Original Article

Association between ultra-processed food exposure and gestational diabetes mellitus by diet balance index for pregnancy in Chinese women

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Background and Objectives: This study aims to investigate the impact of ultra-processed food (UPF) intake and the Chinese Diet Balance Index for Pregnancy (DBI-P) index on cesarean section rates and neonatal weight among women with gestational diabetes mellitus (GDM). **Methods and Study Design:** This study was a retrospective cohort study involving 279 GDM patients. We have collected dietary data, pregnancy information, and calculated UPF intake and the Chinese Diet Balance Index for Pregnancy (DBI-P) index. The impact of UPF exposure and dietary factors on low birth weight and macrosomia was analyzed using logistic regression. **Results:** This study revealed widespread insufficient consumption of several food groups among the GDM population. Specifically, compared with the UPF non-exposed group, the UPF-exposed group had a significantly higher rate of insufficiency in vegetables (Z = -4.94, p <0.001) and dairy products (Z = -2.28, p = 0.007), but a lower intake of plant oils (Z = -2.16, p = 0.03). After adjusting for several factors, the logistic regression results showed that UPF exposure was a risk factor for cesarean section (OR = 1.74, p = 0.046). Moreover, GDM patients who were overweight or obese before pregnancy faced a higher risk of a cesarean section when exposed to UPFs (OR = 4.13, 95%CI(1.35, 12.6)). **Conclusions:** Patients with GDM showed an unbalanced dietary intake pattern, which was more pronounced in the group with higher exposure to UPFs. However, prenatal UPF exposure did not significantly affect the patients' oral glucose tolerance test (OGTT) results. Nonetheless, excessive UPF consumption during pregnancy may increase the risk of cesarean section.

Key Words: gestational diabetes mellitus, ultra-processed foods, Chinese Diet Balance Index for Pregnancy, oral glucose tolerance test, retrospective cohort study

INTRODUCTION

Gestational Diabetes Mellitus (GDM) is a specific type of diabetes that occurs during pregnancy.[1] In recent years, with lifestyle changes, the incidence of GDM has risen significantly. The International Diabetes Federation estimated in 2021 that 14% of pregnancies are affected by GDM.[2] This condition carries significant health implications for both mother and offspring. Women with GDM are at increased risk for adverse pregnancy outcomes, including miscarriage, preterm birth, cesarean section, and macrosomia, compared to those with normoglycemic pregnancies.[3] Moreover, patients with GDM also have a higher risk of developing type 2 diabetes, as well as an increased risk of future cardiovascular disease incidence and mortality.[4] Standard management, typically initiated after diagnosis between 24-28 weeks of gestation, relies on medical nutrition therapy and, if necessary, insulin therapy to achieve glycemic control and mitigate these adverse outcomes.[5]

Dietary factors are central to both the pathogenesis and management of GDM. The modern food environment is characterized by a high intake of ultra-processed foods

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(UPFs). Defined as industrial formulations made mostly from substances extracted from foods, UPFs are typically rich in added sugars, unhealthy fats, and salt, while being depleted of fiber, vitamins, and minerals.[6] Studies have shown that the consumption of UPF during pregnancy can increase the risk of GDM and adverse pregnancy outcomes.[7] First, high UPF intake increases the risk of GDM, pre-eclampsia (PE), poor glycemic control, and excessive weight gain during pregnancy. Second, higher UPF consumption is positively correlated with low birth weight (LBW) and preterm birth (PTB), and may negatively affect childhood cognitive development. Third, increased UPF intake during pregnancy is associated with reduced intake of several essential nutrients commonly found in whole foods, including protein, fiber, zinc, potassium, magnesium, and various vitamins such as A, C, D, B12, and niacin, which are significantly lower in pregnant women with high UPF consumption.[8-10] However, findings across studies remain inconsistent. GDM itself is a risk factor for adverse pregnancy outcomes, yet there is currently a lack of research specifically examining the relationship between UPF intake and the risk of adverse pregnancy outcomes among individuals with GDM.

Furthermore, dietary patterns are complex and cannot be fully captured by the analysis of a single food group. In the Chinese context, the Dietary Balance Index for Pregnancy (DBI-P) offers a validated tool to assess overall dietary quality based on adherence to the Chinese Dietary Guidelines, evaluating dimensions like food variety and the intake of cereals, vegetables, animal foods, and other key components.[11-13] While research has linked components of the DBI, such as high animal food intake, to GDM risk and glucose levels,[10,13,14] the synergistic or interactive effects of a poor overall dietary pattern (as measured by DBI-P) and high UPF intake on pregnancy outcomes in GDM patients have not been explored. This oversight is significant, as evidenced by a large cohort study which found that even among women with higher overall dietary quality scores, high UPF consumption remained positively associated with type 2 diabetes risk.[15] This suggests that UPF intake may exert effects independent of overall diet quality, a concept yet to be investigated in a GDM population using a culturally specific dietary assessment tool.

Therefore, this paper reviews the dietary conditions of GDM patients during the middle and late stages of pregnancy, calculates the intake of UPF and related DBI-P indices, and explores the impact of dietary factors on pregnancy outcome indicators such as cesarean section rates and neonatal weight. It aims to provide a reference for dietary guidance for GDM patients, further improve the pregnancy outcomes of GDM patients and fetal development, and promote maternal and infant health.

METHODS

Study subjects

The study subjects of this research were GDM patients who visited the clinical nutrition department from June 2022 to September 2023, totaling 370 individuals. The subjects were pregnant women who underwent a 75g oral glucose tolerance test (OGTT) at 25-28 weeks of gestation with abnormal results and were diagnosed with GDM. The inclusion and exclusion criteria are as follows: Inclusion criteria: (1) meeting the diagnostic criteria for GDM; (2) having visited the clinical nutrition department ≥2 times and being able to follow dietary and exercise instructions as well as daily blood glucose monitoring; (3) pregnant women who have not been treated with insulin injections; (4) those with pregnancy outcomes. Exclusion criteria: (1) pregnant women treated with insulin injections; (2) those with pre-existing diabetes or other diseases that could potentially affect pregnancy outcomes or glucose metabolism; (3) GDM individuals without dietary records and pregnancy outcomes. This study is a retrospective cohort study of past cases, where the study subjects did not undergo informed consent, no biological samples were collected, and the information of the study subjects was concealed and kept confidential. The study was approved by the Ethical Committee of Beijing Tongren Hospital affiliated with Capital Medical University (ethics number: TREC2024-KY054).

Data collection

The demographic data of the GDM patients in this study were sourced from outpatient medical records, including height, weight, pre-pregnancy body mass index (BMI), education level, and family history of diabetes. Patients diagnosed with GDM based on abnormal OGTT results received dietary surveys and guidance from professional nutritionists during their first visit to the clinical nutrition department. Newborn length and weight were measured by experienced midwives in the delivery ward immediately after birth. Newborns weighing <2500 g were classified as low birth weight, while those weighing >4000 g were classified as macrocosmic. Information on newborn anthropometrics, delivery methods, and gestational weeks at birth, among other pregnancy outcomes, was obtained from obstetric medical records.

Dietary assessment

The method for the initial dietary assessment is the 24-Hour Dietary Recall. Patients are asked to describe all the foods they consumed and their water intake from the previous day. Based on the Food Exchange List system, the patient's approximate food intake is calculated, with one food exchange portion defined as 90 kcal. For example, 50 g of eggs, 50 g of lean meat, and 125 mL of milk each represent one food exchange portion.[16] The nutritionist calculated the patient's basic metabolic rate (BMR) and developed a diet plan accordingly. Subsequently, patients were asked to record the names and amounts of food consumed daily, as well as their physical activity. For processed foods such as slices of bread and steamed buns, the cooked weight after removing the packaging had to be measured, while for other ingredients, the raw weight before cooking needed to be recorded. During follow-up visits, patients were required to bring their diet and exercise record forms. For those who did not record as instructed, a retrospective dietary survey was conducted to assess their dietary intake over the past week. Valid dietary records consisted of three complete days of food intake in the middle and late stages of pregnancy (after completing the OGTT at 24 weeks).

The calculation of DBI_P

DBI-P includes C1-C5, four categories of food (C1: Grains and tubers; C2: Vegetables and fruits; C3: Dairy, soy, and nuts; C4: Animal foods; C5: Dietary diversity), high bound score (HBS), low bound score (LBS), diet quality distance (DQD), and the total score (TS).[12] TS is the cumulative score of all indicators, with a low bound score suggesting possible under-consumption, a high bound score indicating possible over-consumption, and a score of zero not necessarily indicating a balanced diet but possibly due to offsetting excesses and deficits. HBS sums up all positive scores, with higher values indicating dietary over-consumption. LBS sums up the absolute values of all negative scores, with higher values indicating dietary under-consumption. DQD is the sum of the absolute values of each indicator, with a score of zero indicating a balanced diet without issues of under- or over-consumption (Supplementary Table 1).

Definition and collection methods of UPF

UPF definition: According to the NOVA classification system, UPF is defined as: Formulations of ingredients, mostly of exclusive industrial use, made by a series of industrial processes, many requiring sophisticated equipment and technology (hence 'ultra-processed'). Many ready-to-consume products, such as carbonated soft drinks; sweet or savoury packaged snacks; chocolate; Many pre-prepared ready-to-heat products, including pies, pasta, and pizza dishes.[17] Based on the dietary records or surveys, the daily intake of UPF for each GDM patient was calculated (in grams). Currently, there is no established reference cutoff value for UPF exposure in this context. Therefore, we adopted this grouping method with reference to relevant literature,[18] where categorization based on median daily intake of UPF at baseline was used to distinguish between levels of exposure.

Statistical analysis

Based on previous related studies, 7 the incidence of adverse pregnancy outcomes (macrosomia, low birth weight infants, etc.) due to excessive exposure to UPF was set at 40%, with an OR = 2. The sample size calculation was based on a power of 0.8 (β = 0.1) and a significance level of 0.05 (α = 0.05, two-tailed). Using PASS software, the calculated sample size was 264 individuals. A total of 279 GDM patients were included in this study, of which 266 had pregnancy outcomes, meeting the sample size requirements. SPSS 23.0 software was used for statistical analysis. Quantitative data that followed a normal distribution were described using mean ± standard deviation (SD), while non-normally distributed quantitative data were described using median and interquartile range. Categorical variables were expressed as frequency and constituent ratio (%). The differences between the two groups were compared by an independent sample t-test or using χ^2 and Fisher's exact test. Logistic regression analysis was performed to investigate the impact of dietary factors on adverse pregnancy outcomes, low birth weight, and overweight conditions in newborns. The model was adjusted for age, pre-pregnancy BMI, family history of diabetes, HbA1c, gestational week, daily activity duration and educational level factors. A *p*-value <0.05 was considered statistically significant.

RESULTS

Study population

Between June 2022 and September 2023, there were a total of 370 clinical nutrition department visit records for GDM patients, of which 279 met the inclusion and exclusion criteria, and 266 patients had pregnancy outcomes (Figure 1).

The median age of the GDM patients was 32.0 (29.0,

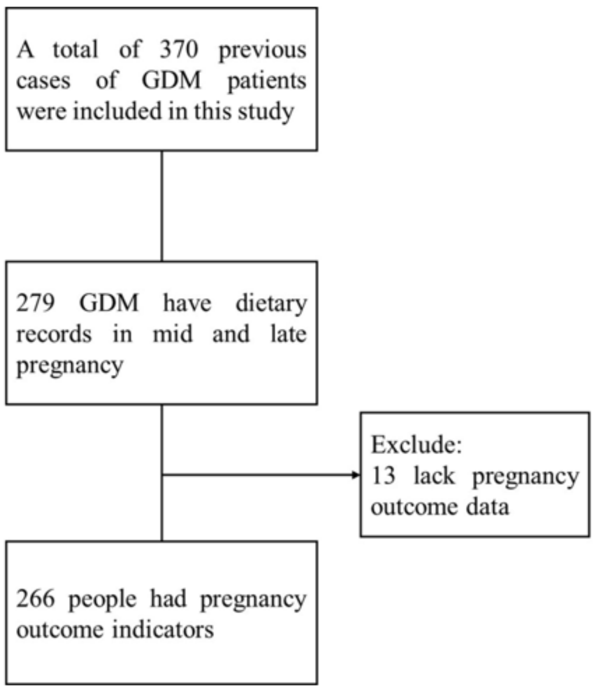

Figure 1. Retrospective cohort study flowchart for GDM patients. A total of 370 clinical nutrition department visited records for GDM patients, of which 279 met the inclusion and exclusion criteria, and 266 had pregnancy outcomes

34.0) years, with a pre-pregnancy BMI calculated based on height and weight of 22.6 (20.7, 24.6) kg/m^2, 78 individuals (28%) had a family history of diabetes, the average systolic blood pressure (SBP) was 111 (103, 119) mmHg, and the diastolic blood pressure (DBP) was 73.0 (68.5, 79.0) mmHg. The average fasting blood glucose from the OGTT was 5.10 (4.70, 5.4.0) mmol/L, the 1-hour OGTT blood glucose was 0.18 (0.16, 0.19) g/dL, and the 2-hour OGTT blood glucose was 0.15 (0.13, 0.17) g/dL. The daily average exercise time was 21.2 min (13.8), the daily average energy intake was 1870 kcal (98.1), the newborns' average weight was 3208 g (475), the average length was 49.9 cm (2.16), including 27 (10.2%) premature infants; 123 individuals (46.3%) had vaginal deliveries, 139 individuals (52.3%) had cesarean sections, and 4 individuals (1.5%) used forceps. Among them, the UPF non-exposed group demonstrated a longer daily activity time (Z = -2.84, p = 0.004) and a higher rate of natural delivery (χ^2 = 5.60, p = 0.02) than the exposed group, while the rate of cesarean section was significantly lower (χ^2 = 4.65, p = 0.03). Complete information on the baseline characteristics of the patients can be found in Table 1.

Differences in DBI-P scores between groups

The DBI-P scores for various food groups in the exposed and non-exposed groups are presented in Table 2. The DBI-P results indicated that both the UPF-exposed and non-exposed groups had insufficient intake of all other food categories, except for red meat, poultry and products, eggs, and plant oil. The UPF-exposed group showed a significantly higher degree of insufficient intake in vegetables (Z = -4.94, p <0.001) and dairy products (Z = -0.28, p = 0.007) compared to the non-exposed group. Additionally, the intake of plant oil was significantly higher in the exposed group than in the non-exposed group (Z = -2.16, p = 0.03). Furthermore, the UPF-exposed group had significantly higher scores for LBS (Z = -3.60, p <0.001) and DQD (Z = -3.67, p <0.001), but a lower TS score (Z = -3.03, p = 0.02) compared to the non-exposed group.

Table 1. Maternal and neonatal characteristics

Characteristics	Total	UPF non-exposure	UPF exposure	p value
Age (year) (n=279)	32.0 (29.0, 34.0)	31.0 (29.0, 33.0)	32.0 (29.0, 34)	0.92
Pre-pregnancy height (cm) (n=279)	161 (158, 165)	161 (158, 165)	162 (159, 165)	0.62
Pre-pregnancy weight (kg) (n=279)	59.0 (53.0, 65.0)	58.0 (53.0, 65.0)	60.0 (53.0, 66.0)	0.56
Pre-pregnancy BMI (kg/m^2) (n=279)	22.6 (20.7, 24.6)	22.3 (20.8, 24.5)	22.7 (20.6, 24.9)	0.65
Diabetes family history	78.0 (0.28)	32.0 (0.26)	46.0 (0.30)	0.43
Education (n=279)				
High school/technical secondary school	17.0(0.06)	8.0 (0.06)	8 (0.05)	0.67
Undergraduate/associate degree	195 (0.70)	89 (0.71)	106 (0.69)	0.67
Postgraduate and above	67 (0.24)	28 (0.22)	39 (0.25)	0.57
Systolic blood pressure (mmHg) (n=279)	111 (103, 119)	113 (105, 119)	110 (102, 119)	0.30
Diastolic blood pressure (mmHg) (n=279)	73.0 (68.5, 79.0)	76.0 (69.0, 80.0)	72.0 (68.0, 78.0)	0.10
Fasting blood glucose	5.10 (4.70, 5.4.0)	5.10 (4.70, 5.30)	5.10 (4.70, 5.40)	0.41
OGTT 1h (g/dL) (n=279)	0.18 (0.16, 0.19)	0.18 (0.16, 0.20)	0.18 (0.16, 0.19)	0.49
OGTT 2h (g/dL) (n=279)	0.15 (0.13, 0.17)	0.15 (0.14, 0.17)	0.15 (0.13, 0.17)	0.81
daily activity duration (min) (n=279)	20.0 (10.0, 30.0)	25.0 (15.0, 30.0)	20.0 (10.0, 30.0)	0.004**
daily calorie intake (kcal) (n=279)	1900 (1800, 1900)	1900 (1800, 1900)	1900 (1800, 1900)	0.94
Birth weight (g) (n=266)	50.0 (49.0, 51.0)	50.0 (49.0, 51.0)	50.0 (49.0, 51.0)	0.79
Birth length (cm) (n=266)	3.20×10^3 (29.6×10^3, 3.49×10^3)	3.23×10^3 (3.00×10^3, 3.48×10^3)	3.20×10^3 (2.92×10^3, 3.50×10^3)	0.62
Weeks' gestation (n=266)				
Premature birth (>37 weeks)	27 (0.10)	17.0 (0.12)	10.0 (0.08)	0.33
Full-term birth (≥37 weeks, <42 weeks)	239 (0.90)	127 (0.882)	112 (0.92)	0.33
Mode of delivery (n=266)				
Natural delivery	123 (0.46)	66 (0.54)	57 (0.40)	0.02*
Cesarean section	139 (0.52)	55 (0.45)	84 (0.58)	0.03**
Forceps delivery	4 (0.01)	1 (0.008)	3 (0.02)	0.40

UPF, ultra-processed food.

Data were expressed as n (%) for categorical variables, and continuous variables with a normal distribution are expressed as mean ± standard deviation, whereas those with a non-normal distribution are expressed as median (interquartile range).

*p <0.05; **p <0.01; ***p <0.001.

Table 2. Differences in DBI-P scores between groups

Variables	UPF non-exposure	UPF exposure	*p*-value
Various Food Groups			
Grains, Starchy roots and products, C1	-2.00 (-5.00, 0.00)	-3.00 (-6.00, 0.00)	0.56
Vegetables, C2	0.00 (0.00, 0.00)	0.00 (-2.00, 0.00)	<0.001***
Fruits, C2	-3.00 (-5.00, -2.00)	-3.00 (-5.00, -2.00)	0.66
Soy, nuts and products, C3	-4.00 (-6.00, -1.00)	-4.00 (-6.00, -2.00)	0.40
Dairy and products, C3	0.00 (-1.00, 1.00)	-1.00 (-2.00, 0.00)	0.007*
Red meat, Poultry and products, C4	2.00 (0.00, 4.00)	2.00 (0.00, 4.00)	0.78
Eggs, C4	1.00 (1.00, 1.00)	1.00 (0.00, 1.00)	0.72
Fish and shellfish, C4	-4.00 (-4.00, 0.00)	-4.00 (-4.00, 0.00)	0.99
Plants oil, C5	1.00 (1.00, 2.00)	1.00 (1.00, 2.00)	0.03*
DBI-P Scores			
HBS	5.00 (3.00, 7.00)	6.00 (4.00, 8.00)	0.61
LBS	18.0 (13.0, 23.0)	20.0 (17.0, 25.0)	<0.001***
DQD	23.5±6.96	26.7±6.67	<0.001***
TS	-12.3±7.4	-15.2±7.84	0.002**
Dietary diversity	-4.00 (-6.00, -3.00)	-5.00 (-6.00, -4.00)	0.05

DBI-P, Chinese Diet Balance Index for Pregnancy; DQD, diet quality distance; HBS, high bound score; LBS, low bound score; TS, total score; UPF, ultra-processed food.
Data were expressed as n (%) for categorical variables, and continuous variables with a normal distribution are expressed as mean ± standard deviation, whereas those with a non-normal distribution are expressed as median (interquartile range).
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Effect of UPF exposure on pregnancy outcomes

This study analyzed the impact of UPF exposure and DBI-P indicators on the mode of delivery, low birth weight, and macrosomia through logistic regression. The model was adjusted for age, pre-pregnancy BMI, family history of diabetes, daily activity duration, gestational week, and educational level factors. The results are shown in Table 3. UPF exposure is a risk factor for cesarean section; pregnant women with GDM in the UPF exposure group had a 1.74 times higher risk of undergoing a cesarean section compared to those not exposed to UPF ($p = 0.046$). There was no statistically significant effect of UPF exposure, HBS, LBS, DQD, and TS on premature infants, low birth weight infants, and macrosomia.

Subgroup analysis

The study stratified analysis based on the pre-pregnancy BMI of GDM individuals. The results showed that GDM individuals who were overweight or obese before pregnancy had a higher risk of undergoing a cesarean section due to UPF exposure during the middle and late stages of pregnancy (OR = 4.13, 95%CI (1.35, 12.6)). The results are presented in Figure 2.

DISCUSSION

The study found that exposure to UPF and the score of DBI-P are associated with cesarean section. Exposure to UPF is a risk factor for cesarean section, and the risk of cesarean section is higher in GDM patients who are overweight or obese before pregnancy and exposed to UPF.

Pregnant women often have higher nutritional needs than in the pre-pregnancy state, and adequate nutrition is a prerequisite for the health of pregnant women and the growth and development of the fetus. During the food processing of UPF, the structure, content, and bioavailability of foods are altered, and UPF is often rich in fats, sugars, and salt, with low fiber content.[19] Cross-sectional studies have shown that when the intake of UPF in the diet during pregnancy accounts for more than 43.4% of the total energy, women have lower intakes of vitamin C, β-carotene, vitamin B6, and potassium,[20] indicating poor dietary quality of pregnant women and that nutritional needs cannot meet the nutritional requirements of pregnancy, increasing the risk of nutrition-related diseases during pregnancy and fetal malnutrition. Currently, there are few studies on UPF exposure during pregnancy, and there are some controversies in the research conclusions. A cross-sectional study found that the highest tertile of UPF intake was positively associated with obesity during pregnancy;[21] Consumption of UPF before pregnancy increases the risk of GDM in women over 30 years of age during pregnancy;[22] other studies have shown that UPF intake during the preconception and the 1st trimester is not associated with excessive weight gain, as well as adverse outcomes for blood glucose and blood pressure;18 Cohort meta-analysis studies have shown that a diet rich in UPF in mothers is associated with an increased risk of gestational diabetes and preeclampsia, with no significant association with neonatal outcomes.[10] A cross-sectional study found that regular consumption of UPF, compared to non-intake and less frequent intake of UPF, was associated with lower head circumference in late-stage fetuses, and regular consumption of UPF was negatively correlated with the bone component of fetal growth in the late stages of pregnancy.[23]

Our study is based on the impact of UPF exposure in GDM patients on pregnancy outcomes. The results show that exposure to UPF increases the risk of cesarean section in GDM patients, and is not associated with adverse pregnancy outcomes such as macrosomia and low birth weight infants. Furthermore, stratified analysis indicates that overweight and obese GDM patients exposed to UPF have a higher risk of cesarean section compared to those unexposed. Obesity is associated with prolonged gestation,[24] and for GDM patients, planned delivery (induction or cesarean section) is chosen between 39 and 40 weeks to reduce the risk of stillbirth and intrapartum

Table 3. The impact of Chinese Diet Balance Index for Pregnancy and ultra-processed food exposure on adverse pregnancy outcomes

	B (SE)	OR (95%CI)	*p*-value
Cesarean section			
UPF	0.55 (0.28)	1.74 (1.01, 2.98)	0.05
HBS	-0.07 (0.05)	0.93 (0.85, 1.02)	0.14
LBS	0.01 (0.02)	1.01 (0.97, 1.05)	0.73
DQD	-0.01 (0.02)	0.99 (0.95, 1.03)	0.73
TS	-0.02 (0.02)	0.98 (0.95, 1.02)	0.36
premature birth			
UPF	0.27 (0.46)	1.31 (0.53, 3.24)	0.55
HBS	-0.09 (0.08)	0.92 (0.78, 1.08)	0.29
LBS	-0.02 (0.04)	0.98 (0.91, 1.05)	0.57
DQD	-0.03 (0.03)	0.97 (0.91, 1.03)	0.31
TS	0.002 (0.03)	1.02 (0.94, 1.06)	0.95
low birth weight infant			
UPF	-0.93 (0.89)	0.39 (0.07, 2.24)	0.29
HBS	-0.19 (0.17)	0.83 (0.59, 1.16)	0.28
LBS	0.02 (0.08)	1.02 (0.88, 1.19)	0.80
DQD	-0.02 (0.07)	0.98 (0.85, 1.13)	0.80
TS	-0.05 (0.07)	0.95 (0.83, 1.09)	0.50
Macrosomia			
UPF	-0.08 (0.60)	0.93 (0.29, 3.02)	0.90
HBS	-0.09 (0.11)	0.91 (0.73, 1.13)	0.40
LBS	0.01 (0.05)	1.01 (0.92, 1.10)	0.84
DQD	-0.01 (0.04)	0.99 (0.91, 1.08)	0.87
TS	-0.02 (0.04)	0.98 (0.91, 1.06)	0.62

DBI-P, Chinese Diet Balance Index for Pregnancy; DQD, diet quality distance; HBS, high bound score; LBS, low bound score; TS, total score; UPF, ultra-processed food.
Logistic regression analysis model adjusting age, pre-pregnancy BMI, family history of diabetes, HbA1c, gestational week, daily activity duration, and educational level factors. β (SE), OR (95%CI), and *p* -values by the group are displayed.
* *p* values are significant at $p < 0.05$; ** *p* values are significant at $p < 0.01$; *** *p* values are significant at $p < 0.001$.

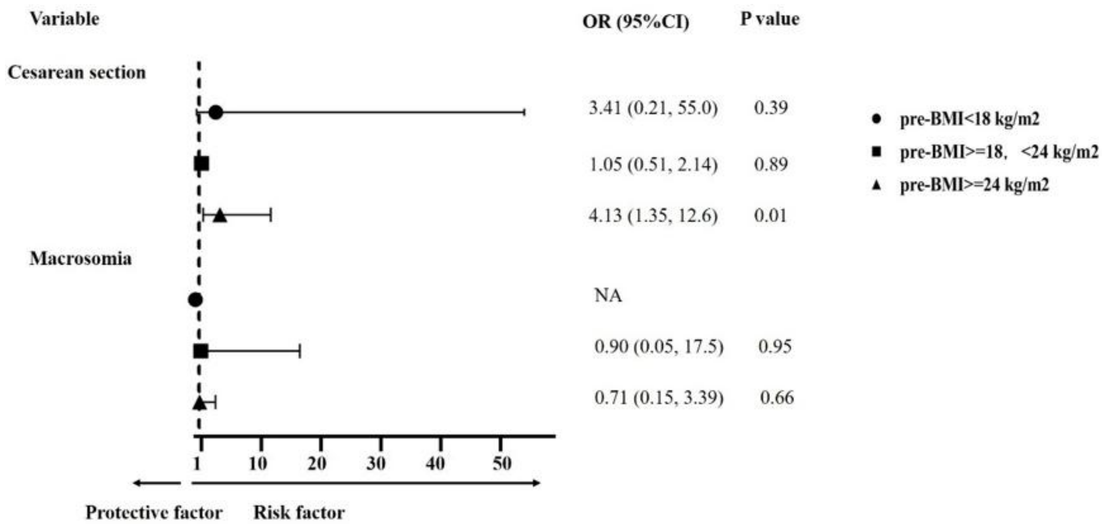

Figure 2. Impact of ultra-processed food exposure on adverse pregnancy outcomes: stratified analysis based on pre-pregnancy BMI

complications. Based on this, we speculate that UPF exposure may increase the probability of prolonged gestation in obese GDM patients, thereby increasing the likelihood of cesarean section. UPF are typically rich in refined sugars, saturated and trans fats, and low in dietary fiber, which may contribute to increased oxidative stress and inflammatory responses, as well as abnormalities in carbohydrate and lipid metabolism.[25, 26] Malondialdehyde (MDA), protein carbonylation (PC), and total antioxidant capacity (TAC) are biomarkers of oxidative stress. Population studies have shown that UPF intake is inversely associated with TAC and MDA levels. Conversely, dietary fiber intake is positively correlated with PC.[26] Oxidative stress can lead to abnormal macrophage polarization, resulting in elevated levels of tumor necrosis factor (TNF)-α, interleukin (IL)-6, and IL-8. This may affect the contractility of uterine smooth muscle, interfere with labor progression, and increase the risk of emergency cesarean section.[27] Abnormal lipid metabolism may increase the risk of preeclampsia and fetal distress, thereby affecting the cesarean section rate.[28] Newborns of GDM mothers are at increased risk of excessive weight gain and macrosomia.[29] A balanced diet is not only beneficial for blood glucose control but also helps to manage excessive fetal growth. High-quality nutrition during pregnancy has been associated with reduced risks of low birth weight and small for gestational age (SGA) infants.[30] A Norwegian mother-child cross-sectional study calculated the adjusted Dietary Quality Index (DQI) and UPF intake. The results indicated that UPF intake was negatively associated with the levels of nutritional biomarkers, whereas the DQI score was positively correlated with the levels of nutritional biomarkers,[31] which suggests that pregnant women should be guided towards a balanced diet and reducing UPF intake, especially for overweight and obese GDM patients, thereby lowering the risk of adverse pregnancy outcomes. Our study did not find a significant association between dietary quality and adverse pregnancy outcomes, nor between UPF consumption and neonatal birth weight. We speculate that the following factors may explain these findings: firstly, the sample size of our study may have been insufficient to detect a statistically significant effect. Secondly, both the UPF-exposed and non-exposed groups received dietary guidance from a nutrition clinic, and participants in both groups reported monitoring their daily caloric intake. This may have mitigated the impact of UPF consumption on gestational weight gain and neonatal weight, leaving dietary composition as the main differentiating factor between the groups.

This study is the first to investigate the impact of UPF exposure in GDM patients on adverse pregnancy outcomes. Compared to non-GDM pregnant women, GDM patients should pay more attention to their dietary intake and avoid foods that are detrimental to the health of both mothers and fetuses. This study has a certain guiding significance for the dietary guidance of GDM patients. Additionally, there are some limitations in this study. First, despite adjustment for multiple covariates, residual confounding from unmeasured factors (e.g., precise dietary patterns and environmental exposures) cannot be ruled out. Second, the observational nature of our study precludes the establishment of causal relationships. Third, our assessment using tools like the FFQ is subject to inherent limitations, including recall bias and measurement error. Finally, our study primarily evaluated UPF consumption based on total intake and did not differentiate between specific categories of UPFs. This limitation in classification may obscure potential differences in health effects among various types of UPFs. Therefore, future research should undertake a more detailed categorical analysis of UPFs.

Conclusion

This study conducted a retrospective survey of the dietary conditions and pregnancy outcomes of GDM patients during the middle and late stages of pregnancy and calculated the DBI-P and UPF intake during pregnancy. The study found that UPF exposure is a risk factor for cesarean section in GDM patients, and overweight and obese GDM patients during pregnancy are more prone to cesarean section. In summary, this study provides new insights for dietary guidance in GDM patients and the prevention of adverse pregnancy outcomes.

DISCLOSURE ON THE USE OF AI AND AI-ASSISTED TECHNOLOGIES

No artificial intelligence (AI) or AI-assisted technologies were used in the conception, data collection, data analysis, result interpretation, or manuscript writing of this study. The authors take full responsibility for the entire content of the publication. The authors reviewed and edited the content and takes full responsibility for the content of the publication.

CONFLICT OF INTEREST AND FUNDING DISCLOSURES

The authors declare that they have no competing interests.

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