Nutrition 60 (2019) 129–135

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Fresh fruit intake in pregnancy and association with gestational diabetes mellitus: A prospective cohort study

Xuezhen Zhou Ph.D. [a], Renjuan Chen Ph.D. [a], Chunrong Zhong Ph.D. [a], Jiangyue Wu M.D. [a], Xiating Li M.D. [a], Qian Li Ph.D. [a], Wenli Cui M.D. [a], Nianhua Yi M.D. [b], Mei Xiao M.D. [b], Heng Yin M.D. [b], Guoping Xiong M.D. [c], Weizhen Han M.D. [c], Liping Hao Ph.D. [a], Xuefeng Yang Ph.D. [a,*], Nianhong Yang Ph.D. [a]

[a] *Department of Nutrition and Food Hygiene, Hubei Key Laboratory of Food Nutrition and Safety, MOE Key Laboratory of Environment and Health, School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, China*
[b] *Hubei Maternal and Child Health Hospital, Wuhan, Hubei, China*
[c] *The Central Hospital of Wuhan, Hubei, China*

A R T I C L E   I N F O

Article History:
Received 21 May 2018
Received in revised form 19 September 2018
Accepted 27 September 2018

Keywords:
Fresh fruit
Gestational diabetes mellitus
Glycemic index
Glycemic load
Plasma glucose

A B S T R A C T

Objective: Fresh fruit intake has been found to be associated with risk of gestational diabetes mellitus (GDM); however, the evidence is limited and the findings are inconsistent. We aimed to assess the association of fresh fruit intake by fruit subgroups based on their glycemic index (GI) and glycemic load (GL) values and GDM incidence in Chinese pregnant women.

Methods: We included 3300 eligible women from the Tongji Maternal and Child Health Cohort. Dietary intakes were assessed by using a validated semiquantitative food frequency questionnaire. GDM was diagnosed based on the results of a 75-g, 2-h oral glucose tolerance test. In the adjusted logistic regression model, odds ratios and 95% confidence intervals for GDM were computed for the highest compared with lowest quintiles of fruit intake.

Results: GDM occurred in 378 (11.5%) of 3300 pregnant women. The average fresh fruit consumption was 381.7 g/d. The adjusted odds ratios (95% confidence intervals) for GDM from the lowest to highest quintile of whole fruit consumption were 1.00 (referent), 0.80 (0.56, 1.12), 0.74 (0.52, 1.05), 0.63 (0.44, 0.92), and 0.41 (0.27, 0.62), respectively; $P_{trend} < 0.001$. Higher overall midpregnancy fresh fruit consumption was associated with lower plasma 1-h OGTT glucose and 2-h OGTT glucose levels (all $P < 0.05$). In addition, the stratified analysis results indicated that greater consumption of low and high GI fruits and low GL fruits were both associated with a lower risk of GDM but not high GL fruits.

Conclusions: Our findings suggested an inverse association of fresh fruit intake with the risk of GDM in Chinese pregnant women. In women with GDM risk, low GI and GL fresh fruit consumption should be privileged versus those with high GI and GL.

Introduction

Gestational diabetes mellitus (GDM), defined as glucose intolerance with onset or first recognition during pregnancy, is a common pregnancy complication. In recent decades, its prevalence has increased substantially in Chinese populations, and approximately 10% of all pregnancies have been reported to be complicated by GDM [1–3]. GDM is not only associated with adverse pregnancy outcomes but also has long-term adverse health outcomes for both mothers and their offspring [4–7].

Maternal diet is a potentially modifiable risk factor and plays an important role in the development of GDM [8–11]. Fruit is rich in fiber, antioxidants, and phytochemicals, which have beneficial health effects [12]. Increasing fruit consumption has been recommended for the primary prevention of many chronic diseases [12]. Although several studies have investigated the association between fruit intake and diabetes [13–16], only a few have addressed this association during pregnancy, and the evidence is limited and the findings are inconsistent [17,18]. For instance, in a

This study was registered at clinicaltrials.gov as NCT03099837.
This work was supported by the National Program on Basic Research Project of China (NO.2013 FY114200) for Nianhong Yang, and the Dietary Nutrition Research and Education Foundation of Danone Nutrition Center in China (DIC201508) for Xuefeng Yang.
* Corresponding author. Tel.: +0086 27 83650523.
E-mail address: xxyxf@mails.tjmu.edu.cn (X. Yang).

https://doi.org/10.1016/j.nut.2018.09.022
0899-9007/

recent study, excessive consumption of fruit, especially fruit with moderate or high glycemic index (GI) values, tropical fruit and citrus fruit, was associated with a higher risk of GDM [17]. However, the results from another study indicated that higher consumption of whole fruits was not associated with an increased GDM risk [18]. These findings suggested that individual fruits might not be equally associated with risk of GDM because fruits have highly variable contents of nutrients (fiber, antioxidants, sugars, etc.) and phytochemicals that jointly may influence the risk. In addition, the GI values, which represent the quality of carbohydrate, or glycemic load (GL) values, which represent the quality and quantity of carbohydrate and their interaction, vary substantially for individual fruits.

Therefore the primary objective of this study was to examine the association between midpregnancy fruit intake and GDM incidence. The secondary objective was to examine the associations of fruit subgroups based on their GI and GL values with further GDM risk.

Materials and methods

Study design

This study was conducted as part of the Tongji Maternal and Child Health Cohort (TMCHC) study, an ongoing population-based prospective cohort, to investigate the association between maternal diet and the health outcomes of mother and offspring [19]. The TMCHC study was established in January 2013 and enrolled healthy pregnant women at 8 to 16 wk gestation when they attended their first antenatal visit at a maternity clinic in one of three public hospitals in Wuhan, China. Of 3792 women who completed the semiquantitative food frequency questionnaire (FFQ) during midpregnancy, we excluded individuals with multiple pregnancies ($n = 71$). Women who developed GDM in a previous pregnancy or had a previous diagnosis of diabetes ($n = 21$) or whose FPG value in this early pregnancy were $\geq$5.1 mmol/L ($n = 55$) were excluded because they may have changed their diets and lifestyles to prevent a recurrence of GDM [20]. In addition, women were excluded from the current analyses if they didn't complete an oral glucose tolerance test (OGTT; $n = 268$) or reported unrealistic total energy intake ($<$600 or $>$3500 kcal/d; $n = 77$). Finally, a total of 3300 women were included in the analysis from September 2013 to May 2016 (Supplemental Fig 1). This study was approved by the ethics review committee of Tongji Medical College, Huazhong University of Science and Technology. All participants gave informed written consent on recruitment.

Dietary assessment

The participants reported their dietary intakes during the past 4 wk using a semiquantitative FFQ and completed FFQ 2 wk before the diagnosis of GDM. In the present study the semiquantitative FFQ was administrated at 23.7 $\pm$ 2.2 wk gestation on average, and the diagnosis of GDM was conducted at 26.2 $\pm$ 2.1 wk gestation on average. The semiquantitative FFQ was validated in a subsample of TMCHC cohort participants, indicating that it is a reasonably reliable and valid tool for assessing most food and nutrient intakes of pregnant women in urban areas of central China [19]. The semiquantitative FFQ consisted of 61 categories of food based on the food nutrient composition and eating habits of Chinese individuals, covering more than 200 food items. For each item, trained interviewers conducted face-to-face interviews, and the participants were asked to recall the frequency of intake and portion size consumed during the past 4 wk. In addition, we asked about 12 categories of fresh fruit, covering more than 40 fresh fruit items: citrus fruits (orange, tangerine, grapefruit, etc.), pome fruits (apples, pears, etc.), berries (strawberries, grapes, kiwi, etc.), bananas, fresh dates, peaches, mango, pineapple, apricots, watermelon, cantaloupe, pawpaw, casaba, litchi chinensis, longan, and sugarcane. Daily intakes of nutrient and energy were calculated based on the continuously updated China Food Composition Database [21], and each energy-yielding macronutrient intake was expressed as the percentage of total energy intake using the nutrient-density method [22].

GDM screening

The primary outcome was GDM. At 24 to 28 wk, participants were routinely offered 75-g, 2-h OGTTs. All participants had overnight fasting of at least 8 h before OGTT. Fasting plasma glucose and 1-h and 2-h postload plasma glucose levels were measured by enzymatic assays using an automated biochemical analyzer. GDM was diagnosed when any of the glucose values during the diagnostic OGTT met or exceeded the criteria as recommended by the International Association of Diabetes and Pregnancy Study Group: fasting plasma glucose $\geq$ 5.1 mmol/L or 1-h plasma glucose $\geq$ 10.0 mmol/L or 2-h plasma glucose $\geq$ 8.5 mmol/L [23].

Measurement of nondietary factors

Information on sociodemographic, clinical, and lifestyle characteristics was obtained using a structured questionnaire at enrollment. This questionnaire included maternal age, prepregnancy weight, physical activity, ethnicity, educational level, average personal income, nulliparous, smoking habits, alcohol consumption habits, family history of diabetes, and family history of obesity. Maternal age (in years) was treated as a continuous variable, except for the descriptive statistics, for which we divided age into four groups ($<$24, 25–29, 30–35, and $\geq$36). Prepregnancy body mass index (BMI; kg/m^2) was calculated from self-reported pregnancy weight [24] and measured height. Gestational weight gain before GDM diagnosis was calculated by subtracting pregnancy weight from weight measured at OGTT test. Physical activity (metabolic equivalent unit h/wk) was calculated using the duration per week of various forms of exercise in early pregnancy, weighting each activity by its intensity level [25]. Ethnicity was divided into two categories (Han Chinese, others). The educational level was recorded as the number of completed years of schooling and divided into four categories ($\leq$9, 10–15, and $\geq$16). Average personal income (per month, Chinese yuan) was divided into five categories ($\leq$2999, 3000~4999, 5000~9999, $\geq$10 000). The other covariates, including nulliparous status, smoking habits, alcohol consumption habits, family history of diabetes, and family history of obesity, were treated as dichotomized variables (yes/no).

Statistical analysis

In multivariate models, total fruit, fruit subtypes (based on their GI and GL values), and the kind of fruit were modeled as quintiles of intake. Quintiles were defined by the distribution of each food group at baseline. The odds ratios (ORs) and 95% confidence intervals (CIs) of GDM for each quintile of fruit consumption compared with the lowest quintile were estimated using logistic regression models. In addition, the ORs and 95% CIs of GDM associated with per 100-g increment of fruit consumption were also calculated. To quantify a linear trend, we assigned the median value for each category and treat the median values as continuous variable in the logistic regression model. Moreover, to estimate the OR of incident GDM for fruit exposure, we also took the recommended fruit consumption (200~400 g/d), according to the current dietary guidelines for Chinese, as the reference group.

We further examined whether the associations of individual fruit consumption with risk of GDM depended on the GI and GL values of fruits. In the present study the GI values for individual fruits were based on the international GI database [26] and Food Glycemic Index [27]. We calculated the GL values per 100 g for individual fruits based on the GI values and the amount of carbohydrate in fruits from China Food Composition Database [21]. We categorized individual fruits into two groups based on their GI values: citrus fruits (orange, tangerine, grapefruit, etc.), pome fruits (apples, pears, etc.), bananas, berries (strawberries, grapes, kiwi, etc.), fresh dates, and peaches for low GI fruits (GI $<$ 55); mango, pineapple, apricots, watermelon, cantaloupe, pawpaw, casaba, litchi chinensis, longan, and sugarcane for high GI fruits (GI $\geq$ 55). In terms of the categorization of fruits by the GL values per 100 g, low GL fruits (GL $<$ 10) included citrus fruits (orange, tangerine, grapefruit, etc.), pome fruits (apples, pears, etc.), berries (strawberries, grapes, kiwi, etc.), mango, pineapple, apricots, watermelon, cantaloupe, pawpaw, casaba, and peaches; and high GL fruits (GL $\geq$ 10) included bananas, litchi chinensis, longan, fresh dates, and sugarcane.

Multivariate linear regression models were estimated to assess the association between fruit consumption and plasma glucose levels. In addition, the area under the curve value of OGTT (AUC_{OGTT}) was calculated by the trapezoidal rule. In the present study, all statistical analyses were performed using SPSS Version 21.0 (IBM Corporation, Armonk, NY, USA). All data collected were double entered into the EpiData software program [19]. Comparisons between groups were performed using χ^2 tests for categorical variables, analysis of variance or t tests for continuous variables with normal distribution, or non-parametric Mann-Whitney and Kruskal-Wallis tests for continuous variables with skewed distributions. Frequencies and percentages were used to describe the distributions of categorical variables, and the mean $\pm$ SD was used to describe the distribution of continuous variables. All tests of statistical significance were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics of study participants

The characteristics of the participants, according to quintiles of total whole fruit consumption, are presented in Table 1. GDM occurred in 378 (11.5%) of 3300 pregnant women. Mean intake of

Table 1
Baseline characteristics according to quintiles of total fruit intake among 3300 participants in Tongji Maternal and Child Health Cohort study*

	Overall n = 3,300	Q1 n = 660	Q2 n = 657	Q3 n = 663	Q4 n = 660	Q5 n = 660	P
Age at enrollment (y)	28.20 ± 3.47	28.49 ± 3.45	28.42 ± 3.48	28.14 ± 3.39	28.10 ± 3.51	27.92 ± 3.51	0.033
pregnancy BMI (kg/m^2)	20.73 ± 2.70	21.09 ± 2.84	20.64 ± 2.60	20.73 ± 2.76	20.58 ± 2.52	20.60 ± 2.72	0.002
GWG before GDM diagnosis (kg)	7.23 ± 3.84	7.22 ± 3.87	7.29 ± 3.91	7.23 ± 3.63	7.06 ± 3.82	7.34 ± 3.97	0.751
Physical activity (MET h/wk)†	28.4 ± 21.5	29.3 ± 21.7	27.6 ± 21.8	29.2 ± 23.0	27.2 ± 20.5	28.8 ± 20.5	0.589
Han Chinese	3216 (97.5%)	646 (97.9%)	633(96.3%)	641 (96.7%)	649 (98.3)	647 (98.0%)	0.082
Education level (years)							0.027
≤9	97 (2.9%)	14 (2.1%)	27 (4.1%)	30 (4.5%)	11 (1.7%)	15 (2.3%)	
10 to −15	1239 (37.5%)	231 (35.0%)	243 (37.0%)	242 (36.5%)	257 (38.9%)	286 (40.3%)	
≥16	1889 (57.2%)	403 (61.1%)	375 (57.1%)	372 (56.1%)	374 (56.7%)	365 (55.3%)	
Missing	75 (2.3%)	12 (1.8%)	12 (1.8%)	19 (2.9%)	18 (2.7%)	14 (2.1%)	
Average personal income (CNY)‡							0.331
≤2999	228 (6.9%)	58 (8.8%)	38 (5.8%)	46 (6.9%)	47 (7.1%)	39 (5.9%)	
3000 to −4999	1032 (31.3%)	219 (33.2%)	204 (31.1%)	202 (30.5%)	204 (30.9%)	203 (30.8%)	
5000 to −9999	1368 (41.5%)	252 (38.2%)	284 (43.2%)	291 (43.9%)	282 (42.7%)	259 (39.2%)	
≥10 000	604 (18.3%)	116 (17.6%)	120 (18.3%)	113 (17.0%)	114 (17.3%)	141 (21.4%)	
Missing	68 (2.1%)	15 (2.3%)	11 (1.7%)	11 (1.7%)	13 (2.0%)	18 (2.7%)	
Nulliparous (yes)	2815 (85.3%)	542 (82.1%)	563 (85.7%)	581 (87.6%)	567 (85.9%)	562 (85.2%)	0.075
Family history of diabetes (yes)	271 (8.2%)	64 (9.7%)	56 (8.5%)	56 (8.4%)	55 (8.4%)	40 (6.1%)	0.349
Family history of obesity (yes)	53 (1.6%)	10 (1.5%)	10 (1.5%)	9 (1.4%)	11 (1.7%)	13 (2.0%)	0.911
Smoking habit (yes)	104 (3.2%)	27 (4.1%)	25 (3.8%)	16 (2.4%)	24 (3.6%)	12 (1.8%)	0.078
Drinking habit (yes)	48 (1.5%)	15 (2.3%)	6 (0.9%)	12 (1.8%)	9 (1.4%)	6 (0.9%)	0.171
Dietary factors							
Energy (kcal)	1958.0 ± 471.9	1659.7 ± 399.8	1852.7 ± 404.8	1973.7 ± 428.3	2058.4 ± 422.1	2244.7 ± 486.3	<0.001
Fruits (g)	381.74 ± 208.42	116.04 ± 68.09	257.62 ± 31.14	359.06 ± 30.30	476.29 ± 39.11	699.21 ± 113.74	<0.001
Vegetables (g)	333.08 ± 226.67	232.48 ± 200.24	290.93 ± 190.99	344.13 ± 206.56	378.99 ± 233.32	418.65 ± 249.04	<0.001
Beans and bean products (g)	13.29 ± 17.32	9.99 ± 17.79	13.59 ± 16.57	13.36 ± 15.94	14.56 ± 17.23	14.97 ± 18.57	<0.001
Whole grains (g)	26.07 ± 37.93	21.15 ± 33.17	23.55 ± 33.84	25.49 ± 39.13	29.08 ± 39.29	31.07 ± 42.60	<0.001
Rice and wheat products (g)	209.16 ± 76.32	207.13 ± 78.25	204.53 ± 70.16	214.55 ± 76.17	208.14 ± 77.27	211.39 ± 79.23	0.143
Red meat (g)	44.47 ± 38.39	38.18 ± 37.65	45.78 ± 38.60	43.85 ± 35.97	45.81 ± 35.89	48.72 ± 42.73	<0.001
Poultry (g)	6.33 ± 12.68	4.09 ± 9.26	5.46 ± 10.54	6.37 ± 12.80	7.42 ± 15.01	8.32 ± 14.41	<0.001
Fish (g)	36.27 ± 39.80	27.00 ± 34.14	35.71 ± 37.97	36.24 ± 37.24	39.10 ± 43.15	43.32 ± 43.95	<0.001
Eggs (g)	40.78 ± 24.23	37.62 ± 24.67	39.98 ± 22.61	40.93 ± 23.51	43.15 ± 26.20	42.20 ± 23.71	<0.001
Dairy products (g)	192.09 ± 150.77	181.57 ± 156.59	177.18 ± 138.02	191.44 ± 142.94	196.53 ± 152.02	213.65 ± 160.82	<0.001
Nuts (g)	14.68 ± 17.29	10.60 ± 14.38	14.84 ± 16.18	15.10 ± 17.76	16.06 ± 17.03	16.81 ± 20.00	<0.001
Protein, En%	12.0 ± 2.0	11.8 ± 2.2	12.2 ± 2.0	12.1 ± 1.9	12.2 ± 2.0	12.0 ± 1.9	0.004
Carbohydrate, En%	56.2 ± 7.4	53.8 ± 8.7	54.5 ± 7.5	56.2 ± 6.7	57.1 ± 6.3	59.2 ± 6.3	<0.001
Total fat, En%	33.2 ± 6.7	35.4 ± 7.8	34.7 ± 6.9	33.1 ± 6.2	32.4 ± 5.8	30.6 ± 5.6	<0.001
Saturated, En%	7.9 ± 2.1	8.4 ± 2.5	8.2 ± 2.0	7.8 ± 2.0	7.7 ± 1.9	7.3 ± 1.8	<0.001
Monounsaturated, En%	10.3 ± 2.8	10.9 ± 3.3	10.8 ± 2.9	10.2 ± 2.6	10.0 ± 2.5	9.4 ± 2.5	<0.001
Polyunsaturated, En%	12.2 ± 2.8	13.1 ± 3.1	12.8 ± 2.9	12.2 ± 2.7	11.8 ± 2.4	10.9 ± 2.5	<0.001
Total dietary fiber (g)§	13.85 ± 4.49	10.36 ± 4.67	13.02 ± 3.68	14.12 ± 3.59	15.34 ± 3.91	16.41 ± 3.98	<0.001
Dietary cholesterol (mg)§	370.38 ± 160.30	385.07 ± 186.72	379.95 ± 159.20	368.33 ± 153.62	371.58 ± 158.26	347.01 ± 137.57	<0.001
Dietary vitamin A (mg)§	771.75 ± 390.99	609.65 ± 388.48	701.55 ± 330.40	799.96 ± 402.27	851.80 ± 407.55	895.36 ± 351.13	<0.001
Dietary vitamin E (mg)§	48.12 ± 8.53	49.21 ± 9.76	49.11 ± 8.97	48.21 ± 7.64	47.81 ± 7.92	46.26 ± 7.88	<0.001
Dietary vitamin C (mg)§	157.83 ± 76.67	102.10 ± 72.00	134.81 ± 59.33	159.72 ± 63.13	180.65 ± 67.62	211.73 ± 71.31	<0.001
Fasting	4.43 ± 0.39	4.44 ± 0.41	4.44 ± 0.39	4.44 ± 0.38	4.43 ± 0.39	4.40 ± 0.38	0.588
1 h after OGTT	7.49 ± 1.48	7.61 ± 1.53	7.57 ± 1.48	7.50 ± 1.47	7.39 ± 1.45	7.38 ± 1.46	0.038
2 h after OGTT	6.41 ± 1.17	6.52 ± 1.23	6.50 ± 1.15	6.45 ± 1.20	6.27 ± 1.11	6.32 ± 1.14	0.001
AUC_{OGTT} (mmol · L^{-1} · h^{-1})	12.86 ± 1.93	13.05 ± 2.01	12.99 ± 1.96	12.88 ± 1.94	12.69 ± 1.82	12.68 ± 1.89	0.005
GDM (yes)	378 (11.5%)	99 (15.0%)	79 (12.0%)	79 (11.9%)	69 (10.5%)	52 (7.9%)	0.002

ANOVA, analysis of variance; AUC_{OGTT}, the area under the curve value of oral glucose tolerance test; BMI, body mass index; CNY, Chinese yuan; GDM, gestational diabetes mellitus; GI, glycemic index; GL, glycemic load; GWG, gestational weight gain; MET, metabolic equivalent units; OGTT, oral glucose tolerance test; Q, quintile.

*Data are expressed as mean ± standard deviation or percentage. P values are from ANOVA for continuous data and from χ^2 tests for categorical data.

†MET h/wk was calculated using the duration per week of various forms of exercise, weighting each activity by its intensity level.

‡1 CNY ≈ 0.16 US dollars.

§Indicates values are energy adjusted (2000 kcal).

total whole fruit consumption was 381.74 ± 208.42 g/d. Women with a higher intake of total consumption were more likely to be younger, have a lower BMI, and be less educated. In addition, women with more total fruit consumption consumed more vegetables, bean products, and whole grains; had higher intake of dietary fiber, vitamin A, and vitamin C; and had higher proportion of energy from carbohydrate, but lower proportion of energy from total fat or protein. No significant differences were identified on gestational weight gain before GDM diagnosis, physical activity, ethnicity, average personal income, parity, family history of diabetes, family history of obesity, smoking habit, or drinking habit among the quintiles of total whole fruit consumption.

Association between fruit consumption and risk of GDM

Logistic regression models were constructed to assess the association of fruit consumption and risk of GDM. ORs (95% CIs) for total fruit consumption associated with GDM are presented in Table 2. A negative association between total fruit consumption and the risk of GDM was identified. The adjusted ORs (95% CIs) for GDM from the lowest to highest quintile of total fruit consumption were 1 (Reference), 0.80 (0.56, 1.12), 0.74 (0.52, 1.05), 0.63 (0.44, 0.92), and 0.41 (0.27, 0.62), respectively; P_{trend} < 0.001. Every 100 g of total fruit consumption was associated with a 14% (95% CI: 8%-20%) decrement in OR of GDM. When compared with the recommended fruit consumption

Table 2
ORs (95% CIs) for total fruit consumption associated with GDM*

	Quintiles of total fruit consumption, g					P trend	Per 100 g increase	P
	Q1	Q2	Q3	Q4	Q5			
Participants *(n)*	660	657	663	660	660			
GDM, *n* (%)	99 (15.0%)	79 (12.0%)	79 (11.9%)	69 (10.5%)	52 (7.9%)		378 (11.5%)	
Fruit intake, (g)	135 (69, 176)	261 (230–285)	360 (332–384)	474 (443–508)	671 (604–773)		360 (230–508)	
Model 1	1 (Reference)	0.78 (0.56–1.06)	0.77 (0.56–1.05)	0.66 (0.48–0.92)	0.49 (0.34–0.69)	<0.001	0.89 (0.84–0.93)	<0.001
Model 2	1 (Reference)	0.75 (0.53–1.06)	0.74 (0.52–1.04)	0.65 (0.46–0.93)	0.37 (0.24–0.55)	<0.001	0.88 (0.83–0.93)	<0.001
Model 3	1 (Reference)	0.74 (0.52–1.05)	0.72 (0.51–1.03)	0.64 (0.44–0.92)	0.35 (0.23–0.54)	<0.001	0.86 (0.81–0.92)	<0.001
Model 4	1 (Reference)	0.80 (0.56–1.12)	0.74 (0.52–1.05)	0.63 (0.44–0.92)	0.41 (0.27–0.62)	<0.001	0.86 (0.80–0.92)	<0.001
	Group of total fruit consumption, g							
	≤200	200~400	≥400					
Participants *(n)*	620	1272	1408					
GDM, *n* (%)	93 (15.0%)	156 (12.3%)	129 (9.2%)					
Fruit intake, (g)	126 (64–168)	300 (251–347)	538 (462–633)					
Model 1	1.26 (0.96–1.67)	1 (Reference)	0.72 (0.56–0.92)					<0.001
Model 2	1.29 (0.96–1.74)	1 (Reference)	0.67 (0.51–0.87)					<0.001
Model 3	1.30 (0.95–1.76)	1 (Reference)	0.66 (0.50–0.88)					<0.001
Model 4	1.27 (0.93–1.71)	1 (Reference)	0.68 (0.52–0.90)					<0.001

BMI, body mass index; CI, confidence interval; GDM, gestational diabetes mellitus; GI, glycemic index; GL, glycemic load; OR, odds ratio; Q, quintiles.
Model 1 was crude model.
Model 2 was adjusted for maternal age, physical activity, ethnology, prepregnancy BMI, gestational weight gain before GDM diagnosis, maternal education, average personal income, personal income, smoking, alcohol, parity, family history of diabetes, and family history of obesity.
Model 3 was adjusted for model 2 + total energy intake.
Model 4 was adjusted for model 3+ vegetables, whole grains, red meat, fish, eggs, and dairy products.
*Median (P_{25}, P_{75}) of intake for each fruit quintile. ORs and 95% CIs calculated by logistic regression. Group of total fruit consumption indicates taking the dietary guidelines for Chinese as the reference group.

(200~400 g/d), our results indicated that fruit intake ≤200 g/d was not associated with GDM incidence (adjusted OR: 1.27; 95% CI: 0.93-1.71), whereas fruit intake ≥400 g/d was associated with a 32% lower GDM incidence (adjusted OR: 0.68; 95% CI: 0.52-0.90).

ORs (95% CIs) for fruit consumption associated with GDM according to different GI and GL values of fruit are presented in Table 3. The results indicated that greater fruit consumption of either low GI values (GI < 55) or high GI values (GI ≥ 55) was associated with a lower risk of GDM. The similar association was noted in the secondary analysis examining the associations between fruit consumption and risk of GDM by low GL values (GL < 10) of fruits but not high GL values (GI ≥ 10).

In addition, we performed similar analyses for different subtypes of fruit consumption, including citrus, pome, berry, gourd, drupe and tropical fruit, and an inverse association with the risk of GDM was found in pome, gourd, and tropical fruit, respectively (Supplemental Table 2).

Association between fruit consumption and plasma glucose levels

Multivariate linear regression models were constructed to assess the association of fruit consumption with plasma glucose levels in Table 4. The adjusted results indicated that per 100 g increase in total fruit consumption, the 1-h and 2-h plasma glucose reading decreased by 0.050 mmol/L (95% CI: −0.081 to −0.019) and 0.035 mmol/L (95% CI: −0.059 to −0.012), respectively. Similar results were found in the fruit group of GI < 55 and the fruit group of GL < 10. In addition, for the fruit group of GI ≥ 55, per 100-g increase in fruit consumption, the fasting plasma glucose reading decreased by 0.016 mmol/L (95% CI: −0.029 to −0.003); for the fruit group of GL ≥ 10, per 100-g increase in fruit consumption, the fasting plasma glucose reading increased by 0.030 mmol/L (95% CI: 0.008–0.053), whereas the 1-h and 2-h plasma glucose reading decreased by 0.137 mmol/L (95% CI: −0.231 to −0.044) and 0.091 mmol/L (95% CI: −0.162 to −0.021), respectively. Moreover, we conducted the AUC_{OGTT} analysis to estimate the association between fresh fruit consumption and plasma glucose, and the results were similar to the postprandial glucose level.

Discussion

In this prospective cohort study, the findings indicated that higher fresh fruit consumption was significantly associated with a lower risk of GDM and lower plasma 1-h OGTT glucose and 2-h OGTT glucose levels. The findings also indicated that women with higher fresh fruit consumption had a better global diet quality; however, the inverse association between fresh fruit consumption and GDM was still strong after adjusting for the other food consumption. Moreover, the stratified analysis suggested that greater consumption of low and high GI fruits and low GL fruits were both associated with a lower risk of GDM, but not high GL fruits.

Information on the association between fruit consumption and GDM is limited. To our knowledge, only a few previous prospective studies have specially assessed the association of fruit consumption with risk of GDM, but these studies have shown inconsistent findings [17,18]. For instance, the Nurses' Health Study II, which was conducted in US female nurses to examine pregnancy fruit consumption and the risk of GDM, found that no significant association was identified between whole fruit consumption and GDM risk, but modest consumption of fruit juice seemed to decrease the risk [18]. The variation in population, food availability, and dietary habits between this study and ours may partly explain the inconsistent findings. Another previous prospective study in China found that higher fruit consumption in the second trimester was significantly associated with higher risk of GDM (with 772 female participants in Guangdong Province, China) [17]. However, the GDM incidence in that study (21.9%) was much higher than incidence reported in Chinese pregnant women (9.3%) [3] and in our study (11.5%). In addition, the median of the highest (fourth) quartile for fruits consumption (710 g/d) in that study was much higher than the fourth quintile in our study (474 g/d) and exceeded our highest quintile (671 g/d). Moreover, in another similar prospective study that was conducted in the same area of

Table 3
ORs (95% CIs) for fruit consumption associated with GDM according to different GI and GL values*

	Quintiles of fruit consumption					P trend	Per 100 g increase	P
	Q1	Q2	Q3	Q4	Q5			
Group of GI values								
GI < 55								
GDM, n (%)	87 (13.1%)	79 (12.0%)	88 (13.3%)	73 (11.1%)	51 (7.7%)		378 (11.5%)	
Fruit intake, (g/d)	88 (22–126)	200 (182–224)	289 (268–311)	392 (360–420)	550 (500–632)		289 (182–420)	
Model 1	1 (Reference)	0.90 (0.65–1.25)	1.02 (0.74–1.40)	0.82 (0.59–1.15)	0.55 (0.39–0.80)	0.003	0.90 (0.84–0.95)	0.001
Model 2	1 (Reference)	0.88 (0.62–1.26)	1.10 (0.78–1.56)	0.83 (0.58–1.19)	0.46 (0.30–0.69)	0.004	0.89 (0.83–0.95)	0.001
Model 3	1 (Reference)	0.89 (0.63–1.27)	1.13 (0.79–1.60)	0.85 (0.58–1.23)	0.47 (0.30–0.73)	0.010	0.89 (0.83–0.96)	0.002
Model 4	1 (Reference)	0.91 (0.64–1.29)	1.10 (0.78–1.56)	0.79 (0.54–1.15)	0.48 (0.31–0.74)	0.001	0.87 (0.81–0.94)	<0.001
GI ≥ 55								
GDM, *n* (%)	88 (13.4%)	73 (11.0%)	86 (12.9%)	75 (11.5%)	56 (8.5%)		378 (11.5%)	
Fruit intake, (g/d)	0 (0–0.1)	0.4 (0.2–3.6)	21 (14–30)	79 (57–100)	221 (166–321)		21 (0.2–100)	
Model 1	1 (Reference)	0.80 (0.57–1.11)	0.96 (0.70–1.32)	0.84 (0.60–1.16)	0.60 (0.42–0.85)	0.017	0.87 (0.78–0.97)	0.010
Model 2	1 (Reference)	0.79 (0.56–1.13)	0.88 (0.62–1.24)	0.72 (0.50–1.04)	0.52 (0.35–0.76)	0.007	0.84 (0.75–0.95)	0.004
Model 3	1 (Reference)	0.79 (0.55–1.12)	0.89 (0.63–1.26)	0.74 (0.51–1.06)	0.54 (0.36–0.80)	0.012	0.85 (0.75–0.95)	0.007
Model 4	1 (Reference)	0.76 (0.53–1.08)	0.93 (0.66–1.31)	0.74 (0.52–1.06)	0.54 (0.36–0.80)	0.003	0.83 (0.73–0.93)	0.002
Group of GL values								
GL < 10								
GDM, *n* (%)	98 (14.8%)	75 (11.4%)	96 (14.5%)	60 (9.1%)	49 (7.4%)		378 (11.5%)	
Fruit intake, (g/d)	107 (43–143)	217 (199–243)	305 (286–329)	405 (380–439)	593 (523–693)		306 (199–439)	
Model 1	1 (Reference)	0.74 (0.54–1.02)	0.97 (0.72–1.32)	0.58 (0.41–0.81)	0.46 (0.32–0.66)	<0.001	0.88 (0.83–0.93)	<0.001
Model 2	1 (Reference)	0.78 (0.55–1.10)	0.94 (0.67–1.31)	0.56 (0.39–0.82)	0.37 (0.25–0.56)	<0.001	0.88 (0.83–0.92)	<0.001
Model 3	1 (Reference)	0.77 (0.55–1.10)	0.93 (0.66–1.31)	0.56 (0.38–0.82)	0.37 (0.24–0.57)	<0.001	0.87 (0.82–0.93)	<0.001
Model 4	1 (Reference)	0.78 (0.55–1.10)	0.96 (0.68–1.35)	0.57 (0.39–0.83)	0.40 (0.26–0.61)	<0.001	0.86 (0.80–0.92)	<0.001
GL ≥ 10								
GDM, *n* (%)	90 (13.5%)	86 (13.2%)	69 (10.6%)	71 (10.7%)	62 (9.4%)		378 (11.5%)	
Fruit intake, (g/d)	0 (0–0.1)	6 (1–13)	31 (24–39)	63 (53–74)	130 (111–171)		31 (1–74)	
Model 1	1 (Reference)	0.98 (0.71–1.34)	0.76 (0.54–1.06)	0.77 (0.55–1.07)	0.67 (0.47–0.94)	0.006	0.85 (0.71–1.02)	0.074
Model 2	1 (Reference)	0.81 (0.57–1.15)	0.70 (0.49–1.01)	0.71 (0.50–1.02)	0.58 (0.40–0.85)	0.032	0.84 (0.69–1.02)	0.070
Model 3	1 (Reference)	0.81 (0.57–1.15)	0.71 (0.49–1.03)	0.73 (0.50–1.05)	0.60 (0.41–0.89)	0.064	0.85 (0.69–1.04)	0.115
Model 4	1 (Reference)	0.92 (0.66–1.30)	0.76 (0.53–1.09)	0.84 (0.59–1.21)	0.68 (0.46–1.00)	0.063	0.88 (0.72–1.08)	0.211

BMI, body mass index; CI, confidence interval; GDM, gestational diabetes mellitus; GI, glycemic index; GL, glycemic load; OR, odds ratio; Q, quintiles.
Model 1 was crude model.
Model 2 was adjusted for maternal age, physical activity, ethnology, pregnancy BMI, gestational weight gain before GDM diagnosis, maternal education, average personal income, smoking, alcohol, parity, family history of diabetes, and family history of obesity.
Model 3 was adjusted for model 2 + total energy intake.
Model 4 was adjusted for model 3+ vegetables, whole grains, red meat, fish, eggs, dairy products, and the consumption of fruit with other GI and GL values.
*Median (P_{25}, P_{75}) of intake for each fruit quintile. ORs and 95% CIs calculated by logistic regression.

Table 4
Associations between fruit consumption and plasma glucose levels (*n* = 3300)*

	Fasting plasma glucose β (95% CI)	P	1-h plasma glucose β (95% CI)	P	2-h plasma glucose β (95% CI)	P	AUC_{OGTT} β (95% CI)	P
Total fruit, 100 g/d								
Crude model	−0.006 (−0.013 to 0.001)	0.090	−0.050 (−0.077 to −0.022)	<0.001	−0.045 (−0.066 to −0.024)	<0.001	−0.075 (−0.111 to −0.039)	<0.001
Adjusted model	−0.002 (−0.010 to 0.005)	0.543	−0.050 (−0.081 to −0.019)	0.002	−0.035 (−0.059 to −0.012)	0.004	−0.072 (−0.111 to −0.032)	<0.001
Group of GI values, 100 g/d								
GI < 55								
Crude model	0.002 (−0.006 to 0.010)	0.631	−0.063 (−0.095 to −0.032)	<0.001	−0.055 (−0.079 to −0.031)	<0.001	−0.088 (−0.129 to −0.046)	<0.001
Adjusted model	0.003 (−0.006 to 0.011)	0.560	−0.062 (−0.097 to −0.028)	<0.001	−0.049(−0.075 to −0.022)	<0.001	−0.083 (−0.127 to −0.039)	<0.001
GI ≥ 55								
Crude model	−0.025 (−0.038 to −0.012)	<0.001	−0.007 (−0.058 to 0.044)	0.792	−0.012 (−0.050 to 0.026)	0.546	−0.029 (−0.095 to 0.038)	0.397
Adjusted model	−0.016 (−0.029 to −0.003)	0.019	−0.014 (−0.067 to 0.040)	0.612	0.001 (−0.040 to 0.041)	0.972	−0.038 (−0.107 to 0.030)	0.274
Group of GL values, 100 g/d								
GL < 10								
Crude model	−0.009 (−0.017 to −0.001)	0.021	−0.038 (−0.069 to −0.008)	0.012	−0.038 (−0.061 to −0.015)	0.001	−0.060 (−0.100 to −0.021)	0.003
Adjusted model	−0.007 (−0.015 to 0.002)	0.115	−0.039 (−0.072 to −0.007)	0.018	−0.028 (−0.053 to −0.003)	0.028	−0.059 (−0.101 to −0.017)	0.006
GL ≥ 10								
Crude model	0.014 (−0.007 to 0.036)	0.194	−0.183 (−0.271 to −0.095)	<0.001	−0.134 (−0.200 to −0.068)	<0.001	−0.252 (−0.367 to −0.138)	<0.001
Adjusted model	0.030 (0.008–0.053)	0.009	−0.137 (−0.231 to −0.044)	0.004	−0.091 (−0.162 to −0.021)	0.011	−0.177 (−0.297 to −0.057)	0.004

AUC_{OGTT}, the area under the curve value of oral glucose tolerance test; BMI, body mass index; CI, confidence interval; GDM, gestational diabetes mellitus; GI, glycemic index; GL, glycemic load.
*Values are linear regression coefficients (95% CIs). Adjusted model was adjusted for maternal age, physical activity, ethnology, prepregnancy BMI, gestational weight gain before GDM diagnosis, maternal education, average personal income, smoking, alcohol, parity, family history of diabetes, family history of obesity, vegetables, whole grains, red meat, fish, eggs, dairy products, and total energy intake, and the consumption of fruit with other GI and GL values for the group of GI and GL values.

China (Guangdong Province), a dietary pattern mainly consisting of vegetable and fruit was found to reduce the risk of GDM (with 3,063 cases) [28], which was consistent with our study. In addition, the stronger inverse association between fruit consumption and GDM risk we reported is largely consistent with previous findings, indicating that higher fresh fruit consumption was associated with significantly lower risk of type 2 diabetes [13,29].

Both dietary GI and GL were used to characterize the capability of food to induce postprandial glycemia [30-32]. In our study, greater consumption of low and high GI fruits and low GL fruits were both associated with a lower risk of GDM but not high GL fruits. Interestingly, both the low and high GI values of fruits seemed to be the protective factor in their association with GDM in the present study, although in a clinical trial, glycemic control among people with type 2 diabetes was improved only with increased consumption of low GI fruits [33]. Moreover, similar to our findings, one previous study also found both higher and lower GI fruits to be associated with lower risk of type 2 diabetes [12]. In addition, our findings indicated that only high GL fruit was not associated with a lower risk of GDM and only high GL fruit was associated with higher plasma fasting glucose (0.05), suggesting that high GL fruit may be not a protective factor for GDM. One previous study found that dietary GL was a stronger predictor of GDM risk than GI or the amount of carbohydrate alone, which may suggest the importance of both the quality and quantity of carbohydrate in determining how a pregnant woman's blood glucose or the GDM risk is affected by carbohydrate-enriched food [34]. Moreover, our findings indicated that the high GL fruits contained a lower dietary fiber content, which may also explain the association found between the high GL fruit and GDM risk in the present study. Further studies are needed to evaluate whether women with GDM risk should limit their fruit consumption of high GI and GL values to a specific amount.

The exact mechanisms through which fresh fruit consumption may be protective against the development and deterioration of GDM are not very well understood, and several biological mechanisms might explain the inverse association between fruit intake and risk of GDM. Fruits are rich in polyphenols, such as flavonoids, and other antioxidant compounds, including carotenoids and vitamins C and E [29,35]. These compounds may decrease risk of GDM by mitigating the oxidative stress that interferes with the glucose uptake by cells. For example, vitamin C may enhance the antioxidant capacity in the body by adjustment of other antioxidants such as direct bilirubin, and our previous study indicated that lower risk of GDM was associated with higher direct bilirubin levels [36], and this may partially be attributed to higher intake of vitamin C. In the present study the findings indicated that high intake of pome fruits (which provide a low GI source of carbohydrate), gourd fruits (which provide a high GI source of carbohydrate), or tropical fruits (which provide a high GI source of carbohydrate) was associated with a low risk of GDM, which may also confirm the potentially protective effects of these compounds in fruits on GDM risk. In addition, fruits are low in energy but high in fiber, which would promote the feeling of fullness and prevent overconsumption of energy-dense foods [34]. Dietary fiber has also been related to improved insulin sensitivity [34] and one recent study found that dietary fiber can alleviate type 2 diabetes by selectively promoting gut bacteria [37]. Fruit contains sugars (i.e., glucose and fructose), which may have negative affects on glycaemic control. However, the natural sugars in fruit may not be metabolized in the same way as refined sugars because other beneficial nutrients such as dietary fiber or phytochemicals may interact with the natural sugars in glycemic response [29,38]. The negative correlation between fruit intake and blood glucose levels in our study also confirms this point. However, we also noted the positive correlation between high GL fruit and plasma fasting glucose in our study, suggesting that excessive sugar contained in the fruits may affect blood glucose levels.

The strengths of our study include the uniform criteria for diagnosis of GDM and the availability of abundant information on covariates, which allowed us to diminish potential confounders as much as possible. For example, our dietary data came from the prospective assessment of the pregnancy diet, which means that women completed a semiquantitative FFQ before their OGTT; thus a diagnosis of GDM could not affect dietary reporting. Second, information on fruit types was collected and the semiquantitative FFQ used in our study has been validated in a TMCHC subsample [19]. In addition, to the best of our knowledge, it is the first prospective study to specifically investigate not only the association between fruit consumption during pregnancy and the risk of GDM but also the association between fruit with different GI and GL values and GDM occurrence. The results may provide a more comprehensive reference for dietary guidelines.

However, there are several limitations of this study. First, information on fresh fruit consumption was only obtained by the semiquantitative FFQ during pregnancy. If possible, dietary questionnaires should be conducted before and during early pregnancy so that the link between fruit intake and the risk of GDM can be explicated more clearly. However, previous data suggest that dietary habits do not vary significantly between periods before conception and periods of pregnancy, and food intake information obtained at one point during pregnancy can provide reliable information of dietary throughout pregnancy [39]. Second, our fruit classification is not detailed enough, although information on fruit types was collected. Finally, despite careful consideration of the known risk factors and potential confounding factors, residual confounding cannot be ruled out.

Conclusions

Our findings suggested an inverse association of fruit intake with the risk of GDM in Chinese pregnant women. In women with GDM risk, low GI and GL fresh fruit consumption should be privileged versus those with high GI and GL. These findings of our study provide important clues for dietary guidance during pregnancy to prevent GDM.

Acknowledgments

The authors gratefully acknowledge the cooperation of the pregnant women who took part in this study. They also thank the staff of Hubei Maternal and Child Health Hospital, Jiang'an Maternal and Child Health Hospital and The Central Hospital of Wuhan. They are sincerely grateful to all members of the TMCHC study Group.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2018.09.022.

References

[1] Buckley BS, Harreiter J, Damm, Corcoy R, Chico A, Simmons D, et al. Gestational diabetes mellitus in Europe: prevalence, current screening practice and barriers to screening. A review. Diabet Med 2012;29:844–54.
[2] Dabelea D, Snell-Bergeon JK, Hartsfield CL, Bischoff KJ, Hamman RF, McDuffie RS, et al. Increasing prevalence of gestational diabetes mellitus (GDM) over time and by birth cohort: Kaiser Permanente of Colorado GDM Screening Program. Diabetes Care 2005;28:579–84.

[3] Leng J, Shao, Zhang C, Tian H, Zhang F, Zhang S, et al. Prevalence of gestational diabetes mellitus and its risk factors in Chinese pregnant women: a prospective population-based study in Tianjin, China. PloS One 2015;10:e0121029.

[4] Reece EA, Leguizamón G, Wiznitzer A. Gestational diabetes: the need for a common ground. Lancet 2009;373:1789–97.

[5] Bentley-Lewis R. Gestational diabetes mellitus as a herald of type 2 diabetes mellitus: an opportunity for a lifetime. Lancet 2009;373:1738–40.

[6] Kessous R, Shoham-Vardi I, Pariente G, Sherf M, Sheiner E. An association between gestational diabetes mellitus and long-term maternal cardiovascular morbidity. Heart 2013;99:1118–21.

[7] Ben-Haroush A, Yogev Y, Hod M. Epidemiology of gestational diabetes mellitus and its association with Type 2 diabetes. Diabet Med 2004;21:103–13.

[8] Zhang C, Ning Y. Effect of dietary and lifestyle factors on the risk of gestational diabetes: review of epidemiologic evidence. Am J Clin Nutr 2011;94: 1975S–9S.

[9] 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.

[10] Schoenaker DA, Mishra GD, Callaway LK, Soedamah-Muthu SS. The role of energy, nutrients, foods, and dietary patterns in the development of gestational diabetes mellitus: a systematic review of observational studies. Diabetes Care 2016;39:16–23.

[11] Ley SH, Hanley AJ, Retnakaran R, Sermer M, Zinman B, O'Connor DL. Effect of macronutrient intake during the second trimester on glucose metabolism later in pregnancy. Am J Clin Nutr 2011;94:1232–40.

[12] Muraki I, Imamura F, Manson JE, Hu FB, Willett WC, van Dam RM, et al. Fruit consumption and risk of type 2 diabetes:results from three prospective longitudinal cohort studies. BMJ 2013;28(347):f5001.

[13] Li S, Miao S, Huang Y, Liu Z, Tian H, Yin X, et al. Fruit intake decreases risk of incident type 2 diabetes: an updated meta-analysis. Endocrine 2015;48:454–60.

[14] Carter, Gray LJ, Troughton J, Khunti K, Davies MJ. Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. BMJ 2010;18(341):c4229.

[15] Li M, Fan Y, Zhang X, Hou W, Tang Z. Fruit and vegetable intake and risk of type 2 diabetes mellitus: meta-analysis of prospective cohort studies. BMJ Open 2014;4:e005497.

[16] Cooper AJ, Sharp SJ, Lentjes MA, Luben RN, Khaw KT, Wareham NJ, et al. A prospective study of the association between quantity and variety of fruit and vegetable intake and incident type 2 diabetes. Diabetes Care 2012;35: 1293–300.

[17] 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.

[18] Chen L, Hu FB, Yeung E, Tobias DK, Willett WC, Zhang C. Prepregnancy consumption of fruits and fruit juices and the risk of gestational diabetes mellitus: a prospective cohort study. Diabetes Care 2012;35:1079–82.

[19] Zhang H, Qiu X, Zhong C, Zhang K, Xiao M, Yi N, et al. Reproducibility and relative validity of a quantitative food frequency questionnaire for Chinese pregnant women. Nutr J 2015;14:56.

[20] Bowers K, Tobias DK, Yeung E, Hu FB, Zhang C. A prospective study of prepregnancy dietary fat intake and risk of gestational diabetes. Am J Clin Nutr 2012;95:446–53.

[21] National Institute of Nutrition and Food Safety, China CDC. China food composition. 2nd ed. Beijing, China: Peking University Medical Press; 2009.

[22] Willett WC, Howe GR, Kushi LH. Adjustment for total energy in take in epidemiologic studies. Am J Clin Nutr 1997;65(suppl):1220S–8S.

[23] International Association of Diabetes and Pregnancy Study Groups Consensus PanelMetzger BE, Gabbe SG, Persson B, Buchanan TA, Catalano PA, et al. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. Diabetes Care 2010;33:676–82.

[24] Rimm EB, Stampfer MJ, Colditz GA, Chute CG, Litin LB, Willett WC. Validity of self-reported waist and hip circumferences in men and women. Epidemiology 1990;1:466–73.

[25] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43:1575–81.

[26] University of Sydney. Online glycemic index database. Available at: www.glycemicindex.com/. [Accessed 3–23 March 2018].

[27] Yang YX. Food glycemic index. Beijing, China: Peking University Medical Press; 2004.

[28] He JR, Yuan MY, Chen NN, Lu JH, Hu CY, Mai WB, et al. Maternal dietary patterns and gestational diabetes mellitus: a large prospective cohort study in China. Br J Nutr 2015;28(113):1292–300.

[29] Du H, Li L, Bennett D, Guo Y, Turnbull I, Yang L, et al. Fresh fruit consumption in relation to incident diabetes and diabetic vascular complications: a 7-y prospective study of 0.5 million Chinese adults. PLoS Med 2017;14:e1002279.

[30] Murakami K, Sasaki S. Glycemic index and glycemic load of the diets of Japanese adults: The 2012 National Health and Nutrition Survey, Japan. Nutrition 2018;46:53–61.

[31] Barclay AW, Petocz P, McMillan-Price J, Flood VM, Prvan T, Mitchell P, et al. Glycemic index, glycemic load, and chronic disease risk—a meta-analysis of observational studies. Am J Clin Nutr 2008;87:627–37.

[32] Venn BJ, Green TJ. Glycemic index and glycemic load:measurement issues and their effect on diet-disease relationships. Eur J Clin Nutr 2007;61(Suppl 1): S122–31.

[33] Jenkins DJ, Srichaikul K, Kendall CW, Sievenpiper JL, Abdulnour S, Mirrahimi A, et al. The relation of low glycaemic index fruit consumption to glycaemic control and risk factors for coronary heart disease in type 2 diabetes. Diabetologia 2011;54:271–9.

[34] 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.

[35] Bahadoran Z, Mirmiran, Azizi F. Dietary polyphenols as potential nutraceuticals in management of diabetes: a review. J Diabetes Metab Disord 2013;12:43.

[36] Liu C, Zhong C, Zhou X, Chen R, Wu J, Wang W, et al. Higher direct bilirubin levels during pregnancy are associated with lower risk of gestational diabetes mellitus. Endocrine 2017;55:165–72.

[37] Zhao L, Zhang F, Ding X, Wu G, Lam YY, Wang X, et al. Gut bacteria selectively promoted by dietary fibers alleviate type 2 diabetes. Science 2018;359:1151–6.

[38] Sievenpiper JL, de Souza RJ, Jenkins DJ. Sugar: fruit fructose is still healthy. Nature 2012;482:470.

[39] Cucó G, Fernández-Ballart J, Sala J, Viladrich C, Iranzo R, Vila J, et al. Dietary patterns and associated lifestyles in preconception, pregnancy and postpartum. Eur J Clin Nutr 2006;60:364–71.