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Dietary patterns during pregnancy derived by reduced-rank regression and their association with gestational diabetes mellitus

Daniela Saes Sartorelli Ph.D. [a,b,*], Daniela Cristina Candelas Zuccolotto Ph.D. [b], Lívia Castro Crivellenti Ph.D. [b], Laércio Joel Franco Ph.D. [a,b]

[a] *Department of Social Medicine, Ribeirao Preto Medical School (FMRP), University of Sao Paulo, Sao Paulo, Brazil*
[b] *Graduate Program in Community Health, Ribeirao Preto Medical School (FMRP), University of Sao Paulo, Sao Paulo, Brazil*

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A B S T R A C T

Objective: Evidence for the combined association of the quality of dietary carbohydrates and fats during pregnancy with gestational diabetes mellitus (GDM) is scarce. The aim of this study was to identify dietary patterns during pregnancy, derived by the reduced-rank regression (RRR) model, associated with fiber density (g/1000 kcal) and the Thrombogenicity Index (TI) and to investigate their relationship with GDM.
Methods: This was a cross-sectional study conducted with 785 pregnant women at gestational weeks 24 to 39. The diagnosis of GDM was based on the World Health Organization criteria. One 24-h dietary recall was obtained from all women and a second measurement from 73% of the sample, with the multiple source method used to estimate the usual diet. The patterns were determined by RRR, and the relationship with GDM was investigated using adjusted logistic regression models.
Results: The mean (standard deviation) age of the women was 28 y and 17.7% had GDM. Dietary pattern 1 (high rice, beans, and vegetables, with low full-fat dairy products, biscuits, and sweets) correlated positively with fiber density and negatively with TI and was inversely associated with GDM after multiple adjustments (odds ratio [OR], 0.58; 95% confidence interval [CI], 0.36–0.95; $P = 0.03$). Dietary pattern 2 (high red meats, full-fat dairy products, chocolate powder and fruits, with low chicken and margarine) correlated positively with both TI and fiber density, with no association with GDM found (OR, 1.48; 95% CI, 0.91–2.40; $P = 0.11$).
Conclusion: These data highlight the joint importance of the quality of dietary carbohydrates and fats in the dietary patterns of pregnant women in relation to the risk for developing GDM.

Introduction

Gestational diabetes mellitus (GDM) not only affects the mother's health by increasing the long-term risk for type 2 diabetes mellitus (T2DM) and cardiovascular disease [1], but also places the fetus at a higher risk for developing chronic non-communicable diseases in adulthood [2]. Therefore, there is an urgent need to develop investigations aimed at better understanding the modifiable maternal risk factors related to the disease.

Evidence suggests that data-driven maternal dietary patterns (DPs), derived from principal component analyses (PCA), might affect the susceptibility for developing GDM [3,4]. However, the food patterns determined by the PCA might not capture the patterns most strongly related to the outcome. Reduced-rank regression (RRR) [5] is a statistical method used to derive disease-related dietary patterns that determine a combination of foods (patterns) that better explain the variation of intermediate variables (usually nutrients or biochemical markers), which are known to be predictive for disease.

To the best of our knowledge, only one previous investigation explored the association between the DP during pregnancy derived by RRR and GDM. That investigation was a cross-sectional study conducted with 253 pregnant American women. Three

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* Corresponding author: Tel.: +55 163 315 2712; fax: +55 163 315 1526.
E-mail address: daniss@fmrp.usp.br (D.S. Sartorelli).

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RRR-derived DPs were associated with GDM, using the prepregnancy body mass index (BMI; kg/m^2), dietary fiber (g/d), and the ratio of total polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs) to total saturated fatty acids (SFAs) as intermediate (response) variables [6].

GDM is triggered by an imbalance between increased insulin resistance (IR) in the second half of pregnancy and compensatory increased insulin production and secretion by pancreatic β cells. Women with preexisting β-cell dysfunction or IR are more prone to the disease [7]. However, enhanced IR during pregnancy also is implicated in the development of the disease. Evidence suggests a connection between maternal gut microbiota composition and inflammation and exacerbated IR in pregnancy [8,9]. It was recently demonstrated that an adequate intake of dietary fat and fiber in early pregnancy is associated with beneficial microbiome composition and linked to lower levels of inflammation [10], suggesting that the combined association of the quality of dietary carbohydrates and fats during pregnancy could be inversely associated with GDM.

The traditional fatty acid ratios only partially reflect the balance between health and the disease-promoting properties of dietary fats as different subclasses of SFAs, PUFAs, and MUFAs exert distinct effects on the risk for diabetes [11,12]. The Thrombogenicity Index (TI) [13] is a ratio between subclasses of SFA (myristic, palmitic, and stearic acids), with a recognized negative action on insulin sensitivity and pancreatic β-cell function [14] and unsaturated fatty acids that improve insulin-stimulated cellular glucose uptake and insulin sensitivity [15]. Barbieiri et al. [16] previously demonstrated an independent positive association between the dietary TI during pregnancy and GDM, which was not verified for the traditional fatty acid ratios (PUFA/SFA; ω-3/ω-6), suggesting that the TI might better explain the quality of fat intake related to GDM.

The present study aimed to identify dietary patterns during pregnancy derived by RRR associated with fiber density (g/1000 kcal) and the TI and to investigate their relationship with GDM. It was hypothesized that a greater adherence to dietary patterns related with a better quality of carbohydrates and fats in pregnancy would be inversely associated to GDM.

Methods

This was a cross-sectional study conducted with 785 women, in singleton pregnancies, receiving prenatal care in the Public Health System of Ribeirão Preto, São Paulo state, Brazil, as reported in detail by Barbieiri et al. [16]. Adult pregnant women (age ≥20 y), in singleton pregnancies, with prepregnancy BMI ≥20 kg/m^2, screened for GDM after gestational week 24, without self-reported pregravid type 1 or type 2 diabetes mellitus were invited to participate in the study.

The recruitment of the women occurred in five laboratories that deal with the public health care centers' requirement for pregnant women to carry out the oral glucose tolerance test (OGTT). All the pregnant women who attended these laboratories between 2011 and 2012 were invited to participate in the study. At the time of the assessment, neither the interviewer nor the pregnant women were aware of the OGTT results. In all, 1446 women were contacted. Of these women, 608 were excluded because of the study criteria, 19 declined to participate, 23 had missing data, and 14 were excluded as a result of being diagnosed with T2DM, leaving 785 participants.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Research Ethics Committee of the Centre for School Health, Ribeirão Preto Medical School, University of São Paulo. Written informed consent was obtained from all participants.

Assessment of GDM

Blood collections were performed after fasting and at 1 and 2 h after the ingestion of 75 g of glucose, with the glucose oxidase method used to determine the plasma glucose. The diagnosis of GDM was based on the 2014 World Health Organization criteria [17], which requires alterations in at least one glycemic value at any time during the pregnancy: fasting from 92 to 125 mg/dL, 1 h after glucose load ≥180 mg/dL or 2 h after glucose load from 153 to 200 mg/dL.

Dietary assessment

Two 24-h dietary recalls (24 hR) were obtained on non-consecutive days, at least 1 wk apart regardless of the day of the week, by trained nutritionists adopting "multiple-pass" technique in three stages: quick listing, detailed description, and review. Of the 785 pregnant women assessed, 573 (73%) responded to the second 24-h dietary recall, which is a replication rate of a second measurement considered adequate for estimates of the usual intake [18]. Participants reported the consumption of food and beverages in household measurements, which were subsequently converted into grams or millilitres using patronized tables. Nutritional composition of dietary intake was estimated using the NutWin software (Nutrition Support Program, Version 1.5, São Paulo, Brazil), adopting the database of the Brazilian Food Composition Table [19]. Dietary underreporting was estimated using the Golberg method [20], adopting the cutoff point of ≤1.35 for the ratio of energy intake by the basal metabolic rate.

The food items (assessed in grams or millilitres per day) were placed into 22 groups according to the nutrient profiles and logic of intake: rice; beans; vegetables; fresh fruits; tubers; natural fruit juices; beef and pork; chicken; fish; eggs; pasta; bread; cheese; full-fat milk and yogurt; butter and margarine; coffee and tea; sweets; fast foods (including pizza, sandwiches, and salty snacks); soft drinks and artificial juices; biscuits and crackers; chocolate powder; and ham, salami, and sausages. Because only 1% of the women reported the intake of low-fat dairy products, this food group was not considered in the analyses.

The multiple source method (MSM) was used to remove within-person variation and then to estimate the usual food intake. The MSM is a model based on the product of the daily intake according to the probability of intake. The correction of the data using the MSM eliminated the need for a large number of replication of the dietary surveys to obtain the usual intake and might estimate the usual intake using a single administration of one 24-h dietary recall plus one repeated measure on a subsample [21,22], with it having previously been shown to adequately estimate the usual food intake among pregnant women [23].

In the present study, the fiber density (g/1000 kcal) was adopted as a marker of the quality of dietary carbohydrates of the usual diet because it reflects a higher intake of food rich in fiber and therefore low in refined grains. The TI is a marker of the quality of dietary fats because the higher the TI the worse the fat quality.

To calculate the TI, the following equation proposed by Ulbricht and Southgate [13] was used, with fatty acids expressed as percent of dietary energy (E%):

$$TI = (14:0 + 16:0 + 18:0)/(0.5 \times MUFA) + \left(0.5 \times \sum n-6\right) + \left(3 \times \sum n-3\right) + \left(\sum n-3/\sum n-6\right)$$

where 14:0 = myristic acid, 16:0 = palmitic acid, 18:0 = stearic acid, Σn-6 = sum of ω-6 fatty acids, and Σn-3 = sum of ω-3 fatty acids.

Covariates

Structured questionnaires were used to obtain sociodemographic data, including age, education, number of children, family history of T2DM, GDM in previous pregnancies, practice of physical activity (minutes per week of walking and exercise), and smoking habits (never smoked, current smoker, former smoker). Gestational age was estimated using the date of last menstruation and data from ultrasound scan, checked in the medical charts.

Height (m) and weight (kg) were obtained at the time of the OGTT using a portable stadiometer (Sanny, model ES 2040, American Medical do Brasil Ltda., São Bernardo do Campo, SP, Brazil) and a digital scale (Tanita, model HS 302, Tanita Corporation. of America, Arlington Heights, IL, EUA), respectively. The BMI classification was based on the Atalah criteria [24], which classifies BMI according to gestational age. Overweight or obese women were classified as having excess body weight according to gestational age.

Statistical methods

For a cross-sectional study with an estimated 20% prevalence of GDM [25], a sample size of 512 women is required, considering a margin of error of 5%. For studies aiming to investigate the relationship between DP and health outcomes, a sample size of at least five individuals per food group is recommended [26]. Because 22 food groups were included in the present analysis, a sample of 110 women was sufficient [26].

DPs were derived by RRR, which is a statistical approach that extracts successive linear combinations of food groups (predictor variables) that explain as much as possible the variation in the response variables that are hypothesized to be associated with the outcome [5]. By definition, the number of patterns generated will be the same as the number of predictor variables considered in the model [5]. In the present study, 22 food groups (g/d) were considered as the predictor variables. Fiber density (g/1000 kcal), as a marker of the quality of dietary carbohydrates, and the TI, as a marker of the quality of dietary fats, were considered as the response variables based on their established relationship with GDM [3,4,16]. The PROC PLS procedure with the reduced rank regression method option was adopted to derive the food patterns, using the SAS Statistical Software Version 9.3 (SAS Institute, Inc. Cary, NC, USA). The residuals of the models were normally distributed.

The association between the food groups and the dietary patterns was designated by factor loadings, which denote the relationship between the foods and the patterns. Food groups with factor loadings ≥0.2 were considered positive contributors to the patterns, and foods with factor loadings up to −0.2 were negative contributors to the patterns. The association between each dietary pattern and the intermediate variables was evaluated through Spearman's correlation coefficients.

Factor scores (a score of adherence) for each DP was attributed to the women and further transformed into tertiles. The women were classified into low adherence (first tertile), medium adherence (second tertile), and high adherence (third tertile). Chi-square for categorical variables and analysis of variance or Kruskal–Wallis tests for continuous variables were used to compare the characteristics of the women according to the level of adherence to the dietary patterns. Non-conditional logistic regression models were used to assess the relationship between the dietary patterns (in tertiles) and GDM. Unadjusted models and models adjusted by two set of variables were investigated: Multivariable model 1 was adjusted for age (y), education (years of schooling), smoking habits (never smoked, former smoker, and current smoker), physical activity (minutes per week of walking and exercise), parity (number of children), prior GDM (yes/no), and family history of GDM (yes/no). Multivariable model 2 was further adjusted for excess body weight according to the gestational age (yes/no), total energy intake (kcal), and dietary underreporting (yes/no).

The selection of the covariates was based on theoretical assumptions of their relationship with the outcome. Because DPs derived by RRR determine a combination of foods that better explain intermediate variables proposed to be the causal pathway between food intake and the outcome, the models were not adjusted for fiber density or TI. The models were adjusted for excess body weight according to the gestational age as a proxy of both prepregnancy overweight and obesity and excessive weight gain during pregnancy. Significance was set at $P < 0.05$ and all analyses were conducted using the SPSS Version 17 (SPSS Inc. Woking, Surrey, UK).

Results

The mean (standard deviation) age of the women was 28 y, and 17.7% were diagnosed with GDM. The women with GDM were older, reported a lower educational level, and had higher prepregnancy BMI compared with the normoglycemic participants (data not shown). Dietary underreporting was observed among 47% of the women. The gestational age at the time of the interview ranged from gestational weeks 24 to 39 (70% from weeks 24–28, 21.5% from weeks 29–32, and 8.5% ≥33 wk).

Table 1 shows the factor loadings of the food groups in the DPs during the pregnancy derived by RRR, using the fiber density and TI as response variables. The score for the DP1 (high rice, beans, and vegetables with low full-fat dairy products, biscuits and sweets) correlated positively with fiber density and negatively with the TI. The score for DP2 (high red meats, full-fat dairy products, chocolate powder and fruits with low chicken and margarine) correlated positively with both TI and fiber density. The two DPs combined explained 12% of the total variation in the food group intake and 56% of the variation in the response variables.

The women with higher adherence to DP1 were older, more likely to smoke, and spent more time walking or practicing exercise during the pregnancy compared with those with lower adherence. Conversely, pregnant women with a higher adherence to DP2 were younger than women with lower adherence (Table 2).

In unadjusted logistic regression models, no association between the DP and GDM was found. After multiple adjustments, the pregnant women with the highest adherence to DP1 had a lower risk for GDM than women with the lowest adherence after adjustments for age, education, smoking status, physical activity, parity, prior GDM, and family history of T2DM. After further adjustment for excess body weight, total energy intake, and dietary underreporting, the association with GDM remained significant. No association was found between DP2 and GDM (Table 3).

Discussion

In this cross-sectional study conducted with 785 pregnant Brazilian women, two DPs during pregnancy derived by RRR were identified. The score for DP1 correlated positively with fiber density and negatively with the TI, with the women with higher adherence to this pattern presenting a 42% lower risk for developing GDM after multiple adjustments compared with pregnant women with the lowest adherence. The score DP2 correlated positively with both the TI and fiber density and was not associated with GDM.

The inverse association between DP1 and GDM, independent of maternal weight status and total energy intake, suggests a beneficial effect through distinct pathways. Fiber density and the TI were the intermediate variables used to derive the DPs by RRR in the present study. A high dietary fiber intake promotes a better postprandial glycemic response and is a marker of the intake of foods rich in compounds that exerts antiinflammatory properties [27]. The combined effect of the intake of SFAs with a high potential for IR and pancreatic β-cell dysfunction [14], at the expense of unsaturated fatty acids with a recognized action on insulin sensitivity and cellular glucose uptake [15], as expressed through the TI, might lead to a higher chance of GDM [16]. Furthermore, previous evidence suggests that the dietary intake of fat and fiber during pregnancy modulates maternal gut microbiota and inflammation [10], which are closely related to maternal IR [8,9].

The advantage of using DPs to explore the relationship between diet and health outcomes is that the synergistic and antagonistic effects between the foods consumed are considered [5]. In the present study, it was possible to identify a pattern of food intake (DP1) during pregnancy that presented a higher fiber density and lower TI. The synergistic effect of the combined consumption of these key foods was inversely associated with GDM. DP2 was characterized a high intake of unhealthy (red meats, full-fat dairy products, and chocolate powder), and also healthy foods (fruits), it was directly associated with both fiber density and the TI and, perhaps for this reason, was not related to GDM.

DP1 was characterized by high intake of rice, beans, and vegetables, which are traditionally eaten during the main meal in Brazil, and has previously been shown to be inversely associated with obesity in pregnant women. The intake of these foods is considered a marker for the consumption of homemade meals instead of unhealthy substitutes, such as fast foods or sandwiches [28]. Therefore, in addition to the undeniable benefits provided by the intake of fiber and nutrients naturally found in beans and vegetables, the higher adherence to this DP might reflect a pattern of healthier eating behavior. Women with higher adherence to DP1 were older and more likely to spend more time walking and exercising, characteristics that have been demonstrated to be related to healthier eating behaviors [29]. However, those women also were more likely to be current smokers, which was not expected and cannot be explained by the literature.

Many possible pathways could explain the inverse association of DP1 with GDM. In a systematic review of observational studies, the authors concluded that a DP derived by PCA with higher intake of vegetables, fruit, fish, and whole grains and a lower intake of red meat, refined grains, and high-fat dairy products was associated with a lower risk for GDM [3,4]. In adults, evidence suggests that a plant-based DP rich in vegetables and fruits and healthy sources of fats and low in red meat and refined grains has beneficial effects on blood lipid levels, oxidative stress, inflammation, and insulin sensitivity [30], which are linked to the risk for diabetes.

Table 1
Factor loadings of food groups in two dietary patterns during pregnancy derived by reduced rank regression: Ribeirão Preto, SP, Brazil, 2011 to 2012 (N = 785)

Food groups (g/d)	Dietary patterns	
	High rice, beans, vegetables with low full-fat dairy, biscuits, and sweets	High red meats, full-fat dairy, chocolate powder and fruits with low chicken and margarine.
Rice	**0.29****	0.11
Beans	**0.59****	**0.33****
Vegetables	**0.27**	−0.03
Fruits	0.13	**0.23****
Tubers	−0.05	0.06
Natural fruit juices	0.05	0.15
Beef and pork	−0.17	**0.21****
Chicken	0.07	**−0.31****
Fish	0.05	−0.18
Eggs	0.03	−0.07
Pasta	−0.18	−0.03
Bread	−0.09	−0.03
Hard cheese	**−0.25****	**0.32****
Full-fat milk and yogurt	**−0.21****	**0.54****
Butter and margarine	−0.04	**−0.23****
Coffee and tea	0.17	−0.11
Sweets	**−0.30****	0.13
Fast foods	−0.18	−0.19
Soft drink and artificial juices	−0.19	−0.16
Biscuits and crackers	**−0.20****	−0.08
Chocolate powder	−0.18	**0.22****
Ham, salami, and sausage	−0.18	0.14
Percent variation of the food groups intake explained by the patterns	7.3	4.9
Cumulative percentage	7.3	12.2
Spearman's correlation coefficient*		
Fibre density (g/1000 kcal)	0.9	0.2
Thrombogenicity index†	−0.7	0.8
Percent variation of the predictor variables explained by the patterns		
Fibre density (g/1000 kcal)	69	5
Thrombogenicity index†	23	16

14:0, myristic acid, 16:0, palmitic acid, 18:0, stearic acid, Σn-6, sum of ω-6 fatty acids; Σn-3, sum of ω-3 fatty acids; MUFA, monounsaturated fatty acid; TI, Thrombogenicity index.
*$P < 0.001$ for all correlations between the factor loadings and the intermediate variables.
**Those are food groups contributers to the patterns, with factor loadings ≥0.2 or −0.2.
†$TI = (14{:}0 + 16{:}0 + 18{:}0)/(0.5 \times MUFA) + (0.5 \times \Sigma n\text{-}6) + (3 \times \Sigma n\text{-}3) + (\Sigma n\text{-}3/\Sigma n\text{-}6)$.

In a prospective cohort of pregnant Brazilian women, a food pattern derived by RRR characterized by the high intake of rice and beans,and low intake of fast foods and red meat was directly associated with adiponectin levels [31]. Because evidence suggests a beneficial effect of adiponectin in the insulin sensibility and pancreatic β-cell function during pregnancy [32], this might be another possible pathway that explains the inverse association between DP1 and GDM found in the present study. Furthermore, DP1 was characterized by a low intake of sweets, biscuits, and full-fat dairy products. Added-sugar foods usually have a high glycemic load that promotes both hyperglycemia and hyperinsulinemia and is directly related to the risk for GDM [33]. The intake of full-fat dairy products has been consistently associated with a higher risk for the disease [3], probably because of the high content of myristic and palmitic fatty acids, known to be directly related to IR [11,12].

To the best of our knowledge, only one previous study has investigated the relationship between DPs derived by RRR and GDM. In a cross-sectional investigation conducted with 253 pregnant American women, three DPs were found to be directly related to GDM. The DP with the strongest direct association with GDM (odds ratio, 22.3; 95% confidence interval, 3.9−127.4) was largely explained by the high intake of added-sugar food and beverages and the low intake of fruits and vegetables [6], which is in line with the findings of the present study. However, in this previous study, the diagnosis of GDM was based solely on fasting plasma glucose levels ≥92 mg/dL in early pregnancy, leading to the misclassification of the disease for three main reasons:

1. It did not distinguish between GDM and previous DM.
2. GDM most likely occurs after 24 wk of gestation.
3. Altered postload glucose levels detects 15% of the cases [7], limiting the interpretation of the results.

Because DPs derived by RRR is considered a method to derive disease-related DP, a higher magnitude of association with GDM, when compared with studies that employed the PCA approach, was expected (5). However, in studies that used the PCA to derive DPs during pregnancy, women with higher adherence to a healthier DP presented 20% to 55% less chance of having GDM [34,35], and the adherence to unhealthier DP doubled chance of developing the disease [36], suggesting that both methods might be useful in these investigations. Because the DPs determined by the PCA approach reflects the eating behavior of the population, the comparison of the findings from studies conducted in countries with distinct cultural food behaviors is limited.

The present study has several strengths. The diagnosis of GDM was based on the 2014 World Heath Organization criteria [17], endorsed by the International Federation of Gynaecology and Obstetrics [7], using both fasting and postload plasma glucose levels. To our knowledge, this is the first study that explored the TI as an intermediate variable to derive DPs by RRR and to investigate their relationship with an IR-related disease. Although the study presents limitations inherent to its cross-sectional design, trained dietititans obtained the data in face-to-face interviews before the diagnosis of the disease, reducing the chance of recall bias. However, the DPs reported by the women at the time of the interview might reflect both before and during pregnancy dietary behavior [37]. Other limitations are that data on weight gain in the first trimester of pregnancy was not available and the models were adjusted for excess body weight according to the gestational age as a proxy for both prepregnancy overweight and obesity and excessive weight gain during pregnancy. Data on the practice of physical activity was based solely on walking and the practice of exercise. In the present study, the dietary underreporting was observed in 47% of women, as estimated by the Golberg method [20], adopting the cutoff point of ≤1.35. However, the high proportion of underreport by pregnant women is in line with a previous investigation conducted in Ireland, in which using a cutoff point of ≤1.2 resulted in ≤45% of pregnant women underreporting their daily energy intake [38]. Because the Goldberg method presupposes the maintenance of body weight, it might not be the best approach to estimate underreporting during pregnancy. Only 73% of the women responded to the second 24-h dietary recall. Nevertheless, according to the recommendation on the Diet Assessment Primer [39], a single administration of one 24-h dietary recall plus one repeated measure on a subsample is considered an acceptable approach to investigate the association between diet and health outcomes. Another point to be highlighted is the usual diet was obtained through the MSM, providing a more accurate estimative of the dietary intake [22]. Nevertheless, the dietary intake was assessed at

Table 2
Characteristics of the women according to dietary pattern adherence in pregnancy, Ribeirão Preto, SP, Brazil, 2011 to 2012 (N= 785)

	Adherence to dietary patterns							
	High rice, beans, vegetables with low full-fat dairy, biscuits, and sweets				High red meats, full-fat dairy, chocolate powder, and fruits with low chicken and margarine			
	Low adherence (First tertile)		High adherence* (Third tertile)		Low adherence (First tertile)		High adherence* (Third tertile)	
Characteristics								
	n	%	*n*	%	N	%	*n*	%
GDM	56	22	41	16	40	15	49	19
Previous GDM	8	3	15	6	13	5	7	3
Family history of T2DM	68	26	74	28	62	24	59	23
Excess body weight	149	57	142	54	154	59	138	53
Smoking status								
Never smoked	207	79	211	81	209	80	205	78
Current smoker	23	9	31	12	28	11	19	7
Former smoker	31	12	20	8†	24	9	38	15
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (y)	27	6	28	6‡	28	5	27	5‡
Education (y)	9	3	9	3	9	3	9	3
Parity	1.1	1	1.3	1	1.3	1	1.1	1
	Median	(P25, P75)	Median	(P25, P75)	Median	(P25, P75)	Median	(P25, P75)
Physical activity (min/wk)‖	30	0, 120	50	0, 140§	40	0, 120	50	0, 150

ANOVA, analysis f variance; GDM, gestational diabetes mellitus; T2DM, type 2 diabetes mellitus.
*Data on medium adherence (second tertile) was also used to compare the characteristics of women across the tertiles.
†$P \leq 0.05$, according to χ^2 test.
‡$P \leq 0.05$, according to ANOVA.
§$P \leq 0.05$, according to Kruskal–Wallis test.
‖Minutes per week of walking and exercise.

Table 3
Logistic regression models for gestational diabetes mellitus according to dietary pattern adherence during pregnancy, Ribeirão Preto, SP, Brazil, 2011 to 2012 (N= 785)

	Adherence to dietary patterns					P_{trend}
	Low (First tertile)	Medium (Second tertile)		High (Third tertile)		
	OR	OR	95% CI	OR	95% CI	
DP1						
Unadjusted model	1.00	0.70	0.45–1.08	0.68	0.44–1.06	0.08
Multivariable Model 1*	1.00	0.68	0.43–1.07	0.59	0.37–0.95	0.03
Multivariable Model 2†	1.00	0.66	0.42–1.05	0.58	0.36–0.95	0.03
DP2						
Unadjusted model	1.00	1.30	0.83–2.06	1.27	0.80–2.01	0.31
Multivariable Model 1*	1.00	1.27	0.79–2.03	1.42	0.88–2.28	0.15
Multivariable Model 2†	1.00	1.29	0.80–2.08	1.48	0.91–2.40	0.11

CI, confidence interval; DM, diabetes mellitus; DP, dietary pattern; GDM, gestational diabetes mellitus; OR, odds ratio.
*Multivariable model 1: Adjusted for age (y), education (years of schooling), smoking (never smoked, former smoker or current smoker), physical activity (minutes per week of walking and exercise), parity, prior GDM (yes/no), and family history of DM (yes/no).
†Multivariable model 2: Further adjustments for excess body weight for the gestational age (yes/no), total energy intake (kcal), and dietary underreporting.

one time point during pregnancy and might not reflect the usual intake throughout the pregnancy. Moreover, because women with BMI $\leq$20 kg/m^2 are less prone to develop GDM, they were not included in the present study, and the results of the present study might not be applicable to this group of women. Finally, although the models were adjusted by relevant confounders, the selection of the covariates was based on theoretical assumptions, and we cannot rule out other uncontrolled potential confounding factors.

The findings of the study highlight the combined importance of the quality of dietary carbohydrates and fats of DPs of pregnant women in relation to the risk for developing GDM.

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