intakes of fat and vegetable fiber between GDM group and control group.

As shown in Table 5, similar to the GW 13-16, the likelihood of GDM decreased as the intake of total fiber and fruit fiber increased. Compared with the corresponding lowest quartiles, the highest quartile for consumption of total fiber and fruit fiber intake were each related to a lower likelihood of GDM (adjusted OR in Model 2, 0.03; 95% CI 0.01 to 0.08; adjusted OR in Model 3, 0.01; 95% CI 0.001 to 0.03, respectively). In parallel with the findings in 13-16 GW, the association between vegetable fiber intake and GDM was inverse after adjusting energy, protein, fat, weight change, and other non-dietary covariables, but was attenuated to null after adjusting other types of fiber (highest vs. lowest quartile in Model 3: OR, 0.49; 95% CI 0.19 to 1.28).

In contrast, compared with the lowest quartile, the highest quartile for consumption of cereal fiber was associated with a higher likelihood of GDM even after adjusted other types of dietary fiber and other confounding factors (adjusted OR in Model 3, 3.34; 95% CI 1.45 to 7.92). Compared with the lowest quartile, the highest quartile for GL consumption was positively associated with the likelihood of GDM in Model 2, but the association attenuated to null after adjusting all dietary fibers in each subgroup (adjusted OR in Model 3, 2.11; 95% CI 0.76 to 5.98). Moreover, no significant association was observed between legume fiber consumption and GDM.

Table 1. The characteristics of participating individuals (n=486)

	GDM case subjects	Control subjects	*p* value
N	162	324	
Maternal age (years)	30.65±3.23	30.23±2.90	
18-25	6 (3.7)	12 (3.7)	
26-30	69 (42.6)	138 (42.6)	
31-35	77 (47.5)	154 (47.5)	
36-40	9 (5.6)	18 (6.2)	
41-45	1 (0.6)	1 (0.6)	
Pre-pregnancy BMI (kg/m^2)	22.09±3.40	22.08±3.41	
Under weight (lower than18.5)	17 (10.5)	34 (10.5)	
Normal weight (18.5-23.9)	107 (66.0)	214 (66.0)	
Overweight (24-27.9)	24 (14.8)	48 (14.8)	
Obese (28 or higher)	14 (8.6)	28 (8.6)	
Education			0.362
Lower than junior high school	1 (0.6)	9 (2.8)	
Senior middle school and vocational school	10 (6.2)	15 (4.6)	
College	41 (25.3)	75 (23.1)	
Higher than university	110 (67.9)	225 (69.4)	
Smoke			0.086
None	160 (98.8)	256 (79.0)	
Less than 1 cigarette per day	1 (0.6)	68 (21.0)	
1-5 cigarettes per day	0	0	
6-9 cigarettes per day	1 (0.6)	0	
More than 10 cigarettes per day	0	0	
Passive smoking			0.069
None	65 (40.1)	122 (37.7)	
Sometimes	86 (53.1)	157 (48.5)	
Often	11 (6.8)	45 (13.9)	
Alcohol			0.042
None	114 (70.4)	256 (79.0)	
Sometimes	48 (29.6)	68 (21.0)	
Wine category			0.176
Spirit	7 (4.3)	10 (3.1)	
Wine	20 (12.3)	36 (11.1)	
Beer	20 (12.3)	21 (6.5)	
Yellow rice or millet wine	0	0	
Others	1 (0.6)	1 (0.3)	
Drinking frequency			0.064
Less than 1-2 times per week	42 (25.9)	63 (19.4)	
1-2 times per week	3 (1.9)	1 (0.3)	
3-4 times per week	0	2 (0.6)	
5-7 times per week	3 (1.9)	2 (0.6)	
Alcohol consumption			0.207
Less than 1 cup per time	44 (27.2)	62 (19.1)	
1-2 cups per time	3 (1.9)	5 (1.5)	
3-4 cups per time	1 (0.6)	1 (0.3)	
Gravidity			0.918
None	111 (68.5)	219 (67.6)	
More than 1 time	51 (31.5)	105 (32.4)	
Parity			0.555
None	162 (100.0)	322 (99.4)	
More than 1 time	0	2 (0.6)	

BMI; body mass index, (kg/m^2).
†Data are presented as n (%) or mean±standard deviation.

DISCUSSION

In our previous study, we found that body weight, energy, carbohydrate, fat, and protein during the second trimester were associated with an increased risk of GDM,[18] which drew attention to the importance of dietary factors in the second trimester. In our nested case-control study, we collected data of dietary intake at the beginning of the second trimester and the time point right before the OGTT test. In this study, we observed that intake of total fiber and fruit fiber in 13-16 GW and in 21-24 GW were significantly correlated with decreased risk of GDM. In contrast, consumption of daily average GL in 13-16 GW and cereal fiber in 21-24 GW was associated with increased risk of GDM. We are unaware of other studies that focused on the association between fiber consumption in the second trimester and GDM risk. Our findings of the protective role of total fiber and fruit fiber in GDM were conforming to the NHSII which involved 13,110 subjects and explored the association between habitual pre-pregnancy fiber intake and GDM risk.[15] There are several potential mechanisms that lead to the protective role of total fiber and fruit fiber. First, dietary fiber may

Table 2. Clinical characteristics of the study population

	GDM (n=162)	Control (n=324)	*p* value
Albumin (g/L)	42.8±5.04	42.9±3.71	0.711
BUN (mmol/L)	2.9±0.89	2.9±0.86	0.501
sCr (mmol/L)	47.8±8.3	47.6±12.3	0.855
TG (mmol/L)	1.4±0.64	1.4±0.70	0.877
TC (mmol/L)	4.7±0.84	4.6±0.78	0.222
HDL-c (mmol/L)	1.7±0.34	1.7±0.31	0.808
LDL-c (mmol/L)	2.5±0.63	2.4±0.60	0.137
SBP (mmHg)	109±8.19	110±8.01	0.380
DBP (mmHg)	70.2±6.43	70.9±6.78	0.286
WG before 13GW	1.5±1.79	1.3±1.50	0.135
WG between 13GW and OGTT	9.3±3.47	8.5±3.38	0.027
BMIG before 13 GW	0.55±0.68	0.47±0.70	0.264
BMIG between 13GW and OGTT	3.5±1.30	3.2±1.26	0.025

BUN: blood urea nitrogen; sCr: serum creatinine; TG: triglyceride; TC: total cholesterol; HDL-c: high density lipoprotein cholesterol; LDL-c: low density lipoprotein cholesterol; SBP: systolic blood pressure; DBP: diastolic blood pressure; WG: weight gain; GW: gestational week; OGTT: oral glucose tolerance test; BMIG: body mass index gain.
Data are mean±standard deviation.

increase satiety and lower the intake of energy.[25] Second, fiber, especially the soluble fiber, can also slow glucose absorption and subsequently promote insulin levels.[26] Third, adequate amount of fiber could promote growth of gut bacteria that could generate short-chain fatty acids and decrease the likelihood of insulin resistance in pregnant women.[27]

Studies focused on fruit fiber intake in the second trimester and GDM is limited. However, there are many studies examining relationship between fruit consumption and GDM risk. A Chinese prospective cohort study in Wuhan involving 3,300 participants found that higher overall fruit consumption in second trimester is protective in GDM.[24] The likelihood of GDM decreased 59% in the highest quintile of fruit consumption (median, 671 g/d). There are many studies that support the protective role of fruit intake in type 2 diabetes.[28-30] Yet, another Chinese cohort study in Guangdong indicated that excessive consumption of fruit (the median of the highest quartile was 710 g) during the second trimester was associated with risk of GDM.[31] In fact, they consumed much more citrus fruit and tropical fruit with moderate-to-high GI values than our population due to geographic difference, and fruits consumed the most in our study were low-GI, fiber-rich fruit, such as apple, pear, peach, and berries. Therefore, GI/GL value of fruits may play a contributive role in the association between fruit/fruit fiber intake and GDM risk. This is in accordance with the finding in the Wuhan cohort that low GL fruits, rather than high GL fruits, were associated with a lower GDM risk.[24]

To the best of our knowledge, no previous studies have especially examined the association between legume fiber and GDM. Our study found no association between legume fiber and GDM likelihood. Large prospective studies involving 75,344 and 71,346 subjects respectively found that moderate to high intake of soy foods was associated with a slightly higher T2DM risk.[32,33] However, a series of other observational studies described a protective role of legume consumption on diabetes risk.[34-36] The reason behind this discrepancy could be different kinds of legume products consumed besides legume fiber. When divided the legume products into unsweetened and sweetened ones, researchers found that unsweetened one was inversely associated with diabetes risk; whereas sweetened one was positively associated with diabetes risk.[34] Therefore, further studies analyzing the influence of legume fiber and added sugar in the legume products on GDM risks are needed in the future.

When analyzed in Model 2 adjusting energy, protein, fat, weight change, and other non-dietary covariables, consumption of cereal fiber in both 13-16 GW and in 21-24 GW were positively associated with GDM. This association still existed in 21-24 GW after adjusting other types of dietary fibers. However, this finding was inconsistent with the NHSII in which the highest quintile of cereal fiber was related to a lower likelihood of GDM.[15] The cut point of the highest quartile/quintile levels of cereal fiber in the current study and the NHSII were 3.5 g/day and 7.2 g/day respectively, which revealed the consumption of cereal fiber was much more in the NHSII population. The probable reason for the discrepant role of cereal fiber in the two studies could be that the population in our study did not consume enough cereal fiber. Moreover, the percentage of whole grain fiber in cereal fiber is also important. In a meta-analysis,[28] researchers found that whole grains consumption, but not refined grains consumption, played a protective role in T2DM. In China, staple food is mainly refined rice and flour which are low in dietary fiber; therefore, it is hard to reach such a high consumption of cereal fiber in a general population. The more cereal fiber one consumed in China; the more carbohydrate was consumed alongside. As a result, the association between cereal fiber and GDM may due to the excessive refined grains intake.

In this study, the protective association between vegetable fiber and GDM was approaching but not yet significant. Correspondingly, the NHSII found no association between pre-pregnancy vegetable fiber consumption and GDM risk even though there seemed to be a reduction in the risk in higher consumption subgroups.[15] Moreover, in a meta-analysis of 13 prospective studies of 63299 individuals about relationship between vegetable intake and T2DM risk found only a borderline inverse association for the high vs low (RR: 0.95; CI 0.89-1.01),[29] with inverse association observed only in Asian and Australian studies and in studies with smaller samples. Therefore,

Table 3. Dietary intake in the second trimester pregnancy

	13-16 GW		*p* value	21-24 GW		*p* value
	GDM (n=162)	Control (n=324)		GDM (n=162)	Control (n=324)	
Energy (kcal/d)	2020±203	1860±221	<0.001	2070±217	1970±192	<0.001
Protein (g/d)	81.1±15.3	73.9±16.2	<0.001	84.4±16.0	79.8±15.1	0.002
Fat (g/d)	75.6±14.5	70.3±14.0	<0.001	77.4±17.4	75.6±14.0	0.217
Carbohydrate (g/d)	246±32.8	231±32.0	<0.001	253±33.5	240±30.1	<0.001
Total dietary fiber (g/d)	11.0±3.5	14.4±4.5	<0.001	11.7±4.7	15.2±4.9	<0.001
Cereal fiber (g/d)	3.5±1.4	2.9±1.3	<0.001	3.5±1.4	3.1±1.4	<0.001
Legume fiber (g/d)	2.9±4.0	2.3±3.2	0.108	3.0±3.4	2.3±3.5	0.046
Fruit fiber (g/d)	1.1±1.2	4.6±2.0	<0.001	1.2±1.2	4.6±1.8	<0.001
Vegetable fiber (g/d)	1.1±1.2	4.2±3.2	0.032	4.2±3.7	4.7±3.2	0.147
Daily average GL	167±25.6	148±22.4	<0.001	170±26.2	153±4.9	<0.001
Grains (g/d)	220±74.7	194±80.8	<0.001	238±86.7	209±78.1	0.002
Vegetables (g/d)	231±42.6	405±39.4	<0.001	416±45.4	464±55.4	<0.001
Fruits (g/d)	142±154	462±154	<0.001	151±100	416±125	<0.001
Meat (g/d)	87.3±29.6	73.5±28.3	<0.001	89.2±29.3	81.1±23.3	0.001
Seafood (g/d)	15.3±9.9	16.7±9.2	0.124	32.8±24.2	17.7±17.1	<0.001
Eggs (g/d)	56.7±15.4	59.0±14.8	0.112	58.3±19.2	49.2±17.3	<0.001
Dairy products (g/d)	210±80.9	227±57.3	0.008	260±100.0	258±92.6	0.793
Soybean (g/d)	9.3±7.2	8.2±6.8	0.100	9.6±5.3	8.6±4.5	0.030
Nuts (g/d)	6.8±4.3	7.5±3.2	0.044	13.7±8.9	12.5±9.4	0.178
Oil (g/d)	33.4±5.7	28.0±6.5	<0.001	38.6±18.4	32.3±9.6	0.166

Table 4. Relative risks of GDM according to quartiles of dietary fiber intakes and glycemic load (GL) in 13-16GW

	Quartiles	GDM (n=162)	Control (n=324)	Model 1		Model 2		Model 3	
				Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value
Total fiber	<11.11	93 (57.4)	81 (25)	Reference		Reference			
(g)	11.12-13.69	40 (24.7)	81 (25)	0.38 (0.22-0.62)	<0.001	0.23 (0.13-0.42)	<0.001	N/A	N/A
	13.70-16.68	15 (9.3)	81 (25)	0.15 (0.08-0.29)	<0.001	0.08 (0.04-0.16)	<0.001		
	>16.68	14 (8.6)	81 (25)	0.14 (0.07-0.26)	<0.001	0.06 (0.03-0.13)	<0.001		
Cereal fiber	<2.02	23 (14.2)	81 (25)	Reference		Reference		Reference	
(g)	2.23-2.63	22 (13.6)	81 (25)	0.97 (0.49-1.90)	0.924	0.89 (0.43-1.83)	0.746	0.58 (0.20-1.67)	0.315
	2.64-3.50	46 (28.4)	81 (25)	1.96 (1.09-3.61)	0.027	1.47 (0.78-2.81)	0.231	0.53 (0.20-1.38)	0.202
	>3.50	71 (43.8)	81 (25)	3.09 (1.76-5.57)	<0.001	2.36 (1.28-4.42)	0.006	1.21 (0.47-3.07)	0.686
Legume fiber	<0.49	41 (25.3)	81 (25)	Reference		Reference		Reference	
(g)	0.50-1.32	30 (18.5)	81 (25)	0.77 (0.43-1.37)	0.380	0.69 (0.36-1.30)	0.248	0.22 (0.08-0.57)	0.002
	1.33-3.01	38 (23.5)	81 (25)	0.94 (0.54-1.65)	0.841	0.75 (0.41-1.36)	0.342	0.61 (0.23-1.57)	0.305
	>3.01	53 (32.7)	81 (25)	1.48 (0.87-2.53)	0.151	1.12 (0.62-2.03)	0.694	0.68 (0.27-1.68)	0.407
Fruit fiber	<3.34	151 (93.2)	81 (25)	Reference		Reference		Reference	
(g)	3.35-4.28	8 (4.9)	81 (25)	0.06 (0.02-0.12)	<0.001	0.04 (0.02-0.10)	<0.001	0.03 (0.01-0.08)	<0.001
	4.29-5.42	2 (1.2)	81 (25)	0.01 (0.002-0.04)	<0.001	0.01 (0.001-0.03)	<0.001	0.01 (0.001-0.02)	<0.001
	>5.42	1 (0.6)	81 (25)	0.005 (0.0003-0.02)	<0.001	0.003 (0.0002-0.02)	<0.001	0.003 (0.0002-0.02)	<0.001
Vegetable	<2.29	44 (27.2)	81 (25)	Reference		Reference		Reference	
fiber	2.30-3.55	52 (32.1)	81 (25)	1.21 (0.71-2.05)	0.482	1.02 (0.57-1.83)	0.932	0.91 (0.39-2.10)	0.818
(g)	3.56-5.04	35 (21.6)	81 (25)	0.81 (0.46-1.41)	0.458	0.76 (0.41-1.39)	0.370	0.73 (0.30-1.73)	0.476
	>5.04	31 (19.1)	81 (25)	0.69 (0.39-1.22)	0.202	0.44 (0.23-0.81)	0.010	0.45 (0.18-1.11)	0.085
Daily	<136.53	19 (11.7)	81 (25)	Reference		Reference		Reference	
average GL	136.54-150.31	17 (10.5)	81 (25)	0.96 (0.45-2.00)	0.905	0.86 (0.39-1.89)	0.707	1.38 (0.49-3.96)	0.540
	150.32-162.69	40 (24.7)	81 (25)	2.18 (1.16-4.22)	0.018	2.04 (1.00-4.22)	0.052	3.50 (1.33-9.56)	0.012
	>162.69	86 (53.1)	81 (25)	4.61 (2.57-8.60)	<0.001	3.40 (1.67-7.10)	0.001	3.88 (1.43-10.89)	0.009

GDM: gestational diabetes mellitus; GW: gestational week; GL: glycemic load; N/A: not applicable.
Model 1: adjusted for education level, cigarette smoking status, passive smoking status, alcohol intake, gravidity, and parity.
Model 2: adjusted for variables in Model 1, energy(quartile), protein intake (quartile), fat intake (quartile), and weight change before 13GW.
Model 3: adjusted for variables in Model 2 and other fiber types (cereal, fruit, vegetable, and legume in quartile).

Table 5. Relative risks of GDM according to quartiles of dietary fiber intakes and glycemic load (GL) in 21-24GW

	Quartiles	GDM (n=162)	Control (n=324)	Model 1		Model 2		Model 3	
				Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value
Total fiber (g)	<11.11	93 (57.4)	81 (25)	Reference		Reference		N/A	N/A
	11.12-13.69	40 (24.7)	81 (25)	0.42 (0.25-0.70)	<0.001	0.32 (0.18-0.55)	<0.001		
	13.70-16.68	15 (9.3)	81 (25)	0.24 (0.13-0.42)	<0.001	0.15 (0.08-0.29)	<0.001		
	>16.68	14 (8.6)	81 (25)	0.07 (0.03-0.15)	<0.001	0.03 (0.01-0.08)	<0.001		
Cereal fiber (g)	< 2.02	23 (14.2)	81 (25)	Reference		Reference		Reference	
	2.23-2.63	22 (13.6)	81 (25)	1.38 (0.71-2.70)	0.343	1.41 (0.71-2.86)	0.328	1.63 (0.64-4.25)	0.310
	2.64-3.50	46 (28.4)	81 (25)	3.03 (1.67-5.66)	<0.001	3.59 (1.90-7.00)	<0.001	3.44 (1.49-8.25)	0.004
	>3.50	71 (43.8)	81 (25)	3.09 (1.71-5.75)	<0.001	3.48 (1.86-6.76)	<0.001	3.34 (1.45-7.92)	0.005
Legume fiber (g)	< 0.49	41 (25.3)	81 (25)	Reference		Reference		Reference	
	0.50-1.32	30 (18.5)	81 (25)	1.20 (0.65-2.22)	0.557	1.08 (0.57-2.06)	0.808	0.62 (0.25-1.53)	0.304
	1.33-3.01	38 (23.5)	81 (25)	1.25 (0.69-2.27)	0.465	0.93 (0.49-1.76)	0.829	0.71 (0.28-1.77)	0.464
	>3.01	53 (32.7)	81 (25)	2.17 (1.25-3.83)	0.006	1.68 (0.92-3.10)	0.091	1.60 (0.67-3.84)	0.291
Fruit fiber (g)	< 3.34	151 (93.2)	81 (25)	Reference		Reference		Reference	
	3.35-4.28	8 (4.9)	81 (25)	0.04 (0.02-0.09)	<0.001	0.03 (0.01-0.08)	<0.001	0.03 (0.01-0.08)	<0.001
	4.29-5.42	2 (1.2)	81 (25)	0.01 (0.002-0.04)	<0.001	0.01 (0.001-0.03)	<0.001	0.01 (0.001-0.03)	<0.001
	>5.42	1 (0.6)	81 (25)	0.01 (0.002-0.04)	<0.001	0.01 (0.001-0.02)	<0.001	0.01 (0.001-0.03)	<0.001
Vegetable fiber (g)	< 2.29	44 (27.2)	81 (25)	Reference		Reference		Reference	
	2.30-3.55	52 (32.1)	81 (25)	1.04 (0.61-1.77)	0895	0.88 (0.50-1.57)	0.678	1.15 (0.51-2.57)	0.737
	3.56-5.04	35 (21.6)	81 (25)	1.00 (0.59-1.69)	0.997	0.68 (0.38-1.21)	0.192	0.74 (0.31-1.72)	0.479
	>5.04	31 (19.1)	81 (25)	0.57 (0.31-1.01)	0.057	0.35 (0.18-0.67)	0.002	0.49 (0.19-1.28)	0.148
Daily average GL	< 136.53	19 (11.7)	81 (25)	Reference		Reference		Reference	
	136.54-150.31	17 (10.5)	81 (25)	1.20 (0.59-2.43)	0.616	1.18 (0.56-2.48)	0.663	0.45 (0.16-1.26)	0.130
	150.32-162.69	40 (24.7)	81 (25)	1.42 (0.72-2.83)	0.317	1.50 (0.72-3.17)	0.278	0.55 (0.18-1.66)	0.296
	>162.69	86 (53.1)	81 (25)	5.17 (2.87-9.69)	<0.001	4.58 (2.26-9.61)	<0.001	2.11 (0.76-5.98)	0.156

GDM: gestational diabetes mellitus; GW: gestational week; GL: glycemic load; N/A: not applicable.
Model 1: adjusted for education level, cigarette smoking status, passive smoking status, alcohol intake, gravidity, and parity.
Model 2: adjusted for variables in Model 1, energy intake(quartile), protein intake (quartile), fat intake (quartile), and weight change between 13GW to OGTT test.
Model 3: adjusted for variables in Model 2 and other fiber types (cereal, fruit, vegetable, and legume in quartile).

studies investigating association between vegetable fiber/vegetable consumption with GDM risks in larger Chinese pregnant women populations is required.

The highest quartile of daily average GL (median 163 g/d) was positively associated with the risk of GDM in both 13-16 GW and 21-24 GW adjusting energy, protein, fat, weight change, and other non-dietary covariables. This association was still significant in 13-16 GW after adjusting other types of dietary fibers. This finding is in parallel with the NHSII in which the highest quintile of GL (median 212 g/d) was associated with increased likelihood of GDM.[15] A dose-response meta-analysis including prospective cohort studies from 1946 to December 2018 also indicated that higher GL substantially increased the likelihood of T2DM.[37] Another meta-analysis confirmed this robust and consistent positive relation between GL and T2DM risk, with 42% increase risk for a 100g increment in GL.[38] In a study of 306 young female, Arikawa et al found that high GL was marginally associated with oxidative stress which was considered to be involved in the etiology of diabetes process.[39] Additionally, a cross-sectional study found that high GL was associated with insulin resistance.[40]

The strength of this study including: a relatively large sample size from multi-centers prospective study, and analyzing association of GDM risk with dietary fiber in various food subgroups. A limitation of present study is the reliability of self-reported dietary recall. Also, the GL was calculated using an international database in which most foods were derived from western countries; therefore, GL of some foods in this study may not been calculated correctly, especially some traditional foods that were unique in Chinese culture. Moreover, we didn't include free sugar in our dietary survey since the major sources come not only from sugar-sweeten foods, but also as a condiment in the cooking process. Notably, the relatively small OR values in fruit fiber consumption in all three models suggesting that sample size of this research may be limited. Besides, the other reason for these small OR values may be the very small variance of fruit fiber consumption as a continuous variable in the studied population. The interquartile of fruit fiber consumption lies between 3.35 g to 5.42 g. One gram of fruit fiber could mean a lot of real fruits, such as 250 g grapes/orange or 333 g cherries. Therefore, even though the number of fruit fiber didn't change much in each quartile, the actual fruit consumption could be quite different. Correspondingly, the small OR of highest quartile versus the lowest quartile may reveal the GDM risk of huge fruit consumption. Further research with larger sample size on fiber consumption of various food groups in the second trimester is needed to verify our findings.

Conclusion

In conclusion, we investigated relationship of GDM risk to the intake of different sorts of dietary fibers and total dietary GL by dietary surveys in the second trimester. Our findings suggested that total fiber and fruit fiber were associated with lower risk of GDM. On the contrary, cereal fiber and daily average GL were positively associated with risk of GDM. This implies that pregnant women should meet daily recommendations for each food category to gain proper fiber intake and limit high GL foods for preventing GDM.

ACKNOWLEDGEMENTS

We are grateful to all subjects who participated in this study, and to Dr Botao Guo for his help in data analysis. We also sincerely thank all the participants who worked on this study in the 11 clinical centers: the First Medical Center of PLA General Hospital General Hospital, the Fourth Medical Center of PLA General Hospital, Beijing Hospital, Tongren Hospital, Haidian District Health Center for Women and Children, Jishuitan Hospital, the Sixth People's Hospital of Shanghai, Chinese PLA General Air Force Center, People's Hospital of Sichuan Province and Bethune International Peace Hospital.

AUTHOR DISCLOSURES

The authors declare no conflict of interest.

REFERENCES

1. Zhu Y, Zhang C. Prevalence of gestational diabetes and risk of progression to type 2 diabetes: a global perspective. Curr Diab Rep. 2016;16:7. doi: 10.1007/s11892-015-0699-x.
2. Gao C, Sun X, Lu L, Liu F, Yuan J. Prevalence of gestational diabetes mellitus in mainland China: A systematic review and meta-analysis. J Diabetes Investig. 2019;10:154-62. doi: 10.1111/jdi.12854.
3. American Diabetes Association. Gestational diabetes mellitus. Diabetes Care. 2004;27(Suppl 1):S88-90. doi: 10.2337/diacare.27.2007.s88.
4. Mirmiran P, Hosseinpour-Niazi S, Moghaddam-Banaem L, Lamyian M, Goshtasebi A, Azizi F. Inverse relation between fruit and vegetable intake and the risk of gestational diabetes mellitus. Int J Vitam Nutr Res. 2019;89:37-44. doi: 10.1024/0300-9831/a000475.
5. D'Arcy E, Rayner J, Hodge A, Ross LJ, Schoenaker D. The role of diet in the prevention of diabetes among women with prior gestational diabetes: a systematic review of intervention and observational studies. J Acad Nutr Diet. 2020;120:69-85.e7. doi: 10.1016/j.jand.2019.07.021.
6. Meyer KA, Kushi LH, Jacobs DR, Jr., Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Am J Clin Nutr. 2000;71:921-30. doi: 10.1093/ajcn/71.4.921.
7. Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, Willett WC. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. N Engl J Med. 2001; 345:790-7. doi: 10.1056/NEJMoa010492.
8. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. Am J Clin Nutr. 2004;80:348-56. doi: 10.1093/ajcn/80.2.348.
9. AlEssa HB, Bhupathiraju SN, Malik VS, Wedick NM, Campos H, Rosner B, Willett WC, Hu FB. Carbohydrate quality and quantity and risk of type 2 diabetes in US women. Am J Clin Nutr. 2015;102:1543-53. doi: 10.3945/ajcn.115.116558.
10. Hopping BN, Erber E, Grandinetti A, Verheus M, Kolonel LN, Maskarinec G. Dietary fiber, magnesium, and glycemic load alter risk of type 2 diabetes in a multiethnic cohort in Hawaii. J Nutr. 2010;140:68-74. doi: 10.3945/jn.109.112441.
11. Willett W, Manson J, Liu S. Glycemic index, glycemic load, and risk of type 2 diabetes. Am J Clin Nutr. 2002;76:274s-80s. doi: 10.1093/ajcn/76/1.274S.
12. Salmerón J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of

non-insulin-dependent diabetes mellitus in women. JAMA. 1997;277:472-7. doi: 10.1001/jama.1997.03540300040031.
13. Sluijs I, van der Schouw YT, van der AD, Spijkerman AM, Hu FB, Grobbee DE, Beulens JW. Carbohydrate quantity and quality and risk of type 2 diabetes in the European Prospective Investigation into Cancer and Nutrition-Netherlands (EPIC-NL) study. Am J Clin Nutr. 2010;92: 905-11. doi: 10.3945/ajcn.2010.29620.
14. Hasbullah FY, Mohd Yusof BN, Shariff ZM, Rejali Z, Yong HY, Mitri J. Factors associated with dietary glycemic index and glycemic load in pregnant women and risk for gestational diabetes mellitus. Int J Food Sci Nutr. 2020;71: 516-24. doi: 10.1080/09637486.2019.1686752.
15. Zhang C, Liu S, Solomon CG, Hu FB. Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. Diabetes Care. 2006;29:2223-30. doi: 10. 2337/dc06-0266.
16. Radesky JS, Oken E, Rifas-Shiman SL, Kleinman KP, Rich-Edwards JW, Gillman MW. Diet during early pregnancy and development of gestational diabetes. Paediatr Perinat Epidemiol. 2008;22:47-59. doi: 10.1111/j.1365-3016.2007. 00899.x.
17. Vega-López S, Venn BJ, Slavin JL. Relevance of the glycemic index and glycemic load for body weight, diabetes, and cardiovascular disease. Nutrients. 2018;10:1361. doi: 10.3390/nu10101361.
18. Xu Q, Gao ZY, Li LM, Wang L, Zhang Q, Teng Y et al. The Association of maternal body composition and dietary intake with the risk of gestational diabetes mellitus during the second trimester in a cohort of Chinese pregnant women. Biomed Environ Sci. 2016;29:1-11. doi: 10.3967/bes2016. 001.
19. Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values: 2002. Am J Clin Nutr. 2002;76:5-56. doi: 10.1093/ajcn/76.1.5.
20. Ianniello F, Quagliozzi L, Caruso A, Paradisi G. Low adiponectin in overweight/obese women: association with diabetes during pregnancy. Eur Rev Med Pharmacol Sci. 2013;17:3197-205.
21. Zhu Y, Li M, Rahman ML, Hinkle SN, Wu J, Weir NL et al. Plasma phospholipid n-3 and n-6 polyunsaturated fatty acids in relation to cardiometabolic markers and gestational diabetes: A longitudinal study within the prospective NICHD Fetal Growth Studies. PLoS Med. 2019;16: e1002910. doi: 10. 1371/journal.pmed.1002910.
22. Feng P, Wang G, Yu Q, Zhu W, Zhong C. First-trimester blood urea nitrogen and risk of gestational diabetes mellitus. J Cell Mol Med. 2020;24:2416-22. doi: 10.1111/jcmm. 14924.
23. Dupont WD. Power calculations for matched case-control studies. Biometrics. 1988;44:1157-68.
24. Zhou X, Chen R, Zhong C, Wu J, Li X, Li Q et al. Fresh fruit intake in pregnancy and association with gestational diabetes mellitus: A prospective cohort study. Nutrition. 2019;60:129-135. doi: 10.1016/j.nut.2018.09.022.
25. Marlett JA, McBurney MI, Slavin JL. Position of the American Dietetic Association: health implications of dietary fiber. J Am Diet Assoc. 2002;102:993-1000. doi: 10. 1016/s0002-8223(02)90228-2.
26. Jovanovski E, Khayyat R, Zurbau A, Komishon A, Mazhar N, Sievenpiper J et al. Should viscous fiber supplements be considered in diabetes control? Results from a systematic review and meta-analysis of randomized controlled trials. Diabetes Care. 2019;42:755-66. doi: 10.2337/dc18-1126.
27. Gomez-Arango LF, Barrett HL, Wilkinson SA, Callaway LK, McIntyre HD, Morrison M, Nitert MD. Low dietary fiber intake increases Collinsella abundance in the gut microbiota of overweight and obese pregnant women. Gut Microbes. 2018;9:189-201. doi: 10.1080/19490976.2017. 1406584.
28. Schwingshackl L, Hoffmann G, Lampousi AM, Knüppel S, Iqbal K, Schwedhelm C, Bechthold A, Schlesinger S, Boeing H. Food groups and risk of type 2 diabetes mellitus: a systematic review and meta-analysis of prospective studies. Eur J Epidemiol. 2017;32:363-75. doi: 10.1007/s10654-017-0246-y.
29. Mamluk L, O'Doherty MG, Orfanos P, Saitakis G, Woodside JV, Liao LM, Sinha R, Boffetta P, Trichopoulou A, Kee F. Fruit and vegetable intake and risk of incident of type 2 diabetes: results from the consortium on health and ageing network of cohorts in Europe and the United States (CHANCES). Eur J Clin Nutr. 2017;71:83-91. doi: 10. 1038/ejcn.2016.143.
30. Muraki I, Imamura F, Manson JE, Hu FB, Willett WC, van Dam RM, Sun Q. Fruit consumption and risk of type 2 diabetes: results from three prospective longitudinal cohort studies. BMJ. 2013;347:f5001. doi: 10.1136/bmj.f5001.
31. Huang WQ, Lu Y, Xu M, Huang J, Su YX, Zhang CX. Excessive fruit consumption during the second trimester is associated with increased likelihood of gestational diabetes mellitus: a prospective study. Sci Rep. 2017;7:43620. doi: 10.1038/srep43620.
32. Morimoto Y, Steinbrecher A, Kolonel LN, Maskarinec G. Soy consumption is not protective against diabetes in Hawaii: the Multiethnic Cohort. Eur J Clin Nutr. 2011;65: 279-82. doi: 10.1038/ejcn.2010.228.
33. Bazzano LA, Li TY, Joshipura KJ, Hu FB. Intake of fruit, vegetables, and fruit juices and risk of diabetes in women. Diabetes Care. 2008;31:1311-7. doi: 10.2337/dc08-0080.
34. Mueller NT, Odegaard AO, Gross MD, Koh WP, Yu MC, Yuan JM, Pereira MA. Soy intake and risk of type 2 diabetes in Chinese Singaporeans [corrected]. Eur J Nutr. 2012;51:1033-40. doi: 10.1007/s00394-011-0276-2.
35. Villegas R, Gao YT, Yang G, Li HL, Elasy TA, Zheng W, Shu XO. Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai Women's Health Study. Am J Clin Nutr. 2008;87:162-7. doi: 10.1093/ajcn/87.1.162.
36. Tatsumi Y, Morimoto A, Deura K, Mizuno S, Ohno Y, Watanabe S. Effects of soybean product intake on fasting and postload hyperglycemia and type 2 diabetes in Japanese men with high body mass index: The Saku Study. J Diabetes Investig. 2013;4:626-33. doi: 10.1111/jdi.12100.
37. Livesey G, Taylor R, Livesey HF, Buyken AE, Jenkins DJA, Augustin LSA et al. Dietary glycemic index and load and the risk of type 2 diabetes: a systematic review and updated meta-analyses of prospective cohort studies. Nutrients. 2019; 11:1280. doi: 10.3390/nu11061280.
38. Livesey G, Taylor R, Livesey H, Liu S. Is there a dose-response relation of dietary glycemic load to risk of type 2 diabetes? Meta-analysis of prospective cohort studies. Am J Clin Nutr. 2013;97:584-96. doi: 10.3945/ajcn.112.041467.
39. Arikawa AY, Jakits HE, Flood A, Thomas W, Gross M, Schmitz KH, Kurzer MS. Consumption of a high glycemic load but not a high glycemic index diet is marginally associated with oxidative stress in young women. Nutr Res. 2015;35:7-13. doi: 10.1016/j.nutres.2014.10.005.
40. Domínguez Coello S, Cabrera de León A, Rodríguez Pérez MC, Borges Álamo C, Carrillo Fernández L, Almeida González D, García Yanes J, González Hernández A, Brito Díaz B, Aguirre-Jaime A. Association between glycemic index, glycemic load, and fructose with insulin resistance: the CDC of the Canary Islands study. Eur J Nutr. 2010; 49:505-12. doi: 10.1007/s00394-010-0110-2.