Original Article

Association of Dietary Pattern during Pregnancy and Gestational Diabetes Mellitus: A Prospective Cohort Study in Northern China*

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Abstract

Objective To examine the association of maternal dietary patterns during pregnancy with gestational diabetes mellitus (GDM) in northern China.

Methods The dietary intakes of pregnant women were recorded twice by 24-hour dietary recalls for three days prior to having been diagnosed with GDM, at 5-15 and 24-28 gestational weeks, respectively. GDM was diagnosed, and serum glycosylated hemoglobin (HbA1c) was measured at 24-28 weeks. Dietary patterns were assessed by factor analysis. The association of the dietary pattern with GDM and HbA1c was examined by multiple logistic models.

Results Of 753 participants, 64 (8.5%) were diagnosed with GDM. Four dietary patterns were identified: Western pattern (dairy, baked/fried food and white meat), traditional pattern (light-colored vegetables, fine grain, red meat and tubers), mixed pattern (edible fungi, shrimp/shellfish and red meat) and prudent pattern (dark-colored vegetables and deep-sea fish). Compared with the prudent pattern, both the Western pattern and the traditional pattern were associated with an increased risk of GDM (a*OR* = 4.40, 95% *CI*: 1.58-12.22; a*OR* = 4.88, 95% *CI*: 1.79-13.32) and a high level of HbA1c (a*OR* = 12.37, 95% *CI*: 1.47-103.91; a*OR* = 26.23, 95% *CI*: 2.54-270.74). Compared to the lowest quartile (Q), Q3 of the Western pattern scores and Q3-Q4 of the traditional pattern scores were associated with a higher risk of GDM.

Conclusion The consumption of the Western pattern or the traditional pattern during pregnancy may increase the risk of GDM.

Key words: Gestational diabetes mellitus; Dietary pattern; Pregnant women; Glycosylated hemoglobin; Factor analysis

Biomed Environ Sci, 2017; 30(12): 887-897 *doi: 10.3967/bes2017.119* *ISSN: 0895-3988*

www.besjournal.com (full text) *CN: 11-2816/Q*

*The study was funded by China Medical Board [CMB Grant 13-131]; the Key Discipline Construction of Public Health of Shang hai [No. 15GWZK0402]; and the National Natural Science Foundation of China [Grant No. 81273066].

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INTRODUCTION

Gestational diabetes mellitus (GDM), presented as impaired glucose tolerance during pregnancy, is one of the most common pregnancy complications worldwide. The global prevalence of GDM is estimated as 8%, ranging from 1%-14% depending on the different population and the diagnostic criteria[1-3]. Substantial studies have shown that GDM poses health threats to both mother and offspring. Pregnant women with GDM had significantly higher risk of type 2 diabetes in later life[4-7]. A baby born to a mother with GDM has a high risk of developing macrosomia, experiencing shoulder dystocia, birth injuries, neonatal hypoglycemia, and perinatal death[6,8-9]. Offspring of mothers with GDM had a higher risk of metabolic syndrome and obesity in later life[10-11].

Large amounts of studies have examined the impact of the dietary intake during pregnancy on the risk of GDM. However, most previous studies only focused on the correlation between the specific macro- or micro-nutrients during pregnancy and the risk of GDM[12-14]. For example, high levels of dietary heme iron intake during the early pregnancy period[12] and energy, protein, fat and carbohydrates during the second trimester[14] were observed significantly positively associated with GDM. In addition, increased polyunsaturated fat intake between 24 and 28 weeks of pregnancy was found associated with a reduced incidence of glucose intolerance[13]. Conclusions from these studies did not account for the interactions or synergistic effects among different foods or nutrients. Furthermore, people usually consume foods in a dietary pattern, instead of a single food or nutrient. Thus, dietary guidance solely based on the above reports might lack practical significance. The dietary pattern, emerging in recent years, is an analysis of combining various foods consumed[15-17]. It examines the effect of the overall diet, rather than a certain food or nutrient, on health outcomes. However, except a few studies in countries, such as Iceland[16] and America[18], there is limited information on the associations of dietary patterns with GDM at various stages of pregnancy.

With rapid economic development in the recent two decades, China has undergone a nutrition transition, characterized by changes in dietary intake and a sedentary lifestyle[19]. It was reported that this change had contributed to the increased prevalence of diabetes in the Chinese general population[20]. Concurrently, the prevalence of GDM in China had increased by 2.8-fold from 1999-2008, from 2.4%-6.8%[21]. By the end of 2012, the prevalence had further increased to 9.3%[19]. However, very few studies examined the association of dietary pattern with GDM among Chinese pregnant women. Only one published study reported that the sweets and seafood pattern were associated with a higher risk of GDM among pregnant women in a southern urban area in China[22]. Considering the large territory and various dietary habits in China, the dietary pattern might vary according to the different geographic area. The aim of the present study was to examine the association of maternal dietary patterns before diagnosis with GDM in a northern urban area in China.

MATERIALS AND METHODS

Participants and Recruitment

This research used a prospective cohort study design. Pregnant women were recruited at 5-15 gestational weeks in the first trimester at the Maternal and Child Health Care Hospital, Tangshan, Hebei province, China. The dietary intakes of pregnant women were recorded twice, with one in the first trimester (5-15 gestational weeks) and another once in the second trimester (24-28 gestational weeks). The 24-h dietary recalls were made for three days at each time. The association of the dietary pattern during the period of 5-28 gestational weeks before diagnosis with GDM was examined.

Tangshan is a medium-sized coastal city in northern China, with a population of around 7,800,000 in 2015[23]. It is a relatively economically developed urban area in China. The maternal and child health hospital has the largest delivery number in Hebei province, with an annual delivery number of 12,000. From September 2013 to June 2014, pregnant women were recruited during the first trimester at the antenatal clinic of the hospital. Pregnant women participating in the antenatal care clinic were firstly approached and introduced to the study by the research investigators. Then, they were assessed for the eligibility of the study. Pregnant women were eligible for the recruitment if they were around 20-40 years old, 5-15 gestational weeks, and had no disease including preconception diabetes, GDM, gestational hypertension, heart disease, chronic renal disease, systemic lupus erythematosus, hypothyroidism, mental disease history and severe anemia. Women were recruited in the study after their informed consent was obtained. A total of 924 pregnant women was recruited at the baseline.

Data Collection and Follow-up

At the recruitment, investigator-administered questionnaire survey was conducted to collect the demographic and health-related information, including pre-pregnancy weight, height, family heredity, life style, and so on. Pre-pregnancy weight was self-reported, and height was measured in standing position without shoes. The measure of interviewer-administered 24-h dietary recall has been validated in pregnant women of Taiwan, China[24] and were usually used as the reference method[25]. Three days of 24-h dietary recalls were collected from each pregnant woman at 5-15 gestational weeks and 24-28 gestational weeks, respectively. One of the three days of the 24-h dietary recalls was taken *via* face-to-face interview by investigators when pregnant women received antenatal care in the clinic. In the interview, pregnant women were asked to recall everything consumed over the past 24 h. If the dietary consumption of the last 24 h was not typical for their usual diet, they would be asked to recall the dietary intakes two days prior to the interview day. The other two days dietary recalls were collected by telephone within 1-7 days after the first dietary recall. All of the investigators were medical students, and they received training on dietary intake recording before the data collection. Training on dietary recall for investigators was carried out using food samples, an electronic scale and picture presentation uniformly. The approaches of estimating the portion sizes and weight in grams were delivered during the training. The pictures with measuring device of different sizes were permitted to be taken home by the pregnant women for the telephone interviews. One day of gestational physical activity was also collected at 5-15 and 24-28 gestational weeks respectively through a validated Chinese physical activity scale[26]. Daily physical activity was expressed as metabolic equivalent task (MET).

Between 24 and 28 gestational weeks, the GDM was screened by the 75-g oral glucose tolerance test (OGTT) after the three days of 24-h dietary recalls. The results of OGTT and the values of glycosylated hemoglobin (HbA1c) were extracted from hospital records. OGTT is widely accepted as the diagnosis criteria for GDM and routinely used in hospitals. HbA1c is measured to identify the average blood glucose levels over the previous three months. It is usually used as a reference for glucose levels[27]. Considering the additional economic burden and necessity, a small portion of participants were tested for HbA1c (n = 88). There was no significant difference between these 88 women tested for HbA1c and the rest of the study population in the demographic characteristics (Table S1 available in www.besjournal.com). At follow-up, we excluded the women with infectious disease (n = 42), multiple pregnancy (n = 6), spontaneous abortion (n = 10), induced abortion (n = 10) or induced labour (n = 16) and stillbirth (n = 2). Of the 838 women who were invited to participate at first dietary recalls, 80 refused to answer the questionnaire the second time and were lost to follow-up. An additional five participants were excluded from the analysis since their energy intake exceeded 25,104 kJ (6,000 kcal). These resulted in a final total of 753 women in the present analysis. Ethics approval was obtained from the Ethics Committee of School of Public Health, Fudan University, China (IRB#2013-07-0460). All the subjects gave writter informed consent.

Dietary Assessment

The average daily intake of energy and nutrients was calculated from three days of 24-h dietary recalls using the Nutrition Calculator Software developed by the Department of Nutrition and Food Hygiene, School of Public Health, Fudan University, China, which based on China Food Composition Table developed by National Institute of Nutrition and Food Safety from Chinese Center for Disease Control and Prevention[28-29].

Briefly, the individual food items from 24-h dietary recall were aggregated into 24 food groups according to the Chinese food dictionary and nutritional ingredient (Table S2 available in www. besjournal.com). The intakes of two dietary recalls at 5-15 and 24-28 gestational weeks were averaged[30], representing the intake of food during the period of 5-28 gestational weeks before diagnosis of GDM. We used factor analysis in the principal component analysis (PCA) with varimax rotation to obtain the preliminary dietary patterns[31-33]. Then, only those with the factor eigenvalues > 1.0 were kept. The combination of the scree plot, Kaiser-Meyer-Olkin statistic, and interpretability were used to identify the final dietary patterns. In each dietary pattern, the factor loading of each food group indicated its association with the dietary pattern. The factor score of each dietary pattern for each pregnant woman was calculated by summing consumptions of food groups weighted by their factor loadings. Each pregnant woman had a factor score for each dietary pattern. A higher factor score suggested that a woman's diet was closer to this dietary pattern[34], and the dietary pattern with the highest factor score of all patterns was considered as the dominating pattern for the woman. In this study, the positive factor loadings > 0.300 were included in each dietary pattern and the dietary patterns were named according to the dietary composition of the predominant food groups. Pregnant women were categorized into quartiles according to their factor score of each dietary pattern.

Sample Size Estimation

The sample size calculation was based on the primary outcome of GDM. According to the literature[35], we estimated the incidence of GDM of 8% in the group exposed to the low risk dietary pattern. We estimated a relative risk of 2.0 for GDM in the group exposed to the high risk dietary pattern. A sample size of 690 was needed to show a difference between the two groups with 90% statistical power, at the 0.05 significance level. Given the 20% estimated dropout rate, a total of 828 pregnant women were needed for the recruitment.

Diagnostic Criteria

Pre-pregnancy body mass index (BMI) was calculated as self-reported weight (kg)/[height (m)]^2. Overweight and obesity were determined based on cut-off points of the Chinese Obesity Working Group: BMI < 18.5 kg/m^2 underweight, 18.5 kg/m^2 ≤ BMI < 24.0 kg/m^2 normal weight, 24.0 kg/m^2 ≤ BMI < 28.0 kg/m^2 overweight, and BMI ≥ 28.0 kg/m^2 obesity[36].

Each pregnant woman had 75-g OGTT in the second trimester (at 24-28 gestational weeks). In accordance with the new diagnostic criteria from International Association of Diabetes and Pregnancy Study Groups (IADPSG), women with one or more values that equaled or exceeded the following criteria, 5.1 mmol/L for fasting plasma glucose, 10.0 mmol/L for the first hour and 8.5 mmol/L for the second hour, from a 75-g OGTT were diagnosed as GDM[37].

We used 5.1% as the cut-off point of the high and low level of serum HbA1c. This cut-off point had acceptable sensitivity, specificity and a negative predictive value of 61%, 68%, and 93% for GDM prediction, respectively[27].

Covariates

Potential confounding factors involved in the multiple logistic regression were maternal age (> 28 years old compared with ≤ 28 years old, categorized by the median), pre-pregnancy BMI (≥ 24 kg/m^2 compared with < 24 kg/m^2), education (below college compared with college and above), partner smoking (yes compared to no), family history of diabetes (yes compared to no), parity (multiparous compared with nulliparous), daily food energy intake as a continuous variable and physical activity being classified into two categories by the median. Data on physical activity were expressed as MET hours per day. The physical activity during 5-28 gestational weeks was calculated by the average of physical activity at 5-15 and 24-28 gestational weeks.

Statistical Analysis

The Students's *t*-test and ANOVA test were used for the continuous variables, and the Pearson chi-square test was used for categorical outcomes. The association of the dietary pattern score quartiles with GDM, the dietary pattern types with GDM and the dietary pattern types with the level of serum HbA1c were determined by multiple logistic regression after controlling for maternal age, pre-pregnancy BMI, education, partner smoking, family history of diabetes, parity, daily food energy intake and physical activity, respectively. The quartiles of dietary pattern scores among pregnant women were considered as an ordinal variable in the multiple logistic regression models to test the *P*-values for the trend. In addition, dietary patterns were included in the multiple logistic models as dummy variables. The Package for Social Sciences (SPSS Inc., Chicago, IL, USA) for Windows Version 19.0 was used for all data analysis. A *P*-value < 0.05 was considered significant.

RESULTS

A total of 924 women were recruited, and 753 were followed up to the second dietary recalls (24-28 gestational weeks) before diagnosis of GDM. The median (interquartile range) of gestational week for the first time dietary recall was 12.7 (12.0, 13.3) weeks. Their three days of 24-h dietary recalls were recorded at 5-15 and 24-28 gestational weeks, respectively. The prevalence of GDM among study participants was 8.5% (64/753). Among 88 women who had been tested for HbA1c, the mean serum level was (5.36 ± 1.34)% and 63.6% (56/88) had elevated levels (> 5.1%) of serum HbA1c.

The gestational age of the dietary records ranged from 5-15 weeks in the first trimester and from 24-28 weeks in the second trimester. Four dietary patterns were identified in the first and second trimester, respectively (Table S3 and Table S4 available in www.besjournal.com). The dietary patterns during the period of 5-28 gestational weeks before the diagnosis of GDM are shown in Table 1. Four dietary patterns were identified by factor analysis, with eigenvalues of 1.41, 1.38, 1.31, and 1.22 for the Western, traditional, mixed and prudent patterns, respectively. The cumulative variance of the four dietary patterns was 22.2%. The Western pattern mainly included 'dairy, baked/fried food and white meat', accounting for 5.9% of the total variance. The traditional pattern was characterized by 'light-colored vegetables, fine grain, red meat and tubers' accounting for 5.7% of the total variance. The mixed pattern consisted of 'edible fungi, shrimp/shellfish and red meat', and the prudent pattern had 'dark-colored vegetables and deep-sea fish' accounting for 5.5% and 5.1% of the total variance, respectively.

Table 1. Dietary Pattern during Pregnancy before Diagnosis of Gestational Diabetes Mellitus (GDM)[a] (*n* = 753)

Dietary Pattern	Food Group	Factor Loading	Accumulative Variance (%)
Western pattern	Dairy products	**0.718**[b]	5.9
	Baked/fried food	**0.707**	
	White meat	**0.375**	
	Algae	0.189	
	Nuts	0.179	
	Fruit products	0.171	
	Beverage	-0.158	
	Fine grain	-0.179	
Traditional pattern	Light-colored vegetables	**0.673**	11.6
	Fine grain	**0.592**	
	Red meat	**0.529**	
	Tubers	**0.351**	
	Algae	0.239	
Mixed pattern	Edible fungi	**0.586**	17.1
	Shrimp/shellfish	**0.563**	
	Red meat	**0.413**	
	Deep-sea fish	0.252	
	Light-colored vegetables	0.233	
	Coarse grain	0.222	
	White meat	0.170	
	Beverage	0.155	
	Fruit products	-0.188	
	Fine grain	-0.272	
	Tubers	-0.334	
Prudent pattern	Dark-colored vegetables	**0.722**	22.2
	Deep-sea fish	**0.574**	
	Tubers	0.281	
	Fine grain	0.277	
	Fresh fruit	0.164	
	Coarse grain	0.160	
	Light-colored vegetables	-0.167	
	Algae	-0.224	

Note. [a]Factor loadings ≥ 0.150 or ≤ -0.150 were included in each factor. [b]The positive factor loadings > 0.300 were included in each dietary pattern and are presented in bold.

The median age of pregnant women was 28 years, ranging from 19-38 years old. Over 80% of women had an education level above college. The mean pre-pregnancy BMI was 21.3 kg/m^2, 14% (111/753) categorized as overweight, and 4% (30/753) obesity. More than 85% of the women were primipara. About half of the women's partners smoked. Approximately 25% of participants reported family history of diabetes. The proportion of women who suffered from moderate-severe nausea during early pregnancy was 44% (334/753). Maternal characteristics by quartiles of dietary pattern scores are presented in Table 2. Pregnant women with a higher score of the Western pattern (dairy, baked/fried food and white meat) appeared to have a higher education and were more likely to be nulliparous. A higher score of the mixed pattern (edible fungi, shrimp/shellfish and red meat) was associated with lower pre-pregnancy BMI. No significant difference was found among other characteristics by different dietary pattern scores.

Multiple logistic regression analysis showed that neither in the first trimester nor in the second trimester, there was significant association between

Table 2. Distributions of Maternal Characteristics by Quartiles of Dietary Pattern Scores (*n* = 753)

Characteristics	All Participants	Western Pattern[a]		Traditional Pattern[a]		Mixed Pattern[a]		Prudent Pattern[a]	
		Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4
Age (years)									
$\bar{x} \pm s$	28.0 ± 3.2	28.0 ± 2.8	28.0 ± 3.0	28.0 ± 3.1	28.0 ± 2.9	28.0 ± 3.5	28.0 ± 2.5	28.0 ± 2.4	28.0 ± 3.4
P^b		0.34		0.22		0.64		0.91	
19-28	537 (71.3)	132 (73.3)	131 (70.8)	129 (71.7)	125 (67.2)	133 (73.5)	124 (67.4)	123 (66.8)	130 (69.9)
29-38	216 (28.7)	48 (26.7)	54 (29.2)	51 (28.3)	61 (32.8)	48 (26.5)	60 (32.6)	61 (33.2)	56 (30.1)
P^b		0.59		0.35		0.20		0.53	
Education									
Below college	132 (17.5)	47 (26.1)	25 (13.5)	34 (18.9)	29 (15.6)	29 (16.0)	21 (11.4)	33 (17.9)	27 (14.5)
College and above	621 (82.5)	133 (73.9)	160 (86.5)	146 (81.1)	157 (84.4)	152 (84.0)	163 (88.6)	151 (82.1)	159 (85.5)
P^b		**0.002**		0.40		0.20		0.37	
Pre-pregnancy BMI (kg/m^2)									
$\bar{x} \pm s$	21.3 ± 3.4	21.6 ± 3.5	21.1 ± 3.4	21.5 ± 3.7	21.2 ± 3.1	21.6 ± 3.9	20.8 ± 3.3	21.4 ± 3.2	21.2 ± 3.2
P^b		0.14		0.35		**0.04**		0.53	
Underweight[c]	156 (20.7)	32 (17.8)	46 (24.9)	37 (20.6)	37 (19.9)	38 (21.0)	44 (23.9)	39 (21.2)	32 (17.2)
Normal weight[c]	456 (60.6)	112 (62.2)	109 (58.9)	106 (58.9)	111 (59.7)	103 (56.9)	113 (61.4)	104 (56.5)	128 (68.8)
Overweight[c]	111 (14.7)	27 (15.0)	24 (13.0)	26 (14.4)	32 (17.2)	31 (17.1)	20 (10.9)	34 (18.5)	19 (10.2)
Obesity[c]	30 (4.0)	9 (5.0)	6 (3.2)	11 (6.1)	6 (3.2)	9 (5.0)	7 (3.8)	7 (3.8)	7 (3.8)
P^b		0.35		0.55		0.13		0.06	
Parity									
0	648 (86.1)	144 (80.0)	162 (87.6)	150 (83.3)	154 (82.8)	148 (81.8)	163 (88.6)	157 (85.3)	154 (82.8)
≥ 1	105 (13.9)	36 (20.0)	23 (12.4)	30 (16.7)	32 (17.2)	33 (18.2)	21 (11.4)	27 (14.7)	32 (17.2)
P^b		**0.05**		0.89		0.07		0.51	
Partner smokers									
No	405 (53.8)	101 (56.1)	93 (50.3)	98 (54.4)	107 (57.5)	93 (51.4)	90 (48.9)	105 (57.1)	99 (53.2)
Yes	348 (46.2)	79 (43.9)	92 (49.7)	82 (45.6)	79 (42.5)	88 (48.6)	94 (51.1)	79 (42.9)	87 (46.8)
P^b		0.26		0.55		0.64		0.46	
Family history of diabetes									
No	564 (74.9)	134 (74.4)	130 (70.3)	137 (76.1)	135 (72.6)	126 (69.6)	132 (71.7)	142 (77.2)	137 (73.7)
Yes	189 (25.1)	46 (25.6)	55 (29.7)	43 (23.9)	51 (27.4)	55 (30.4)	52 (28.3)	42 (22.8)	49 (26.3)
P^b		0.37		0.44		0.66		0.43	

Note. Data are shown as mena ± SD *n*(%). [a]Western pattern: dairy, baked/fried food and white meat; traditional pattern: light-colored vegetables, fine grain, red meat and tubers; mixed pattern: edible fungi, shrimp/shellfish and red meat; prudent pattern: dark-colored vegetables and deep-sea fish. [b]ANOVA and Chi-square tests were used to test the associations between maternal characteristics and dietary patterns. [c]Underweight: BMI < 18.5 kg/m^2; normal weight: 18.5 kg/m^2 ≤ BMI < 24.0 kg/m^2; Overweight: 24.0 kg/m^2 ≤ BMI < 28.0 kg/m^2; obesity: BMI ≥ 28.0 kg/m^2.

dietary patterns and GDM (Table S5 and Table S6 available in www.besjournal.com). After combining the data of two times, during the period of 5-28 gestational weeks, compared with the women in the lowest quartile (Q1) of the Western pattern scores, pregnant women in the second quartile (Q2) did not have a statistically significant difference in the risk of GDM (*OR* = 1.78, 95% *CI*: 0.72-4.43); the women in the third quartile (Q3) had a significantly higher risk of GDM (*OR* = 3.29, 95% *CI*: 1.39-7.82); while the fourth quartile (Q4) did not show a statistically significant difference (*OR* = 1.68, 95% *CI*: 0.66-4.29). The *P*-value for the trend of the risk of GDM across increasing quartiles of the Western pattern scores was not significant (*P* trend = 0.15). Compared to pregnant women in the Q1 of the traditional pattern scores, no significant association was found for Q2 for the risk of GDM (*OR* = 1.29, 95% *CI*: 0.50-3.33), while Q3 and Q4 had a significantly higher risk of GDM (*OR* = 2.86, 95% *CI*: 1.19-6.83; *OR* = 2.92, 95% *CI*: 1.19-7.17). The trend between the risk of GDM and increasing quartiles of the traditional pattern scores was statistically significant (*P* trend = 0.005). Compared with the lowest consumption (Q1), there was no significant difference of other individual qualities including Q2, Q3, and Q4 on the risk of GDM, neither for the mixed pattern, nor for the prudent pattern (Table 3).

Furthermore, we examined the association of dietary patterns during 5-28 gestational weeks with the risk of GDM. There were 192, 190, 195, and 176 women assigned to each dietary pattern, respectively. Compared with the prudent pattern, both the Western pattern and the traditional pattern were significantly associated with GDM (*OR* = 4.40, 95% *CI*: 1.58-12.22; *OR* = 4.88, 95% *CI*: 1.79-13.32), but the mixed pattern was not associated with GDM (*OR* = 1.61, 95% *CI*: 0.52-4.97) (Table 4). In addition, compared with the prudent pattern, both the Western pattern and the traditional pattern were also significantly associated with a high level of HbA1c (*OR* = 12.37, 95% *CI*: 1.47-103.91; *OR* = 26.23, 95% *CI*: 2.54-270.74), but the mixed pattern showed no significant difference (*OR* = 7.06, 95% *CI*: 0.90-55.45) (Table 5).

DISCUSSION

Our study identified four dietary patterns among pregnant women and examined the association of dietary pattern based on two measures at 5-15 and 24-28 gestational weeks with GDM in a northern costal urban area of China. No significant association was found between the dietary patterns in the first and second trimester in relation to GDM separately.

Table 3. Multiple Logistic Regression for the Risk of GDM According to the Quartiles of Dietary Pattern Scores during Pregnancy before Diagnosis of GDM[a] (*n* = 753)

Dietary Pattern		Non-GDM	GDM	*OR* (95% *CI*)[b]	*P*[b]	*P*-trend[c]
Western pattern (Dairy, baked/fried food and white meat)	Q1	179	8	1.00		
	Q2	172	16	1.78 (0.72, 4.43)	0.21	
	Q3	165	25	3.29 (1.39, 7.82)	**0.007**	
	Q4	173	15	1.68 (0.66, 4.29)	0.28	0.15
Traditional pattern (Light-colored vegetables, fine grain, red meat and tubers)	Q1	179	9	1.00		
	Q2	179	11	1.29 (0.50, 3.33)	0.60	
	Q3	164	20	2.86 (1.19, 6.83)	**0.02**	
	Q4	167	24	2.92 (1.19, 7.17)	**0.02**	**0.005**
Mixed pattern (Edible fungi, shrimp/shellfish and red meat)	Q1	171	17	1.00		
	Q2	175	14	0.88 (0.41, 1.93)	0.76	
	Q3	169	20	1.15 (0.56, 2.38)	0.70	
	Q4	174	13	0.70 (0.32, 1.55)	0.39	0.56
Prudent pattern (Dark-colored vegetables and deep-sea fish)	Q1	170	18	1.00		
	Q2	171	15	0.92 (0.43, 1.96)	0.82	
	Q3	167	22	1.42 (0.69, 2.92)	0.34	
	Q4	181	9	0.49 (0.20, 1.22)	0.12	0.35

Note. [a]Controlled for maternal age, pre-pregnancy BMI, education, partner smoking, family history of diabetes, parity, daily food energy intake and physical activity. [b]Odds ratios (and 95% *CI*) and *P*-value according to the reference of Q1. [c] *P*-trend value for the trend test.

However, the dietary patterns identified using the averaged data during 5-28 gestational weeks was found to be associated with GDM. Compared with the prudent pattern (healthy diet consisting of dark-colored vegetables and deep-sea fish), the Western pattern (dairy, baked/fried food, and white meat) and the traditional pattern (light-colored vegetables, fine grain, red meat, and tubers) were associated with an increased risk of GDM and a high level of serum HbA1c. Compared to the Q1, Q3 of the Western pattern scores and Q3-Q4 of the traditional pattern scores were associated with a higher risk of GDM. It is speculated that the dietary intake might have a continuous impact on health outcomes rather than having the affection at the first or second trimester solely.

In the present study, the prudent dietary pattern characterized by dark-colored vegetables and deep-sea fish was considered to be the healthy dietary pattern associated with a reduced risk of GDM. Previous studies have also shown the significant association between dietary pattern and GDM. For example, a study by Tryggvadottir et al. in Iceland indicated that the prudent dietary pattern had positive factor loadings for seafood, eggs, vegetables, fruit and berries, vegetable oils, nuts and seeds, pasta, breakfast cereals and coffee and tea and negative factor loadings for soft drinks and French fries, associated with a lower risk of GDM[16]. Another study conducted in a southern region of China using a food frequency questionnaire also reported a significant association of maternal dietary pattern with GDM, by showing the highest tertile of vegetable pattern characterized by root vegetables, beans, mushrooms, melon vegetables, seaweed, other legumes, fruits, leafy and cruciferous vegetables, processed vegetables, nuts, and cooking oil associated with a lower risk of GDM[22]. In contrast, Shin et al. reported that high intake of refined grains, fat, added sugars and low intake of fruits and vegetables were associated with higher risk of GDM among American pregnant women in a cross-sectional study[18]. However, a study by He et al. showed that the dietary pattern including seafood consumption of molluscs and shellfish, accompanied by sweets and low grain and leafy and cruciferous vegetables, was associated with an increased risk of GDM[22]. Inconsistent findings from various studies may be explained by the dietary patterns consisting different foods items in various studies.

Table 4. Multiple Logistic Regression for Risk of GDM According to the Type of Dietary Patterns during Pregnancy before Diagnosis of GDM[a] (n = 753)

Dietary Pattern	Non-GDM (n = 689)	GDM (n = 64)	OR (95% CI)	P
Western pattern (dairy, baked/fried food and white meat)	170 (88.5%)	22 (11.5%)	4.40 (1.58, 12.22)	**0.004**
Traditional pattern (light-colored vegetables, fine grain, red meat and tubers)	163 (85.8%)	27 (14.1%)	4.88 (1.79, 13.32)	**0.002**
Mixed pattern (edible fungi, shrimp/shellfish and red meat)	185 (94.9%)	10 (5.1%)	1.61 (0.52, 4.97)	0.41
Prudent pattern (dark-colored vegetables and deep-sea fish)	171 (97.2%)	5 (2.8%)	1.00	-

Note. [a]Controlled for maternal age, pre-pregnancy BMI, education, partner smoking, family history of diabetes, parity, daily food energy intake, and physical activity; the prudent pattern as the reference group.

Table 5. Multiple Logistic Regression for the Level of HbA1c According to the Type of Dietary Patterns during Pregnancy before Diagnosis of GDM[a] (n = 88)

Dietary Pattern	HbA1c < 5.1% (n = 32)	HbA1c ≥ 5.1% (n = 56)	OR (95% CI)	P
Western pattern (dairy, baked/fried food and white meat)	12 (40.0%)	18 (60.0%)	12.37 (1.47, 103.91)	**0.013**
Traditional pattern (light-colored vegetables, fine grain, red meat and tubers)	4 (18.2%)	18 (81.8%)	26.23 (2.54, 270.74)	**0.004**
Mixed pattern (edible fungi, shrimp/shellfish and red meat)	8 (34.8%)	15 (65.2%)	7.06 (0.90, 55.45)	0.06
Prudent pattern (dark-colored vegetables and deep-sea fish)	8 (61.5%)	5 (38.5%)	1.00	-

Note. [a]Controlled for maternal age, pre-pregnancy BMI, education, partner smoking, family history of diabetes, parity, daily food energy intake and physical activity; the prudent pattern as the reference group.

In the present study, women following the prudent dietary pattern had lower levels of serum HbA1c than women following the Western pattern and the traditional pattern. None of the previous studies reported an association of dietary pattern and serum HbA1c among pregnant women. A higher HbA1c level indicates poorer control of blood glucose levels and higher risk of GDM. The finding from the present study was consistent with the observed association of dietary patterns with GDM. The association of dietary pattern with circulating HbA1c levels has also been observed in the general population. Berkowitz et al. reported that diabetic patients with more intake of dark green and orange vegetables and legumes had a lower serum HbA1c level among general population[38]. Another study showed that marine collagen peptides (MCPs) supplement from deep-sea fish could significantly reduce the level of HbA1c in Chinese patients with type 2 diabetes mellitus[39]. In addition, a randomized controlled clinical trial in women diagnosed with GDM showed that adherence to a dietary pattern rich in fruits, vegetables, whole grains and low-fat dairy products resulted in decreased HbA1c levels[40]. Our study for the first time identified that the prudent dietary pattern was associated with lower levels of serum HbA1c and reduced risk of GDM in pregnant women.

Our analysis on dietary pattern considered the groups of foods and the interaction of a variety of food intakes among pregnant women. The findings will be informative for clinical practice. Particularly in our study, the significant association of the dietary pattern during 5-28 gestational weeks before the diagnosis of GDM suggested that the dietary intake in this period of pregnancy might have effect for preventing GDM. Recent trials aiming at reducing GDM through dietary interventions during early pregnancy have shown the beneficial effects[41-42]. A randomized controlled trial in the Finland aiming to prevent GDM has alluded to modest dietary improvements in pregnant women and reduced GDM risk after dietary counselling in early pregnancy[41]. In addition, a quasi-experimental trial in Chinese overweight and obese women found that lifestyle intervention including dietary improvement in early pregnancy could reduce the incidence of GDM[42]. In view of the fact that most clinical dietary consultation was being provided only at the second trimester all cross China[43-44], pre-pregnancy and early pregnancy dietary consultation should be considered, which may curtail adverse outcomes, such as GDM. In addition, the traditional pattern characterized by 'light-colored vegetables, fine grain, red meat and tubers' was associated with increased risk of GDM. However, the red meat in the traditional pattern would be beneficial to alleviating anemia[45-46]. Red meat might have a different effect when being combined with different foods. Therefore, caution should be taken to balance the different dietary patterns when providing pregnant women with dietary guidance.

The strength of our study included, first, that the dietary intakes of pregnant women were recorded before the diagnosis of GDM. The prospective cohort design was employed to examine the association of maternal dietary patterns with GDM. Second, three days of 24-hour dietary recalls were used to assess the dietary intake of pregnant women. The dietary intakes both in the first trimester and the second trimester were collected. Compared to the data collection through food-frequency questionnaire (FFQ) at a certain gestational time point in other studies[22,47], the dietary intake collection in our study minimized recall bias and, thus, reflected more truly the dietary status of pregnant women. Third, the combination of the epidemiologic observation and detection of biochemical indicators provided consistent evidence of the impact of dietary pattern on GDM.

There were several limitations in the present study. First, due to the difficulty of recruiting pre-conception women and long-term following up, we did not collect pre-pregnancy dietary information that might also have a fundamental and long-term effect on health. Second, only one day of physical activity of pregnant women was recorded at 5-15 or 24-28 gestational weeks, which might incompletely reflect their physical activity throughout the pregnancy period. Third, the sample size of the HbA1c test was small, which resulted in wider 95% confidence intervals. Fourth, in the early pregnancy, many women were affected by nausea, so the measurement of dietary intakes at the first time point might not be able to fully reflect the true situation. However, we have delayed the time of the first time dietary intake recording to 5-15 (interquartile range: 12.0-13.3) gestational weeks, when nausea had disappeared in most women to reduce the impact of nausea. In addition, women involved in the present study lived in an urban area in China and were overall well educated, which was similar to other studies[26,48]. And the dietary patterns defined in this study were derived from the study data. Therefore the study findings were specific to the diet in this population and the generalizability might be limited. Last, pre-pregnancy weight was self-reported by women from the baseline questionnaire, which could lead to recall bias on BMI.

CONCLUSION

Our study has identified that two dietary patterns characterized by 'dairy, baked/fried food and white meat' and 'light-colored vegetables, fine grain, red meat and tubers' before 28 gestational weeks had a significant association with increased risk of GDM. These findings suggest that an earlier dietary guidance at pre-conception or early pregnancy may help curtail GDM. Future prospective studies with multiple research sites are warranted to further confirm the association of dietary patterns with GDM.

ACKNOWLEDGEMENTS

The authors express their thanks to all participants for their collaboration and all of the members of the cohort study team.

AUTHOR CONTRIBUTORS

QIAN Xu, HE Geng Sheng, JIANG Hong, O Karmin and DU Hong Yi contributed to the study protocol and grant applications for the study. DU Hong Yi, XU Lin Ji, LIU Shu Ping, and YI Jian Ping conducted the data collection. DU Hong Yi, JIANG Hong, and CHEN Bo undertook the analyses reported in the paper. All authors contributed to the interpretation of the data and the writing of the manuscript. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

No conflict of interest to declare.

Received: June 7, 2017;
Accepted: September 30, 2017

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