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Empirically Derived Prepregnancy Dietary Patterns and the Risk of Gestational Diabetes Mellitus: A Case-Control Study

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ABSTRACT

Background: Gestational diabetes mellitus (GDM), diabetes first recognized during pregnancy, is associated with complications for mothers and their offspring. This study aimed to identify empirically-derived dietary patterns in pregnant women and their associations with GDM. **Methods:** A total of 274 pregnant women (138 women with GDM and 136 controls) participated in this case-control study. Anthropometric measurements were performed for all the participants. The participants dietary intake data was collected via a valid food frequency questionnaire. The major dietary patterns were obtained via principal component analysis (PCA) based on participants' actual food consumption data. The participants were divided into tertiles based on their adherence to each dietary pattern and the associations between dietary patterns and GDM were investigated via multivariate logistic regression. **Results:** The findings revealed three major dietary patterns. Adherence to the "traditional pattern" was associated with an increased risk of GDM. This association remained significant after adjusting for all confounding factors (highest vs. lowest tertile: OR=3.44, 95% CI=1.54-7.69, *P-trend*=0.001). Similarly, women in the third tertile of the "western pattern" had an elevated risk of GDM compared with those in the first tertile (third vs. first tertile: OR=1.96, 95% CI=1.02-3.80, *P-trend*=0.011). In contrast, participants who adhered to a healthy pattern had a negative association with GDM risk (after adjustment *P-trend*<0.001). **Conclusions:** This study demonstrates that dietary patterns of empirically-derived prepregnancy significantly influence the risk of GDM. These findings underscore the importance of targeted nutritional counseling and interventions before pregnancy to mitigate GDM risk and promote maternal and fetal health.

Introduction

Gestational diabetes mellitus (GDM) is diagnosed when diabetes or glucose intolerance is first recognized during pregnancy (Expert Committee on the Diagnosis and Classification of Diabetes Mellitus, 2003), and it is associated with an increased risk of short-term and long-term adverse outcomes for both mothers and infants . The prevalence of GDM varies regionally,

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ranging from 5.8% in Europe to 12.9% in the Middle East and North Africa (Zhu and Zhang, 2016). The prevalence of GDM was estimated at 3.4% in Iran (Jafari-Shobeiri *et al.*, 2015).

Several risk factors for GDM include older age during pregnancy, a family history of diabetes, and race or ethnicity (Seshadri, 2002). Furthermore, obesity, physical activity, smoking, and dietary factors are modifiable risk factors for GDM (Solomon *et al.*, 1997, Zhang and Ning, 2011).

The objective of dietary pattern analysis is to evaluate the usual foods consumed as a result of overall dietary exposure (Hu, 2002, Kant, 2004). Dietary patterns are described as the quantities, proportions, varieties, or combinations of different foods and beverages in diets and the frequency with which they are consumed regularly (Food and Agricultural Organization, 2016). Dietary pattern analysis provides a comprehensive view of nutrient and food intake. Another advantage of assessing overall food patterns is that they can also explain any interactions or synergistic effects among single foods or nutrients (Tobias *et al.*, 2012). Previous studies have reported that maternal dietary patterns during pregnancy can affect the health of mothers and infants; and are associated with poor pregnancy outcomes, such as GDM, preterm birth, and low birth weight.

Previous studies examining the relationship between dietary patterns and GDM have reported conflicting results. For example, adherence to a Western dietary pattern characterized by a high intake of red meat, processed meat, refined grain products, sweets, French fries, and pizza among USA pregnant women in the USA, a pasta-cheese-processed meat pattern in a Singaporean population, a sweet and seafood pattern in China , and an unhealthy dietary pattern (high intake of mayonnaise, juice, fries, red meat, soft drinks, pizza, sweets, etc) among pregnant women in Iran has been associated with an elevated risk of GDM . In contrast, pregnant women who had a healthy dietary pattern characterized by high consumption of vegetables, rye bread, fruits, and fish , a prudent dietary pattern (high intake of potato, low-fat dairy, nuts, and organ meat), and plant-based dietary patterns during pregnancy or prepregnancy were inversely associated with the odds of GDM. However, some studies have shown no association between dietary patterns and GDM (Mak *et al.*, 2018, Yong *et al.*, 2020).

Considering the short-term and long-term complications of GDM for both mothers and offspring, the limited number of studies investigating the relationship between dietary patterns and GDM, and the conflicting results between different studies, the current study was conducted to identify major dietary patterns in pregnant women with GDM.

Materials and Methods

Design and participants

This case-control study was conducted from August 2022 to January 2023 among pregnant women visiting public health centers in Abadan city. A total of 290 pregnant women (145 cases and 145 controls) aged 18-40 were recruited. The exclusion criteria included any physical or mental disability, diabetes before pregnancy, a history of GDM in previous pregnancies, and multiple pregnancies. All the subjects were informed about the study protocol and aims and signed a consent form at recruitment. The ethics committee of Jundishapur University of Ahvaz also approved the study.

GDM was diagnosed according to the criteria of the American Diabetes Association (ADA). It is recommended that all pregnant women without overt diabetes undergo a 75-g oral glucose tolerance test (OGTT) at 24-28 weeks of gestation. The diagnostic cutoff values for GDM included fasting blood glucose ≥ 92 mg/dl, 1 hour ≥ 180 mg/dl, and 2-hour ≥ 153 mg/dl. The diagnosis of GDM is confirmed if any of the plasma glucose values are exceeded (American Diabetes Association, 2014). The women in the control group were matched with the women affected by GDM in terms of their age (in five-year categories).

Measurements

Demographic and anthropometric: At the first visit, theparticipants demographic information, including age, family history of diabetes, family

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history of GDM, previous history of GDM, supplement use, educational level, smoking status, ethnicity, and marital status was collected through a questionnaire.

Prepregnancy body mass index (BMI) data were obtained from the patients' electronic files. Anthropometric measurements were performed for all the participants. Body weight was measured via a digital scale and recorded to the nearest 0.1 kg in light clothes and without shoes. Height measurement was performed via a tape meter while the participant was standing in a straight position against the wall with no shoes (World Health Organization, 1995). BMI was calculated as weight in kg divided by the square of height in meters.

Physical activity assessment: A validated questionnaire was used to evaluate the level of physical activity. Physical activity was measured and presented as metabolic equivalents hours/day (METs-h/d). In this questionnaire, nine different METs were categorized on a scale ranging from sleep/ rest (0.9 METs) to high-intensity physical activities (>6 METs) (Aadahl and Jørgensen, 2003). On the basis of the participant's report about the time spent per day in each activity, the METs were calculated as follows: the time spent in each activity was multiplied by its typical energy expenditure; the resulting values were then summed to yield a MET-hour/day score.

Dietary assessment: A semiquantitative food frequency questionnaire (FFQ) was used to measure the frequency of intake of various food items per day, week, month, or year. This FFQ includes 147 food items, and its reliability, and validity were confirmed for the Iranian population. The participants were asked to report their usual frequency of intake of each food item while considering the standard serving size during the previous year. The size of the food consumed was then changed to grams on the basis of household scale guidelines. Then, the selected frequency category for each food item was converted into a daily intake. Household measures were applied to convert the portion size of the consumed foods to grams. To obtain food patterns, 147 food items were categorized into 19 groups on the basis of their similarity in nutritional composition and previous studies. Finally, principal component analysis (PCA) was applied to determine major dietary patterns.

Participants who completed less than 40% of the dietary questionnaire (15 participants) and one participant whose energy intake exceeded 4000 kcal were excluded from the study to prevent measurement error and reporting bias. However, the possibility of recall bias due to the self-reported nature of the FFQ tool still exists and should be considered in the interpretation of the results.

Ethical considerations

This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (IR.AJUMS.REC.1401.213). Informed consent was obtained from all participants, and the authors ensured confidentiality and anonymity during study.

Data analysis

The data were analyzed via SPSS (version 25; SPSS Inc., Chicago, IL, USA). Quantitative variables are reported as the mean±SD, and qualitative variables are expressed as percentages. Student's t-test and the Mann-Whitney test were applied for normally and nonnormally distributed variables, respectively. Following that, chi-square tests were used for categorical variables. Principal component analysis was used to generate major dietary patterns. With respect to sampling adequacy, Bartlett's test of sphericity and Kaiser-Myer-Olkin (KMO) must be used, and considering a KMO value > 0.6 and $P \leq 0.05$ for Bartlett's test, the adequacy of sampling and data was confirmed. The number of factors (dietary patterns) to be retained in this study was determined by considering the criteria of an eigenvalue > 1.3 and analysis of the scree plot. Although the common criterion was an eigenvalue > 1.0 scree plot, in this study, by using the scree plot test and interpreting the factor loads, choosing a value of 1.3 led to the extraction of clearer and more interpretable dietary patterns. Orthogonal rotation (varimax) was applied to simplify the interpretation of the data.

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Food groups were included in the analysis if they had a factor loading ≥ ±0.3. The dietary patterns were subsequently divided into tertiles, where the first and third tertile represent the lowest and highest adherence to the dietary pattern, respectively. The association between dietary patterns and the risk of GDM was shown by the odds ratio (OR) and the 95% confidence intervals (CIs) calculated via multivariable logistic regression. Confounding factors were then recognized on the basis of previous studies. To adjust for the effects of confounding variables, three models of logistic regression were assessed: model 1 was crude, model 2 was adjusted for age, BMI, and energy intake, and model 3 was further adjusted for life facilities, education levels, physical activity, and family history of diabetes.

Results

The general characteristics of the participants are presented in **Table 1**.

Table 1. Characteristics of participants**.**

Variables	GDM (n=138)	Control (n=136)	P-value[a]
Quantitative variables			
Age (year)	30.28 ± 5.01[b]	29.07 ± 5.57	0.09
prepregnancy weight (kg)	73.40 ± 14.70	66.65 ± 12.95	<0.001
Height (cm)	159.31 ± 14.40	159.64 ± 5.81	0.35
BMI (kg/m2)	29.03 ± 6.14	26.39 ± 5.89	< 0.001
Age of first pregnancy (year)	23.34 ± 5.11	23.09 ± 4.94	0.68
Time between pregnancies (year)	3.92 ± 3.50	3.54 ± 3.73	0.22
Energy intake (kcal/day)	2392.98 ± 714.41	2308.00 ± 670.29	0.31
Protein intake (% total kcal)	13.03 ± 1.75	13.24 ± 1.97	0.33
Carbohydrate intake (% total Kcal)	55.13 ± 5.24	56.21 ± 5.43	0.09
Fat intake (% total kcal)	32.98 ± 5.21	31.94 ± 5.35	0.1
Physical activity (met-hour/day)	33.90 ± 3.36	33.52 ± 2.53	0.38
Categorical variables			
Family history of diabetes			0.01
Yes	79 (57.2)[c]	57 (41.9)	
No	59 (42.7)	79 (58.0)	
Family history of GDM			0.08
Yes	19 (13.7)	10 (7.3)	
No	119 (86.2)	126 (92.6)	
History of spontaneous abortion			0.05
Yes	45 (32.6)	30 (22.0)	
No	93 (67.3)	106 (77.9)	
History of hypertension			0.01
Yes	19 (13.7)	6 (4.4)	
No	118 (85.5)	130 (95.5)	
History of preeclampsia			0.06
Yes	7 (5.0)	1 (0.7)	
No	130 (94.2)	135 (99.2)	
Life facilities			0.009
High	16 (11.5)	11 (8.0)	
Intermediate	80 (57.9)	59 (43.3)	
Low	42 (30.4)	66 (48.5)	

[a]: t-test and Mann-Whitney test used for quantitave and Chi-square for categorical variables; [b]: Mean±SD; [c]: n (%); ***BMI****: Body mass index;* ***GDM****: Gestational diabetes mellitus.*

The data of 15 participants (9 controls and 6 cases) were excluded from the analysis because at least 40% of the FFQ questionnaire was not completed. Furthermore, one of the participants in the case group was eliminated because her caloric intake was more than 4000 kcal. Finally, a

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total of 274 participants were included in the analysis. There were significant differences in prepregnancy weight and BMI between the case and control groups (*P<0.0001*). Moreover, significant differences in family history of diabetes (*P=0.01*), history of hypertension, and life facilities were detected between the study groups.

The analysis of the dietary data of the participants was performed via principal component analysis, and three dietary patterns with eigenvalues>1.3 were identified. The first pattern was the traditional dietary pattern, which is characterized by a high intake of sweets and biscuits, drinks, white meats and eggs, refined grains, high-fat dairy, red meats, and organ meats, and this pattern explained 13.54% of the total variance. The second pattern is the healthy dietary pattern, which is characterized by a high intake of fruits, vegetables, fruit juices, legumes, and low-fat dairy. The third was the Western dietary pattern, characterized by high consumption of fast foods, potatoes, red meats, whole grains, and organ meats. The healthy and western dietary patterns explained 11.71% and 9.55% of the total variance, respectively. **Table 2** lists the food groups and their factor loadings for each dietary pattern. The associations between tertiles of dietary patterns and the odds of GDM are presented in **Table 3**.

Table 2. Rotated factor loading matrix for the three dietary patterns.

Food groups	Dietary patterns		
	Traditional	Healthy	Western
Sweets and biscuits	0.650		
Sweetened Beverages	0.637		
White meats and eggs	0.586		
Refined Grains	0.529		
High-fat dairy products	0.419		
Fruits		0.700	
Vegetables		0.660	
Fruit juices		0.518	
Legumes		0.481	
Low-fat dairy products		0.439	
Fast foods			0.627
Potato			0.595
Red meats	0.384		0.577
Whole grains			0.469
Organ meats	0.384		0.413
Total variance explained	13.54	11.71	9.55

Values less than /0.3/ were excluded. Bartlett's test of sphericity: 645.3, significance <0.0001; Kaiser–Meyer–Olkin test = 0.64.

Table 3. OR and 95% CI for the associations between dietary patterns and GDM.

Paterns	Q1	Q2	Q3	P-trend[a]
Traditional pattern				
Model 1	1	2.34 (1.29-4.25)	2.45 (1.35-4.45)	0.002
Model 2	1	3.07 (1.60-5.88)	3.37 (1.53-7.38)	0.001
Model 3	1	3.08 (1.59-5.98)	3.44 (1.54-7.69)	0.001
Healthy pattern				
Model 1	1	1.14 (0.63-2.04)	0.76 (0.42-1.37)	0.037
Model 2	1	1.01 (0.54-1.98)	0.56 (0.30-1.09)	<0.001
Model3	1	0.93 (0.49-1.77)	0.50 (0.25-1.08)	<0.001
Western pattern				
Model 1	1	1.49 (0.83-2.68)	2.23 (1.23-4.03)	0.009
Model 2	1	1.61 (0.86-3.00)	2.17 (1.15-4.07)	0.011
Model 3	1	1.56 (0.82-2.96)	1.96 (1.02-3.80)	0.036

[a]*: Logistic regression, P-value <0.05 was considered significant, n=274;* ***Model 1****: Crude;* ***Model 2****: Adjusted for age, BMI, and energy intake;* ***Model 3****: Adjusted for* ***Model 2*** *+ life facility, education, physical activity, and family history of diabetes.*

To minimize the effects of confounding factors, three logistic regression models were used. model 1 was crude, model 2 was adjusted for age, BMI, and energy intake, and model 3 was adjusted for

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life facility, education, physical activity, and family history of diabetes, in addition to variables mentioned in Model 2. After adjusting for all confounding factors (Model 3), women in the second and third tertiles of the "traditional pattern" had a significantly increased risk of GDM compared with those in the first tertile (second vs. first tertile: OR=3.08, 95% CI=1.59-5.98, third vs. first tertile: OR=3.44, 95% CI= 1.54-7.69), and there was a significant dose-response relationship (*P-trend<0.001*). Moreover, individuals in the third tertile of the Western pattern presented an elevated risk for GDM (third vs. first tertile: OR=1.96, 95% CI:1.02-3.80), and there was a significant dose-response relationship (*P-trend<0.03*). On the other hand, women in the third tertile of the healthy pattern had a decreased risk of GDM compared with those in the first tertile, although this result was not statistically significant (third vs. first tertile: OR=0.50, 95% CI:(0.25-1.08)). However, the dose-response relationship revealed that this pattern effectively reduced the risk of GDM (*P-trend<0.001*).

Discussion

Three major dietary patterns were recognized in the current study. These patterns are named based on the basis of their food groups and previous studies as the "traditional dietary pattern," the "healthy dietary pattern," and the "Western dietary pattern". The findings showed that adherence to the "traditional" and "Western" patterns during the prepregnancy period was associated with an increased risk of GDM, whereas adherence to the "healthy" pattern decreased the risk of GDM among the study population. This is the first study investigating the associations between major dietary patterns and GDM among pregnant women in Abadan city in southwestern Iran.

The "traditional pattern" is characterized by a high intake of sweets and biscuits, drinks, white meats and eggs, refined grains, high-fat dairy, red meats, and organ meats. Most food groups in this dietary pattern are energy-dense foods and contain high amounts of sugar, animal protein, and fat, especially saturated fats. High adherence to this dietary pattern was associated with GDM, and this association remained statistically significant after adjustment for confounding factors (Model 3). Similar findings were also reported in previous studies. For example, Zareei *et al*. reported that adherence to an unhealthy dietary pattern characterized by a high intake of sweets and desserts, fries, red meats, soft drinks, refined cereals, high-fat dairy products, etc., was associated with an increased risk of GDM among pregnant women (Zareei *et al.*, 2018). Additionally, in a cohort study among Chinese women, a Western pattern characterized by high intakes of red meat, processed meat, refined grains, sweets and desserts, French fries, and pizza was positively correlated with GDM (Zhang *et al.*, 2006). Sedaghat et al. reported that adherence to a Western dietary pattern (high consumption of sweets, jams, mayonnaise, soft drinks, salty snacks, solid fats, high-fat dairies, organ meats, red meats, eggs, etc.) one year before pregnancy was associated with an elevated risk of GDM (Sedaghat *et al.*, 2017). As mentioned above, red and organ meats are among the major components of this dietary pattern. These food groups contain high amounts of saturated fat, heme iron, and other nutrients, which can potentially cause beta cell damage, oxidative stress, and insulin resistance (Zhu and Zhang, 2016). Another mechanism proposed for the association between red meats and diabetes is the formation of advanced glycosylation end-products (AGEs) through the heating and processing of meats and high-fat products (Peppa *et al.*, 2002). Previous studies have suggested that AGEs are associated with the progression of diabetes (Piercy *et al.*, 1998). In addition, a diet high in AGEs can increase the production of inflammatory markers such as TNF-α and C-reactive protein, which might play a role in the progression of diabetes, and increase the risk of GDM. Heme iron found in red and organ meat might also play a role in the pathogenesis of GDM. Iron overload may induce insulin resistance and increase the likelihood of type 2 diabetes (Jiang *et al.*, 2004). Moreover, iron supplements and elevated iron stores in pregnant women without

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iron deficiency are positively associated with the risk of GDM (Lao and Ho, 2004). Refined grains and sugar consumption result in high energy intake, and therefore obesity, which is a known risk factor for GDM. Furthermore, consuming foods with relatively high glycemic load may result in hyperglycemia and hyperinsulinemia (Brand-Miller *et al.*, 2003).

Adherence to the Western pattern in this study was associated with a greater risk of GDM. The food items in this pattern include fast foods, potatoes, red meats, whole grains, and organ meats. As discussed above, these food items can increase the risk of GDM through several mechanisms (Zhu and Zhang, 2016). Fast foods, including pizza and processed meats such as sausages, are the main components of Western dietary patterns and contain high amounts of saturated fat, trans fats, and nitrosamines. Nitrites which are usually used as preservatives in processed meats, react with amine compounds in the gastrointestinal tract and result in the production of nitrosamines. Nitrosamines contribute to the suppression of beta cell function, enhanced lipid peroxidation, and proinflammatory cytokine activation (Tong *et al.*, 2010).

In the present study, a healthy pattern characterized by high consumption of fruits, vegetables, fruit juices, legumes, and low-fat diaries decreased the risk of GDM among pregnant women. In line with this study, Pajunen et al. reported that high adherence to a healthy dietary pattern characterized by a high intake of vegetables, fruits and berries, rye bread, pasta and rice, poultry, etc. reduced the risk of GDM (Pajunen *et al.*, 2022). Another study by Tryggvadottir et al. revealed that women with a prudent dietary pattern, including vegetables, eggs, fruits, vegetable oils, nuts and seeds, and seafood, had a decreased risk of GDM (Tryggvadottir *et al.*, 2016). In contrast, some studies could not find any relationship between adherence to a healthy pattern and GDM (Sedaghat *et al.*, 2017, Zuccolotto *et al.*, 2019). A possible explanation for the beneficial effect of this dietary pattern on reducing the risk of GDM may be the lower energy density and glycemic load. Fruits, vegetables, and legumes are good sources of dietary fiber. Dietary fiber intake could postpone emptying of the stomach, and, through slowing food digestion, absorption may cause a reduction in postprandial plasma glucose levels. Moreover, fruits and vegetables contain polyphenols and other antioxidant nutrients, including vitamin C, vitamin E, and carotenoids, leading to the mitigation of the oxidative stress induced by free radicals, which is a situation associated with pancreatic tissue damage. Polyphenols may play a role in glucose homeostasis by inducing insulin secretion, regulating the digestion and absorption of glucose, regulating glucose release from the liver, and eventually, activating insulin receptors (Santangelo *et al.*, 2016). The protective mechanisms of dairy products against GDM may be due to their contents, such as calcium and whey protein. A previous study revealed that high dietary calcium intake is associated with a lower risk of GDM (Osorio-Yáñez *et al.*, 2017). Whey protein contributes to stimulating the secretion of insulin and the function of incretin hormones such as glucagon-like polypeptide-1 and gastric inhibitory peptide, and therefore, improves hyperglycemia (Adams and Broughton, 2016).

The current study had several strengths. To the best of the authors' knowledge, this is the first study regarding the associations between major dietary patterns and GDM among pregnant women in the province of Khuzestan, Iran. Furthermore, the authors identified possible confounding factors and controlled for them in the analysis.

Another strength of this study is the potential practical application of these results. The findings can be directly used in designing prepregnancy educational interventions or developing specific dietary guidelines for women of childbearing age. Additionally, at the public health policy level, identifying high-risk groups on the basis of dietary patterns can help target resources more effectively and improve pregnancy outcomes.

However, some limitations exist. First, confirming a causal relationship between dietary patterns and GDM is impossible because of the case-control design of the study. Second, there is a

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possibility of errors in estimating dietary intake when a semiquantitative FFQ is used for data collection. Additionally, recall bias is an issue due to the self-reported nature of the questionnaire. Another limitation is that the three extracted patterns explain only 35% of the total dietary variance, indicating the presence of other potential dietary patterns that were not covered in this analysis. Nonetheless, with a precise design and adjustment for confounding variables, efforts were made to maintain the accuracy of the analyses.

Conclusions

This study demonstrates that high adherence to traditional and Western dietary patterns - marked by elevated intake of animal products, processed meats, refined grains, and sweets - is linked to increased risk of GDM. In contrast, adherence to a healthy dietary pattern abundant in vegetables, fruits, legumes, and low-fat dairy products is associated with a reduced risk of GDM among pregnant women in Abadan population. Given the rising prevalence and significant health and economic burdens of GDM, these findings highlight the importance of promoting healthy dietary habits for prevention. Further prospective studies and clinical trials are needed to confirm these associations and establish causality.

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Authors' contribution

Gharang M, Mansoori A, Fateh R and Veissi M designed and conducted research; Mansoori M analyzed data; and Gharang M, Mansoori A and Veissi M wrote the paper. Veissi M had primary responsibility for final content. All authors read and approved the final manuscript.

Confilict of interests

The authors declared no competing interests.

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