

Maternal dietary patterns and gestational diabetes mellitus: a large prospective cohort study in China

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Abstract

Few studies have explored the relationship between dietary patterns and the risk of gestational diabetes mellitus (GDM). Evidence from non-Western areas is particularly lacking. In the present study, we aimed to examine the associations between dietary patterns and the risk of GDM in a Chinese population. A total of 3063 pregnant Chinese women from an ongoing prospective cohort study were included. Data on dietary intake were collected using a FFQ at 24–27 weeks of gestation. GDM was diagnosed using a 75 g, 2 h oral glucose tolerance test. Dietary patterns were determined by principal components factor analysis. A log-binomial regression model was used to examine the associations between dietary pattern and the risk of GDM. The analysis identified four dietary patterns: vegetable pattern; protein-rich pattern; prudent pattern; sweets and seafood pattern. Multivariate analysis showed that the highest tertile of the vegetable pattern was associated with a decreased risk of GDM (relative risk (RR) 0.79, 95% CI 0.64, 0.97), compared with the lowest tertile, whereas the highest tertile of the sweets and seafood pattern was associated with an increased risk of GDM (RR 1.23, 95% CI 1.02, 1.49). No significant association was found for either the protein-rich or the prudent pattern. The protective effect of a high vegetable pattern score was more evident among women who had a family history of diabetes (*P* for interaction=0.022). These findings suggest that the vegetable pattern was associated with a decreased risk of GDM, while the sweets and seafood pattern was associated with an increased risk of GDM. These findings may be useful in dietary counselling during pregnancy.

Key words: Dietary patterns: Gestational diabetes mellitus: Prospective studies: China

Gestational diabetes mellitus (GDM), defined as glucose intolerance with onset or first recognition during pregnancy, is one of the most common pregnancy complications, and has adverse health effects on both mothers and offspring⁽¹⁾. Women with GDM have an elevated risk of hypertensive disorders and type 2 diabetes after delivery^(1,2), while offspring of women with GDM have an increased risk of obesity, the metabolic syndrome, and diabetes later in life^(1,2). In addition, epidemiological studies have provided evidence that the incidence of GDM is rising over time^(3,4), although consensus on a universal standard for diagnosis has not been reached⁽⁵⁾. Therefore, there is an urgent need to identify risk factors for the prevention of GDM.

As a modifiable factor, dietary habits have been shown to contribute to the development of type 2 diabetes, while research into the relationship between dietary factors and GDM is just emerging⁽⁶⁾. For instance, several cross-sectional or retrospective studies have shown that high intakes of saturated fat, cholesterol or eggs are associated with an increased risk of GDM^(7–9), and polyunsaturated fat intake appears to have a protective effect^(7,10). In contrast, another study has found no association between the risk of GDM and intakes of total dietary, saturated and polyunsaturated fat⁽¹¹⁾. In addition, high glycaemic load has been reported to increase the risk of GDM⁽¹²⁾. In addition, a recent prospective study has found that high intakes of animal protein increased the

Abbreviations: BIGCS, Born in Guangzhou Cohort Study; GDM, gestational diabetes mellitus; GWCMC, Guangzhou Women and Children's Medical Center; OGTT, oral glucose tolerance test; RR, relative risk.

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risk of GDM, while high intakes of vegetable protein decreased the risk⁽¹³⁾.

Most previous studies exploring the effects of dietary factors on the risk of GDM have focused on individual nutrients or food items^(7–12). However, individual foods contain numerous nutrients, and foods are not consumed in isolation; thus, studying a single nutrient or food item cannot account for the complex interactions of multiple nutrients. In contrast, dietary pattern analysis could present a broader view of food and nutrient consumption, and examine the effects of overall diet on health⁽¹⁴⁾. Nevertheless, only a few studies in Western countries have examined the effects of dietary patterns on the risk of GDM^(11,15–17). Furthermore, to our knowledge, there is a lack of studies on Asian populations, who have distinct dietary habits. In the present study, we used data from a large prospective cohort study to examine the associations between major dietary patterns and the risk of GDM in a Chinese population.

Materials and methods

Design

The present study was embedded in the Born in Guangzhou Cohort Study (BIGCS), an ongoing collaboration between the Guangzhou Women and Children's Medical Center (GWCMC), China and the University of Birmingham, UK. This prospective study commenced in February 2012 and aims to investigate short- and long-term health consequences of environmental risk factors in the next generation in China, whose parents have experienced rapid societal transitions in their lifetime.

The sampling frame only included pregnant women attending their first routine antenatal examinations (usually about week 16) at two campuses of the GWCMC, which is the largest of its kind in southern China with patronage throughout the municipality of Guangzhou and its vicinity, handling 12 000–15 000 deliveries annually (out of a total of 220 000 births in the entire municipality). However, only those who resided within Guangzhou and intended to remain in Guangzhou with their child for ≥ 3 years were considered eligible and were invited to participate in the BIGCS.

Maternal exposure was assessed using self-completed questionnaires. The first (Q1), second (Q2) and third (Q3) questionnaires were administered at recruitment and at gestational ages of 24–27 and 35–38 weeks, respectively; the questionnaires acquired demographic and socio-economic information, as well as data on exposures in the workplace and at home, personal lifestyle, medical history, and health status before and during pregnancy. The protocols of the BIGCS were approved by the Institutional Ethics Committee of the GWCMC. Written informed consent was obtained from all participants.

For the present study, we used data collected from pregnant women recruited between February 2012 and February 2014. During this period, we approached 9494 pregnant women attending their first routine antenatal examinations, and 94.9% were eligible; among those who were eligible, a total

of 6252 (69.4%) agreed to participate in the BIGCS, while 2758 (30.6%) refused. Of the women recruited, we excluded those who had a history of previous diabetes (type 1 or type 2) or hypertension (n 15), had pregnancy terminations or stillbirths (n 49), had multiple gestation (n 114), had missing (n 351) or incomplete (n 107) records on oral glucose tolerance test (OGTT), had an incomplete dietary questionnaire (n 1803), completed the dietary questionnaire after the OGTT (n 563), had missing (n 11) or implausible (n 17) data on food items, or dropped out before the OGTT (n 159), resulting in a final total of 3063 women in the present analysis. The comparisons of the characteristics between women who took part in the BIGCS and those who were eligible but did not participate are presented in online Supplementary Table S1. The age distributions in the two groups were similar, while educational level was higher among women who participated. Women who were included in the present study tended to be slightly older and nulliparous and had a higher education and income level than those who were not included.

Assessment of diet and covariates

Dietary intake was assessed using a self-administered FFQ at the Q2 interview. Participants were asked about the frequency of consumption of sixty-four specified food items as well as additional questions about soup, beverages and cooking oil. For each food item, participants reported how many times they had consumed it 'in the past week'. Data on the amount consumed were not collected. Individual food items were combined into twenty-four groups according to a similar nutrient profile or culinary uses. The frequencies of intake of food groups were calculated by summing the weekly consumption frequencies of grouped foods, assuming that different food items contributed equally in the same group. Some food items were classified individually if the nutrient content was distinctly different (e.g. eggs or nuts) or if they were suspected to represent distinct dietary patterns (e.g. mushrooms or seaweed)⁽¹⁶⁾. The validity and reproducibility of this FFQ was evaluated based on a subsample of cohort participants. In the validation study, a total of 210 women completed (1) the first FFQ (FFQ1) at 24–27 weeks of gestation, (2) three 24 h dietary recalls, including two weekdays and one weekend, once per week during weeks 29–31 of gestation, and (3) the second FFQ (FFQ2) at 33–35 weeks of gestation. The crude Spearman correlation coefficients for consumption frequencies of food groups between the FFQ1 and the FFQ2 ranged from 0.33 (sea vegetable) to 0.71 (soup). For the FFQ2 and the 24 h dietary recalls, the crude Spearman correlation coefficients for consumption frequencies of food groups ranged from 0.23 (preserved vegetable) to 0.62 (dairy products).

Participants who completed the FFQ after the OGTT were excluded because their diet may have changed after the OGTT. Additional information collected from the FFQ1 included maternal age at recruitment, education level (middle school or below, college, undergraduate, or post-graduate), monthly income (<1500, 1500–4500, 4501–9000

or ≥ 9001 yuan, where 1 yuan = 0.16 US cents), parity, pre-pregnancy maternal height and weight, and history of diabetes (first-degree relatives). Pre-pregnancy BMI (kg/m^2) was calculated as the ratio of weight (kg) to squared height (m^2), and was categorised into three groups (< 18.5 , 18.5 – 23.9 and $\geq 24 \text{ kg}/\text{m}^2$)⁽¹⁸⁾.

Glucose tolerance outcomes

Participants were routinely given a 75 g, 2 h OGTT for GDM screening at a prenatal care visit. The diagnosis of GDM was made when any of the following blood glucose values was met or exceeded based on the criteria developed by the International Association of Diabetes and Pregnancy Study Groups⁽¹⁹⁾: fasting, $5.1 \text{ mmol}/\text{l}$; 1 h, $10.0 \text{ mmol}/\text{l}$; 2 h, $8.5 \text{ mmol}/\text{l}$.

Statistical analysis

The principal components factor analysis with orthogonal (varimax) rotation was used to derive the dietary patterns. To reduce the influence of food groups with a higher frequency and greater variance, the consumption frequencies of each food group were standardised according to the mean and standard deviation before extraction of dietary patterns⁽²⁰⁾. We retained four factors (dietary patterns) based on an inspection of scree plots and the interpretability of the results. Each dietary pattern was formed using linear combinations of food groups. The factor loadings, namely coefficients defining these linear combinations, represent the correlations of each food group with the corresponding dietary pattern. Food groups with loadings $> \pm 0.25$ were selected to describe the dietary patterns. We calculated factor scores for each dietary pattern by summing the consumption frequencies of each food group, weighted by their factor loadings for each participant. These scores were used as exposure variables for further analysis. Differences in maternal characteristics among groups were tested by using *t* tests or ANOVA for continuous variables or χ^2 tests for categorical variables. The analyses were performed using SPSS software version 17.0 (SPSS, Inc.).

A log-binomial regression model was used to examine the associations between dietary pattern scores and the risk of GDM, adjusting for maternal age, education level, monthly income, parity, pre-pregnancy BMI and family history of diabetes. Relative risks (RR) with their corresponding 95% CI were calculated using PROC GENMOD in SAS statistical software version 9.2 (SAS Institute, Inc.)^(21,22).

The dietary pattern scores were included in the model as tertiles (tertile 1–tertile 3). All four dietary patterns were simultaneously entered into the models. *P* for trend was evaluated using the median score for each category of dietary patterns and analysed as a continuous variable in multivariate models. We also performed stratified analysis to examine whether the effect of dietary patterns differed across maternal characteristics, including maternal age (< 35 *v.* ≥ 35 years), education level (middle school or below *v.* college, undergraduate and postgraduate), monthly income (< 1500 *v.*

1500 – 4500 , 4501 – 9000 and ≥ 9001 yuan), pre-pregnancy BMI (< 18.5 *v.* 18.5 – 23.9 and $\geq 24 \text{ kg}/\text{m}^2$), family history of diabetes (no *v.* yes) and parity (0 *v.* ≥ 1). The interaction between the dietary patterns and maternal characteristics was evaluated by including multiplicative interaction terms in multivariate models.

A two-tailed *P* value < 0.05 was considered statistically significant.

Results

Dietary patterns

In the present study, four main dietary patterns were extracted from the factor analysis. The factor loadings for each dietary pattern are listed in Table 1. The first pattern indicated the vegetable pattern and explained 12.2% of the total variance of food intake. It was characterised by frequent intake of root vegetables, beans, mushrooms, melon vegetables, seaweed, other legumes, fruits, leafy and cruciferous vegetables, processed vegetables, nuts, and cooking oil. The second pattern indicated the protein-rich pattern and explained 8.2% of the total variance. It was characterised by frequent intake of poultry, red meat, animal organ meat, grains (mainly refined), processed meat, fish, soups, leafy and cruciferous vegetables, and eggs. The third pattern indicated the prudent pattern and explained 6.7% of the total variance. It was characterised by frequent intake of dairy products, nuts, eggs, fish, soups, fruits, and infrequent intake of processed meat, sugar-sweetened beverages, and processed vegetables. The fourth pattern indicated the sweets and seafood pattern and explained 5.8% of the total variance. It was characterised by frequent intake of Cantonese desserts, molluscs and shellfish, and sugar-sweetened beverages and low intakes of grains (mainly refined) and leafy and cruciferous vegetables. All the four patterns together accounted for 32.9% of the total variation (Table 1). There were 1259 (41.1%) and 1224 (40.0%) women who were categorised into the highest and lowest tertiles for more than one pattern, respectively.

Participant characteristics

The characteristics of the study participants are presented in Table 2. The mean age was 28.9 (SD 3.2) years. In addition, 53.4% of the participants had an education level of undergraduate, 40.4% reported a monthly income of 4501–9000 yuan, 8.8% were overweight or obese (pre-pregnancy BMI $\geq 24 \text{ kg}/\text{m}^2$), 19.4% had a family history of diabetes, and most (93.3%) were nulliparous (Table 2).

Participant characteristics based on dietary pattern scores

The distributions of the baseline characteristics according to tertiles of dietary pattern scores are presented in Table 2. Women with a high vegetable pattern score tended to have a higher education and income level, while those with a high protein-rich pattern score were more likely to be younger and parous and have less education level (Table 2).

Table 1. Factor loadings for the four dietary patterns identified by the principal components factor analysis in 3063 pregnant women from the Born in Guangzhou Cohort Study*

Dietary patterns	Food	Factor loading coefficient	Cumulative variance explained (%)		
Vegetable	Root vegetables	0.63	12.2		
	Beans	0.63			
	Mushrooms	0.61			
	Melon vegetables	0.59			
	Seaweed	0.56			
	Other legumes	0.49			
	Fruits	0.43			
	Leafy and cruciferous vegetables	0.34			
	Processed vegetables	0.34			
	Nuts	0.32			
	Cooking oil	0.25			
	Protein-rich	Poultry		0.62	20.3
		Red meat		0.49	
		Animal organ meat		0.48	
Grains		0.48			
Processed meat		0.41			
Fish		0.36			
Soups		0.34			
Leafy and cruciferous vegetables		0.33			
Eggs		0.30			
Prudent		Dairy products	0.53	27.1	
		Nuts	0.50		
		Eggs	0.50		
		Fish	0.38		
		Soups	0.32		
	Fruits	0.27			
	Processed meat	-0.30			
	Sugar-sweetened beverages	-0.37			
	Processed vegetables	-0.38			
	Sweets and seafood	Cantonese desserts	0.68		32.9
		Molluscs and shellfish	0.62		
		Sugar-sweetened beverages	0.36		
		Grains	-0.29		
		Leafy and cruciferous vegetables	-0.34		

* For simplicity, factor loadings $< \pm 0.25$ were not listed.

In addition, a high prudent pattern score was associated with a slightly older age, higher education level and less parity, while a high sweets and seafood pattern score was associated with a higher income level and more parity (Table 2).

Multivariate regression analysis

Among the 3063 pregnant women, 544 (17.8%) were diagnosed with GDM. Table 3 summarises the multivariate regression analysis for the associations between the tertiles of dietary pattern scores and the risk of GDM. After adjustment for maternal age, education level, monthly income, parity, pre-pregnancy BMI and family history of diabetes, the highest tertile (tertile 3) of the vegetable pattern was associated with a decreased risk of GDM (RR 0.79, 95% CI 0.64, 0.97, P for trend=0.036) compared with the lowest tertile (tertile 1; Table 3), whereas the third highest tertile of the sweets and seafood pattern was associated with an increased risk of GDM (RR 1.23, 95% CI 1.02, 1.49, P for trend=0.010) compared with the lowest tertile (Table 3). In contrast, we found no significant association in the adjusted analysis for either the protein-rich or the prudent pattern (Table 3).

Stratified analysis

In the stratified analyses, there were no modification effects for the protein-rich, prudent, and sweets and seafood patterns by maternal age, education level, monthly income, pre-pregnancy BMI and parity (P for interaction > 0.05 , for all). However, the protective effect of a high vegetable pattern score appeared to be more evident among women who had a family history of diabetes (Fig. 1). Compared with the lowest tertile of the vegetable pattern score, the RR of the highest tertile were 0.94 (95% CI 0.74, 1.19) and 0.49 (95% CI 0.31, 0.76) for women with no family history of diabetes and those with a family history of diabetes, respectively (P for interaction=0.022; Fig. 1).

Discussion

In the present large prospective study, we investigated the associations between dietary patterns during pregnancy and the risk of GDM, and found that the vegetable dietary pattern was significantly associated with a decreased risk of GDM. In contrast, the sweets and seafood pattern was positively associated with the risk of GDM. To our knowledge, this is the first

Table 2. Distributions of maternal characteristics by dietary pattern score tertiles in 3063 pregnant women from the Born in Guangzhou Cohort Study (Mean values and standard deviations; number of participants and percentages)

Characteristics	All participants		Vegetable pattern*				Protein-rich pattern*				Prudent pattern*				Sweets and seafood pattern*			
	n	%	Tertile 1		Tertile 3		Tertile 1		Tertile 3		Tertile 1		Tertile 3		Tertile 1		Tertile 3	
Age (years)																		
Mean	28.9		28.7		28.9		29.1		28.7		28.7		29.1		28.9		29	
SD	3.2		3.4		3.0		3.4		3.1		3.2		3.4		3.3		3.3	
P†			0.266			0.002				0.004			0.294					
Education level																		
Middle school or below	306	10	121	11.9	85	8.3	106	10.4	108	10.6	133	13.0	75	7.3	111	10.9	98	9.6
College	756	24.7	292	28.6	217	21.3	235	23.0	261	25.6	281	27.5	223	21.8	245	24.0	253	24.8
Undergraduate	1637	53.4	545	53.4	541	53.0	526	51.5	566	55.4	485	47.5	592	58.0	537	52.6	549	53.8
Postgraduate	364	11.9	63	6.2	178	17.4	154	15.1	86	8.4	122	11.9	131	12.8	128	12.5	121	11.9
P†			<0.001			0.001				<0.001			0.875					
Monthly income (Yuan)‡																		
< 1500	227	8.2	76	8.1	54	5.9	75	8.1	78	8.4	80	8.7	66	7.1	82	9.0	72	7.6
1500–4500	1038	37.4	433	46.2	287	31.3	317	34.4	354	38.3	348	37.9	348	37.3	346	38.0	325	34.2
4501–9000	1120	40.4	334	35.6	417	45.4	379	41.1	380	41.1	366	39.9	377	40.4	373	41.0	393	41.4
≥ 9001	387	14	95	10.1	160	17.4	151	16.4	113	12.2	123	13.4	142	15.2	109	12.0	159	16.8
P†			<0.001			0.100				0.683			0.020					
Pre-pregnancy BMI (kg/m ²)‡																		
< 18.5	690	24.8	247	26.2	220	23.8	211	23.0	238	25.8	221	24.2	236	25.3	241	26.4	218	22.9
18.5–23.9	1844	66.4	616	65.4	633	68.4	623	67.8	604	65.4	600	65.6	627	67.1	582	63.7	650	68.3
≥ 24	244	8.8	79	8.4	73	7.9	85	9.2	82	8.9	94	10.3	71	7.6	90	9.9	84	8.8
P†			0.301			0.567				0.365			0.169					
Family history of diabetes‡																		
No	2274	80.6	769	80.3	748	79.7	770	81.9	755	80.7	741	79.4	756	79.9	763	82.0	770	79.6
Yes	549	19.4	189	19.7	190	20.3	170	18.1	181	19.3	192	20.6	190	20.1	167	18.0	197	20.4
P†			0.558			0.300				0.238			0.365					
Parity‡																		
0	2639	93.3	889	92.6	871	92.8	899	95.4	860	91.6	845	90.5	906	95.5	875	93.8	881	91.1
≥ 1	190	6.7	71	7.4	68	7.2	43	4.6	79	8.4	89	9.5	43	4.5	58	6.2	86	8.9
P†			0.185			0.003				<0.001			0.002					

*For simplicity, the numbers for tertile 2 are not listed.

†ANOVA and χ^2 tests were used to test the overall associations between maternal characteristics and three tertiles of dietary pattern scores.

‡The number of missing values for monthly income, pre-pregnancy BMI, family history of diabetes and parity was 291, 285, 240 and 234, respectively.

Table 3. Associations between the dietary patterns and the risk of gestational diabetes mellitus (GDM)

(Relative risks (RR) and 95% confidence intervals)

Dietary patterns	GDM cases*		Model 1†		Model 2‡	
	n	%	RR§	95% CI	RR§	95% CI
Total	544	17.8				
Vegetable						
Tertile 1	192	18.8	1.00	Reference	1.00	Reference
Tertile 2	194	19.0	1.01	0.84, 1.20	1.00	0.83, 1.21
Tertile 3	158	15.5	0.81	0.67, 0.99	0.79	0.64, 0.97
P for trend				0.047		0.036
Protein-rich						
Tertile 1	181	17.7	1.00	Reference	1.00	Reference
Tertile 2	183	17.9	1.01	0.83, 1.21	0.99	0.81, 1.20
Tertile 3	180	17.6	0.98	0.82, 1.19	0.95	0.78, 1.16
P for trend				0.887		0.659
Prudent						
Tertile 1	181	17.7	1.00	Reference	1.00	Reference
Tertile 2	175	17.1	0.98	0.81, 1.18	0.96	0.78, 1.17
Tertile 3	188	18.4	1.04	0.87, 1.25	1.00	0.82, 1.22
P for trend				0.719		0.914
Sweets and seafood						
Tertile 1	173	16.9	1.00	Reference	1.00	Reference
Tertile 2	156	15.3	0.88	0.73, 1.08	0.84	0.68, 1.04
Tertile 3	215	21.1	1.23	1.03, 1.48	1.23	1.02, 1.49
P for trend				0.010		0.010

* Percentage of GDM in each third.

† Adjusted for other dietary patterns.

‡ Adjusted for model 1 and for maternal age, education level, monthly income, pre-pregnancy BMI, family history of diabetes and parity.

§ RR (95% CI) were derived by log-binomial regression models.

study to specifically identify the effects of dietary patterns on the risk of GDM in a Chinese population, which has distinct dietary habits compared with the Western population. Although there was a lack of direct evidence for dietary changes after conception in China, women are advised to follow a set of dietary customs, including avoidance of certain foods such as mutton and increasing consumption of special foods such as soup and fat during pregnancy according to traditional Chinese culture^(23,24). However, there is a lack of scientific justification for these dietary customs^(23,24).

Only a few studies have examined the effects of dietary patterns on the risk of GDM^(11,15–17,25). Of these studies, three were from a large prospective study, the Nurses' Health Study II^(16,17,25). Among these three studies, the one by Zhang *et al.*⁽¹⁶⁾ reported that the Western dietary pattern score was positively associated with the risk of GDM, whereas the prudent dietary pattern score was inversely associated. The prudent dietary pattern consisted of a high consumption of fruit, green leafy vegetables, poultry and fish, while the Western pattern represented a high consumption of red meat, processed meat, refined grain products, sweets, French fries and pizza⁽¹⁶⁾. Tobias *et al.*⁽²⁵⁾ reported that healthy dietary patterns (alternate Mediterranean, Dietary Approaches to Stop Hypertension and alternate Healthy Eating Index) were significantly associated with a lower risk of GDM. Bao *et al.*⁽¹⁷⁾ found that a pre-pregnancy low-carbohydrate dietary pattern with high protein and fat from animal food sources was positively associated with the risk of GDM, whereas no association was found for a pre-pregnancy

low-carbohydrate dietary pattern with high protein and fat from vegetable food sources. Another study from Mediterranean countries also observed that the Mediterranean diet was associated with a lower incidence of GDM⁽¹⁵⁾. However, a study from Massachusetts, USA did not find an association between dietary patterns during early pregnancy and the risk of GDM⁽¹¹⁾.

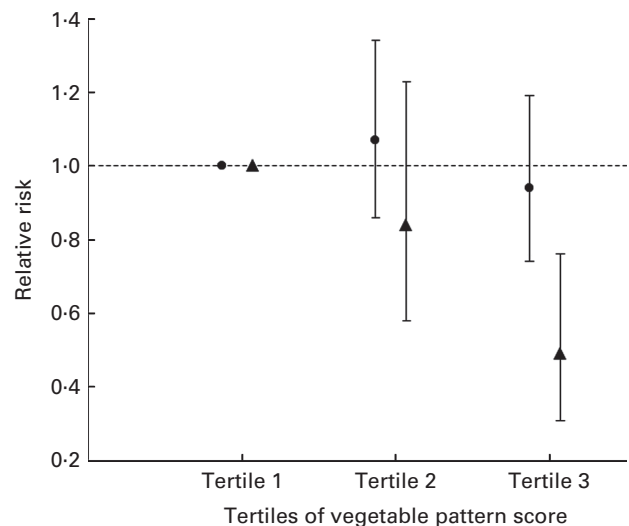


Fig. 1. Associations between vegetable pattern score tertiles and the risk of gestational diabetes mellitus, stratified by maternal family history of diabetes. P for interaction=0.022. ●, Women without a family history of diabetes; ▲, women with a family history of diabetes.

In the present study, we observed that the vegetable dietary pattern was significantly associated with a decreased risk of GDM. This is in line with previous studies, in which vegetables and fruits were important components of protective dietary patterns^(16,17,25). In addition, there is evidence that dietary fibre was significantly associated with a decreased risk of GDM^(12,26). The association between dietary fibre patterns and the risk of GDM might be explained by some potential mechanisms. For instance, high dietary fibre intake may reduce appetite and food consumption, then reduce adiposity and improve insulin sensitivity^(12,27). Another possible mechanism might be that fibre intake could delay gastric emptying, and slow food digestion and absorption, thereby decreasing glucose absorption and plasma insulin levels^(12,27,28). Finally, SCFA, derived from colonic fermentation of indigestible dietary fibre, have been shown to improve lipid homeostasis, hence increasing insulin sensitivity^(29,30).

Family history of diabetes is a well-established risk factor for the development of type 2 diabetes as well as for GDM⁽³¹⁾. The underlying mechanisms might involve environmental factors that cluster within a family and genetic components that are shared among relatives. In addition, as a specific complication occurring during pregnancy, the risk of GDM could be affected not only by the maternal genome, but also by the fetal and paternal genomes^(32–34). In the present study, we observed that the protective effects of a high vegetable pattern score were more evident among women who had a family history of diabetes, including the family history of their partners. In contrast, previous studies have also reported significant interactions between family history of diabetes and other known risk factors, including obesity and occupational physical activity, on the risk of type 2 diabetes^(35–37). To our knowledge, the present study is the first to report on the effect of the interaction between dietary factors and family history of diabetes on the risk of diabetes. We speculated that the harmful effects of other risk factors of GDM, along with family history of diabetes, might be attenuated by the effects of a high vegetable pattern score. Although the underlying mechanism remains to be elucidated, this finding may have a significant implication for public health, as interventions focusing on women with a family history of diabetes may be highly effective.

We also found that the sweets and seafood pattern was associated with an increased risk of GDM. In the Nurses' Health Study II, a high intake of sugar-sweetened cola, but not other sugar-sweetened beverages, was associated with an increased risk of GDM⁽³⁸⁾. These findings might be explained by the evidence that a high-sugar diet can decrease insulin sensitivity and insulin secretion^(6,39,40).

The protein-rich pattern was not associated with the risk of GDM, although previous studies have shown that a high intake of animal protein (especially red meat) was significantly associated with an elevated risk of GDM^(13,16). In addition, we did not find a significant effect of the prudent pattern on the development of GDM. Nevertheless, there is some epidemiological evidence suggesting that a high consumption of dairy products may be protective for type 2 diabetes and other components of the metabolic syndrome⁽⁴¹⁾. It has also been

reported that a higher intake of nuts was associated with a significantly lower risk⁽¹³⁾. Since dietary habits are population-specific, differences in study findings might be partly explained by differences in race/ethnicity between study populations.

The present study had several strengths, including the prospective design and a relatively large sample size. Compared with the analysis of individual nutrients or food items, dietary pattern analysis is able to capture synergistic effects among various nutrients and food, and the findings from dietary pattern analysis might be more comprehensive and informative for clinical practice and public health. However, there are also several limitations. First, we did not collect data on portion sizes of food items, and were unable to calculate the amount of food consumption. As previous studies have reported^(42–45), frequencies of food intake were used as a proxy for a quantitative indicator in the present study. Thus, misclassification of exposure is inevitable. Such sources of error would bias results towards the null; hence, the strength of the observed associations might be underestimated. Second, we assessed food intake 'in the past week'. The information during this short period might not be representative of dietary habits throughout early pregnancy. However, previous studies have suggested that overall dietary patterns remain stable during pregnancy^(46,47). Third, dietary consumption was based only on the frequency of food intake and information on portion size was not collected in the present study; thus, we were unable to adjust for total energy intake. Finally, residual confounding, which is common in observational studies, cannot be excluded, although we adjusted for several factors in the statistical analysis.

In conclusion, we found that the vegetable dietary pattern was significantly associated with a decreased risk of GDM, while the sweets and seafood pattern was positively associated with the risk of GDM. These findings provide evidence to support the recommendation to eat a balanced diet for pregnant women in the Chinese population. Further studies are needed to clarify the associations between dietary patterns and the risk of GDM as well as pregnancy outcomes in other Asian populations.

Supplementary material

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S0007114515000707>

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The authors' contributions are as follows: H.-M. X. and X. Q. conceived and designed the study; J.-R. H. and M.-Y. Y. conceived and designed the study, analysed and interpreted the data, and drafted the manuscript; N.-N. C., J.-H. L. and Y. L.

analysed and interpreted the data; C.-Y. H., W.-B. M., R.-F. Z., Y.-H. P., L. Q., Y.-F. W. and W.-Q. X. collected and assembled the data. All authors performed critical revision for important intellectual content and approved the final version of the manuscript.

There are no conflicts of interest.

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