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ORIGINAL RESEARCH

Analysis of Risk Factors Associated with Gestational Diabetes Mellitus: A Retrospective Case-Control Study

Jing Zhong[1], Hua Zhang[1], Jie Wu[2], Bosen Zhang[2,3], Liubing Lan[1,2]

[1]Department of Obstetrics, Meizhou People's Hospital, Meizhou Academy of Medical Sciences, Meizhou, People's Republic of China; [2]Department of Prenatal Diagnostic Center, Meizhou People's Hospital, Meizhou Academy of Medical Sciences, Meizhou, People's Republic of China; [3]Department of Ultrasound, Meizhou People's Hospital, Meizhou Academy of Medical Sciences, Meizhou, People's Republic of China

Correspondence: Liubing Lan, Department of Prenatal Diagnostic Center, Meizhou People's Hospital, Meizhou Academy of Medical Sciences, No. 63 huangtang Road, Meijiang District, Meizhou, People's Republic of China, Email lanliubing@126.com

Objective: Gestational diabetes mellitus (GDM) is a complication of abnormal glucose tolerance during pregnancy, with incidence is on the rise. There are inconsistent results on the risks of GDM and it has not been reported in our region. The purpose of this study is to explore the risk factors of GDM.

Methods: A total of 383 pregnant women were analyzed, including 67 (17.5%) pregnant women with GDM and 316 (82.5%) with normal glucose tolerance (NGT). The relationship of personal history, family history and reproductive history of pregnant women, the levels of alpha-fetoprotein (AFP), human chorionic gonadotropin (HCG), inflammatory markers in blood cell analysis at the first prenatal examination, and fetal ultrasound indices and the risk of GDM were analyzed.

Results: The fetal biparietal diameter, head circumference, and femur length were negatively correlated with HCG level, but not inflammatory markers. The proportion of pregnant women aged ≥30 years old, body mass index (BMI) in early pregnancy≥24.0 kg/m^2, history of polycystic ovary syndrome (PCOS), cesarean section, adverse pregnancy, and oral contraceptive use, and pregnant women who conceived through assisted reproduction in GDM group were higher than those in NGT group. Logistic regression analysis showed that age of pregnant woman ≥30 years old (≥30 vs <30 years old, odds ratio (OR): 2.142, 95% confidence interval (CI): 1.183–3.878, p=0.012), BMI≥24.0 kg/m^2 (≥24.0 kg/m^2 vs 18.5–23.9 kg/m^2, OR: 1.887, 95% CI: 1.041–3.420, p=0.036), history of adverse pregnancy (yes vs no, OR: 1.969, 95% CI: 1.022–3.794, p=0.043), and history of oral contraceptive use (yes vs no, OR: 2.868, 95% CI: 1.046–7.863, p=0.041) were associated with GDM.

Conclusion: Age of pregnant woman ≥30 years old, BMI≥24.0 kg/m^2, history of adverse pregnancy and oral contraceptive use were independent risk factors for GDM.

Keywords: gestational diabetes mellitus, advanced age, overweight, history of adverse pregnancy, history of oral contraceptive use

Introduction

Gestational diabetes mellitus (GDM) is an abnormal glucose tolerance or glucose metabolism that occurs or is first detected during pregnancy and is one of the most common pregnancy complications.[1,2] The global standardized total prevalence of GDM was approximately 14.0%.[3] The total incidence of GDM in mainland China was about 14.8%.[4] GDM can lead to important short- and long-term health risks for both pregnant women and fetuses, such as adverse maternal outcomes (gestational hypertension and eclampsia) and neonatal outcomes (hyperinsulinemia, macrosomia, shoulder dystocia, diabetes).[1] Pregnant women who developed GDM and their offspring have a significantly increased risk of diabetes, obesity, and premature cardiovascular disease over the next 10 to 12 years.[5–8] The risks of preterm birth[9] and macrosomia[10] in fetuses of GDM women are 3–5 times and 4 times higher than those of normal glucose tolerance (NGT) women, respectively. The incidence of hypoglycemia in fetuses of GDM pregnant women within 48 hours after birth is about 50%.[11] A study showed that the risk of neonatal respiratory distress syndrome (NRDS) in neonates of

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mothers with GDM was 23.7 times higher than that in neonates of NGT women.[12] In addition, GDM is a key factor leading to congenital heart disease in newborns,[13] with an 8-fold higher risk of cardiovascular disease than in infants born to NGT mothers.[14] The hyperglycemia environment of pregnant women with GDM has adverse effects on the fetus before the diagnosis of GDM,[15] early intervention during pregnancy can reduce the incidence of GDM and significantly reduce maternal and infant complications.[16]

Pregnant women with GDM usually have glucose metabolism disorders in the first trimester of pregnancy. In the second and third trimester of pregnancy, the secretion of antagonistic insulin hormones such as estrogen and progesterone increases, presenting a state of hyperglycemia.[17] GDM patients usually have no typical clinical symptoms, and it is difficult to diagnose in time without detecting the glucose tolerance of the patients.[18] The risk factors of GDM have been extensively studied worldwide, and some independent risk factors for GDM have been identified, such as maternal age, overweight, previous history of GDM, and family history of diabetes mellitus (DM).[17,19] Some studies have also found that the two consecutive periods before and during pregnancy may be closely related to the development of GDM, such as maternal physical activity,[20,21] psychological status,[22,23] and sleep status[24,25] may be related to the risk of GDM. However, there are inconsistent results among some studies. The study by Yang et al found that the age of the pregnant woman and the weight gain during pregnancy were not associated with GDM.[26] De Souza et al found that subcutaneous adipose tissue (SAT) depth was not associated with GDM.[27]

Moreover, the risk factors of GDM may be different in different regions and different populations.[28] It may be due to differences in the sample size and the indicators included in different studies. The Hakka people are an ethnic group formed by the integration of the people from the central plains of China with different ethnic groups during the southward migration, and Meizhou city is one of the main gathering places of Hakka people.[29] The potential risk factors of GDM has not been reported in this region. Therefore, this study intends to screen out the potential risk factors of GDM through the analysis of clinical data, especially those that are less studied. This study may provide scientific basis for identifying the high-risk population of GDM, reducing the incidence of GDM, early prevention and timely control of the occurrence, improving the pregnancy outcome of GDM, and formulation of public health strategies.

Materials and Methods

Study Cohort

The cross-sectional study included 383 pregnant women who visited the obstetrics clinic of Meizhou People's Hospital from 2019 to 2023 for analysis. This study was approved by the Medical Ethics Committee of Meizhou People's Hospital, and the written informed consent of pregnant couples for prenatal diagnosis was obtained. GDM is diagnosed using the diagnostic criteria recommended by the International Association for Diabetes in Pregnancy Society Group (IADPSG).[30] A 75g oral glucose tolerance test (OGTT) was performed at 24–28 weeks of gestation: (1) fasting plasma glucose (FPG) ≥ 5.1 mmol /L, (2) 1-h plasma glucose (1hPG) ≥ 10.0 mmol /L, and (3) 2-h plasma glucose (2hPG) ≥8.5 mmol/L, if one of the above three criteria was met, GDM was diagnosed.

The inclusion criteria of subjects were follows: (1) age ≥18 and <35 years old; (2) OGTT was performed at 24 to 28 weeks of gestation; (3) singleton pregnancy; and (4) complete clinical data. Exclusion criteria: (1) pregnant women without OGTT test; (2) some diseases that could affect metabolic function, such as heart disease, hematological system disease, chronic kidney disease, autoimmune system disease, chronic hypertension, diabetes and thyroid disease; (3) multiple pregnancy; (4) pregnant women with missing basic information; and (5) unwilling to accept the survey.

Medical Records and Data Collected

Information collected in this study includes:

(1) Data of pregnant women: age, body mass index (BMI) in early pregnancy, whether to take contraceptives, history of induced abortion, cesarean section, adverse pregnancy, and polycystic ovary syndrome (PCOS), and mode of conception of this pregnancy. History of adverse pregnancy mainly includes spontaneous abortion, embryo discontinuance, fetal malformation or defect, postpartum hemorrhage, and so on. According to Chinese standards, BMI was divided into three grades: <18.5 kg/m^2, 18.5–23.9 kg/m^2, and ≥24.0 kg/m.^{2} [31,32]

(2) Laboratory test indicators: blood cell analysis results (inflammatory markers) at the first prenatal examination were collected, alpha-fetoprotein (AFP), human chorionic gonadotropin (HCG) levels, FPG, OGTT 1-hour and OGTT 2-hour blood glucose levels in the second trimester were collected.

(3) First and second trimester prenatal ultrasound results, including nuchal translucency (NT) (mm), biparietal diameter (mm), head circumference (mm), and femur length (mm).

Data Processing and Statistical Analysis

The immune inflammatory response is involved in the development and progression of many diseases.[33,34] The inflammation index systemic immune inflammation index (SII), system inflammation response index (SIRI), neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and lymphocyte-to-monocyte ratio (LMR) were calculated according to the following formula:

SII=platelet×neutrophil/lymphocyte

SIRI=monocyte×neutrophil/lymphocyte

NLR=neutrophil/lymphocyte

PLR=platelet/lymphocyte

LMR= lymphocyte/monocyte.

SPSS statistical software version 26.0 (IBM Inc., USA) was used for data analysis. Continuous variables were expressed as means ± standard deviations and were compared using either Student's *t*-test or the Mann–Whitney *U*-test. Count variables were evaluated by *Chi*-square test or Fisher's exact test. Spearman correlation analysis was used to analyze the correlation of variables. Logistic regression analysis was used to evaluate the independent risk factors of GDM. $p<0.05$ was set as statistically significant.

Results

Baseline Characteristics of Study Cohort

In this study, 251 (65.5%) cases were aged <30 years, and 132 (34.5%) cases were ≥30 years old. There were 15 (3.9%) cases with history of PCOS, 79 (20.6%) cases with history of induced abortion, 80 (20.9%) with history of cesarean section, 67 (17.5%) with history of adverse pregnancy, and 24 (6.3%) with history of oral contraceptive use, respectively. There were 355 (92.7%) pregnant women conceived naturally and 28 (7.3%) pregnant women conceived by assisted reproductive technology. The mean value of AFP, HCG, SII, SIRI, NLR, PLR, and LMR of the subjects was 46.55 ±24.78ng/mL, 15405.37±22,112.77mIU/mL, 957.56±479.45, 1.93±1.14, 3.83±1.55, 142.53±48.82, and 4.00±1.36 respectively. Prenatal ultrasound results in the second trimester showed that the mean value of NT, biparietal diameter, head circumference, and femoral length was 1.50±0.34mm, 56.60±3.35mm, 209.58±10.62mm, and 39.64±3.09mm, respectively (Table 1).

Correlation Analysis of Biparietal Diameter, Head Circumference, Femur Length and Hematological Indices

The level of HCG was negatively correlated with biparietal diameter (r=−0.162, p=0.002), head circumference (r= −0.122, p=0.017), and femur length (r=−0.113, p=0.027). There was no correlation between biparietal diameter, head circumference, femur length and AFP, SII, SIRI, NLR, PLR, LMR (all p>0.05) (Table 2).

Comparison of Maternal Clinical Information and General Characteristics of Fetuses Between GDM and NGT Groups

In this study, there were 67 (17.5%) pregnant women with GDM and 316 (82.5%) pregnant women with NGT. The proportions of pregnant women aged ≥30 years old (53.7% vs 30.4%, p<0.001), BMI in early pregnancy≥24.0kg/m^2 (43.3% vs 23.1%, p=0.001) in the GDM group were significantly higher than those in the NGT group. The proportion of history of PCOS (9.0% vs 2.8%, p=0.031), cesarean section (32.8% vs 18.4%, p=0.009), adverse pregnancy (31.3% vs 14.6%, p=0.002), and oral contraceptive use (14.9% vs 4.4%, p=0.004) in the GDM group were significantly higher than

Table 1 The Maternal Clinical Information and General Characteristics of Fetuses

Characteristics	All Cases (n=383)
Age of pregnant woman (years)	
<30, n(%)	251(65.5%)
≥30, n(%)	132(34.5%)
BMI in early pregnancy (kg/m^2)	
<18.5, n(%)	49(12.8%)
18.5–23.9, n(%)	232(60.6%)
≥24.0, n(%)	102(26.6%)
History of polycystic ovary syndrome (PCOS)	
No, n(%)	368(96.1%)
Yes, n(%)	15(3.9%)
History of induced abortion	
No, n(%)	304(79.4%)
Yes, n(%)	79(20.6%)
History of cesarean section	
No, n(%)	303(79.1%)
Yes, n(%)	80(20.9%)
History of adverse pregnancy	
No, n(%)	316(82.5%)
Yes, n(%)	67(17.5%)
History of oral contraceptive use	
No, n(%)	359(93.7%)
Yes, n(%)	24(6.3%)
Mode of conception	
Natural conception, n(%)	355(92.7%)
Assisted reproduction, n(%)	28(7.3%)
Alpha-fetoprotein (AFP) (ng/mL)	46.55±24.78
Human chorionic gonadotropin (HCG) (mIU/mL)	15405.37±22,112.77
Inflammation indices levels	
SII, means±SD	957.56±479.45
SIRI, means±SD	1.93±1.14
NLR, means±SD	3.83±1.55
PLR, means±SD	142.53±48.82
LMR, means±SD	4.00±1.36
Nuchal translucency (mm)	1.50±0.34
Biparietal diameter (mm)	56.60±3.35
Head circumference (mm)	209.58±10.62
Femur length (mm)	39.64±3.09

those in the NGT group. The ratio of pregnant women who conceived through assisted reproduction in the GDM group was also significantly higher than that in the NGT group (14.9% vs 5.7%, p=0.017). There were no significant differences in HCG, AFP, SII, SIRI, NLR, PLR, LMR levels and prenatal ultrasound findings among the two groups (all p>0.05) (Table 3).

Logistic Regression Analysis of Risk Factors for GDM

The results of univariate analysis showed that age of pregnant woman ≥30 years old (≥30 vs <30 years old, odds ratio (OR): 2.661, 95% confidence interval (CI): 1.556–4.552, p<0.001), BMI ≥24.0 kg/m^2 (BMI ≥24.0 kg/m^2 vs BMI 18.5–23.9 kg/m^2, OR: 2.163, 95% CI: 1.238–3.779, p=0.007), history of PCOS (yes vs no, OR: 3.355, 95% CI: 1.152–9.771, p=0.026), cesarean section (yes vs no, OR: 2.175, 95% CI: 1.213–3.900, p=0.009), adverse pregnancy (yes vs no, OR: 2.680, 95% CI: 1.465–4.899, p=0.001), oral contraceptive use (yes vs no, OR: 3.784, 95% CI:

Table 2 Correlation Analysis of Biparietal Diameter, Head Circumference, Femur Length and Hematological Indices

Variables	Biparietal Diameter		Head Circumference		Femur Length	
	r	*p* Values	r	*p* Values	r	*p* Values
Alpha-fetoprotein (AFP)	−0.037	0.469	−0.033	0.525	−0.020	0.698
Human chorionic gonadotropin (HCG)	−0.162	0.002	−0.122	0.017	−0.113	0.027
SII	0.069	0.176	0.022	0.663	−0.004	0.934
SIRI	0.037	0.475	−0.012	0.817	−0.033	0.522
NLR	0.044	0.395	−0.014	0.780	−0.023	0.658
PLR	0.056	0.270	0.023	0.658	0.011	0.829
LMR	−0.023	0.660	0.018	0.729	0.016	0.750

Table 3 Comparison of Maternal Clinical Information and General Characteristics of Fetuses Between GDM and NGT Groups

Characteristics	NGT (n=316)	GDM (n=67)	*p* Values
Age of pregnant woman (years)			
<30, n(%)	220(69.6%)	31(46.3%)	<0.001
≥30, n(%)	96(30.4%)	36(53.7%)	
BMI in early pregnancy (kg/m^2)			
<18.5, n(%)	47(14.9%)	2(3.0%)	0.001
18.5–23.9, n(%)	196(62.0%)	36(53.7%)	
≥24.0, n(%)	73(23.1%)	29(43.3%)	
History of PCOS			
No, n(%)	307(97.2%)	61(91.0%)	0.031
Yes, n(%)	9(2.8%)	6(9.0%)	
History of induced abortion			
No, n(%)	250(79.1%)	54(80.6%)	0.869
Yes, n(%)	66(20.9%)	13(19.4%)	
History of cesarean section			
No, n(%)	258(81.6%)	45(67.2%)	0.009
Yes, n(%)	58(18.4%)	22(32.8%)	
History of adverse pregnancy			
No, n(%)	270(85.4%)	46(68.7%)	0.002
Yes, n(%)	46(14.6%)	21(31.3%)	
History of oral contraceptive use			
No, n(%)	302(95.6%)	57(85.1%)	0.004
Yes, n(%)	14(4.4%)	10(14.9%)	
Mode of conception			
Natural conception, n(%)	298(94.3%)	57(85.1%)	0.017
Assisted reproduction, n(%)	18(5.7%)	10(14.9%)	
Alpha-fetoprotein (AFP) (ng/mL)	46.57±23.01	46.48±32.06	0.979
Human chorionic gonadotropin (HCG) (mIU/mL)	15416.47±22,523.57	15,353.02±20,220.43	0.983
Inflammation indices levels			
SII, means±SD	949.49±488.88	995.66±433.54	0.475
SIRI, means±SD	1.91±1.14	2.06±1.11	0.320
NLR, means±SD	3.80±1.49	3.96±1.80	0.453
PLR, means±SD	143.39±50.42	138.48±40.56	0.456
LMR, means±SD	4.00±1.39	3.99±1.23	0.946
Nuchal translucency (mm)	1.49±0.35	1.53±0.33	0.341
Biparietal diameter (mm)	56.61±3.43	56.54±3.02	0.865
Head circumference (mm)	209.55±10.82	209.70±9.70	0.916
Femur length (mm)	39.58±3.16	39.90±2.77	0.450

Table 4 Logistic Regression Analysis of Risk Factors for GDM

Variables	Univariate OR (95% CI)	*p* Values	Multivariate OR (95% CI)	*p* Values
Age of pregnant woman (years) (≥30 vs <30)	2.661 (1.556–4.552)	<0.001	2.142 (1.183–3.878)	0.012
BMI in early pregnancy (kg/m^2)				
<18.5	1.000 (reference)		1.000 (reference)	
18.5–23.9	0.232 (0.054–0.997)	0.049	0.336 (0.076–1.477)	0.149
≥24.0	2.163 (1.238–3.779)	0.007	1.887 (1.041–3.420)	0.036
History of PCOS (Yes vs No)	3.355 (1.152–9.771)	0.026	1.994 (0.491–8.102)	0.335
History of induced abortion (Yes vs No)	0.912 (0.470–1.770)	0.785	0.602 (0.282–1.285)	0.190
History of cesarean section (Yes vs No)	2.175 (1.213–3.900)	0.009	1.626 (0.834–3.171)	0.154
History of adverse pregnancy (Yes vs No)	2.680 (1.465–4.899)	0.001	1.969 (1.022–3.794)	0.043
History of oral contraceptive use (Yes vs No)	3.784 (1.602–8.938)	0.002	2.868 (1.046–7.863)	0.041
Mode of conception (Assisted reproduction vs Natural conception)	2.904 (1.275–6.617)	0.011	1.133 (0.390–3.296)	0.818

1.602–8.938, *p*=0.002), and mode of conception with assisted reproduction (assisted reproduction vs natural conception, OR: 2.904, 95% CI: 1.275–6.617, *p*=0.011) were significantly associated with GDM. Multivariate logistic regression analysis showed that age of pregnant woman ≥30 years old (≥30 vs <30 years old, OR: 2.142, 95% CI: 1.183–3.878, *p*=0.012), BMI ≥24.0 kg/m^2 (BMI ≥24.0 kg/m^2 vs BMI 18.5–23.9 kg/m^2, OR: 1.887, 95% CI: 1.041–3.420, *p*=0.036), history of adverse pregnancy (yes vs no, OR: 1.969, 95% CI: 1.022–3.794, *p*=0.043), and oral contraceptive use (yes vs no, OR: 2.868, 95% CI: 1.046–7.863, *p*=0.041) were independent risk factors for GDM (Table 4).

Discussion

Various medical and surgical diseases can occur during pregnancy, and pregnancy and medical and surgical diseases affect each other, such as GDM.[1,2] GDM may cause long-term metabolic complications for the mother and also increase the risk of neonatal complications.[35,36] GDM is a rapidly growing public health problem, which is harmful to both mothers and their offspring. More attention should be paid to the risk factors of GDM, so as to provide scientific basis for the formulation of prevention and control strategies of GDM. Maternal age ≥30 years old, BMI ≥24.0 kg/m^2, history of adverse pregnancy, and oral contraceptive use were found associated with GDM in this study.

The reported incidence of GDM varies greatly among different regions and populations. Two studies in the United States separately assessed the prevalence of GDM among multiracial pregnant women between 1991 and 2002 found that the prevalence of GDM increased over time, between 4% and 6%.[37,38] Kaiser Permanente Health System reports higher rates among Asian (17%) and Hispanic (11%) women, and lower rates among non-Hispanic white (7%) and non-Hispanic black (7%) women.[39] According to the data of the International Diabetes Federation (IDF), the incidence of GDM was about 14% globally, 9% in Africa, 12.6% in North America, 21% in Asia, and 11.9% in China.[40] In this study, the percentage of GDM women was 17.5% (67/383). In general, populations and regions with higher rates of GDM deserve more attention.

It is essential to explore the risk factors of GDM for the prevention, control, and treatment of GDM.[41] In this study, age of pregnant woman ≥30 years old, and BMI ≥24.0 kg/m^2 were independent risk factors for GDM. Advanced maternal age is one of the most recognized risk factors for GDM. Several studies have found that advanced age are associated with an increased risk of GDM, regardless of the groups comparison based on the age (≥25, 30, or 35 years old).[28,42–44] GDM was positively associated with the advanced maternal age (≥30 years old).[45] A study showed that the risk of GDM increases linearly with maternal age.[46] In pregnant women, the contents of various hormones secreted by the placenta and insulin-resistant substances in the body increase, such as glucocorticoids, placental prolactin, progesterone, estrogen, and placental insulinase, which will increase the utilization of glucose by the body and decrease the sensitivity to islets.[47] With the increase of the age of pregnant women, the metabolic capacity of the body will decline, and the amount of insulin secretion will be insufficient, resulting in the decline of the function of islet beta cells.[48] However, it has not been determined whether there is an age threshold for a significant increase in the risk of GDM, that is, after the age of the pregnant woman, the risk of GDM is significantly increased.

Increased BMI increases the likelihood of GDM.[49–53] Elevated BMI and hypothyroidism were the strongest factors associated with GDM.[54] Weight gain prior to pregnancy was significantly associated with a higher risk of GDM.[55] Several studies showed that pre-pregnancy overweight or obesity are important risk factors for GDM.[42,43] Ferrara et al found that when a pregnant woman's pre-pregnancy BMI increased from obese (BMI: 18.5–23.9 kg/m^2) to severely obese (BMI>40 kg/m^2), the risk of developing GDM increased by 2 to 9 times.[38] There are several possible mechanisms by which increased BMI leads to increased risk of GDM. The fat cells of obese people have hypertrophy, and the insulin receptors on the fat cells per unit area are less than those of normal weight people, which leads to the decrease of the sensitivity of the cells to insulin and aggravation of insulin resistance, thus increasing the blood sugar.[56] In addition, hypertrophic fat cells secrete inflammatory factors, leading to systemic inflammation, enhance lipid activity, reduce insulin-induced glucose metabolism in fat cells, and promote the development of insulin resistance.[57]

The results of univariate regression analysis in this study showed that history of adverse pregnancy, oral contraceptive use, and mode of conception with assisted reproductive technology were risk factors for GDM. Some studies have suggested that a history of miscarriage is associated with an increased risk of GDM.[58,59] Wang et al[60] and Cozzolino et al[61] found that the risk of GDM among pregnant women who received assisted reproductive technology was 1.28 times and 2.86 times that of pregnant women who did not receive assisted reproductive, respectively. In this study, multivariate regression analysis showed that history of adverse pregnancy, and oral contraceptive use were independent risk factors for GDM, but not mode of conception with assisted reproductive technology. Therefore, more data on the relationship between a pregnant woman's personal history and the risk of GDM may be needed.

In recent years, the role of inflammatory response level in the occurrence of GDM and other diseases has gradually received extensive attention.[62] When it comes to GDM, it is inevitably closely related to the existence of insulin resistance, and the elevated level of inflammation will induce insulin resistance.[63] With the increase of gestational age, the insulin sensitivity of pregnant women decreases, and for pregnant women with abnormal islet function, the balance between insulin and glucose is lost, causing the maternal blood sugar to rise, resulting in gestational diabetes. A study has found that the incidence of GDM in pregnant women with high white blood cell count in the first trimester is significantly higher than that in those with normal white blood cell count, and it is an independent risk factor for GDM.[64] In this study, there was no significant difference in SII, SIRI, NLR, PLR, LMR between GDM group and NGT group. However, based on the association of inflammatory factors-inflammatory response-insulin resistance, inflammatory markers may be risk factors for the development of GDM.[65,66]

Based on the results of this study, we believe that pregnant women should control their weight during pregnancy. In addition, for pregnant women with a history of adverse pregnancy and oral contraceptive use, they should pay more attention to their blood sugar levels during pregnancy to avoid the occurrence of GDM. The findings of this study will provide scientific basis for reducing the incidence of GDM, prevention and control of the occurrence of GDM, improving the pregnancy outcome of GDM, and formulation of public health strategies in this region. However, there were some limitations in this study. First, in this study, the personal history, family history, and reproductive history of pregnant women were collected, the included factors are limited and cannot completely cover all the influencing factors of GDM, such as dietary habits.[67] Second, there were only 67 were pregnant women with GDM in this study, and the results may not be fully representative. Third, this study was based on a single-center retrospective study with limited regional and ethnic representation. Therefore, we need to conduct a larger sample size study to enrich the relevant data.

Conclusions

In summary, age of pregnant woman ≥30 years old, BMI ≥24.0 kg/m^2, history of adverse pregnancy, and oral contraceptive use were independent risk factors for GDM. Further investigation of the risk of GDM and elucidation of the underlying biological mechanisms will help to provide valuable information for the clinical diagnosis and treatment of GDM and the formulation of public health strategies.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Medicine, Meizhou People's Hospital, Meizhou Academy of Medical Sciences. All participants signed informed consent in accordance with the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

References

1. Ye W, Luo C, Huang J, Li C, Liu Z, Liu F. Gestational diabetes mellitus and adverse pregnancy outcomes: Systematic review and meta-analysis. *BMJ*. 2022;377:e067946. doi:10.1136/bmj-2021-067946
2. Sweeting A, Wong J, Murphy HR, Ross GP. A clinical update on gestational diabetes mellitus. *Endocr Rev*. 2022;43(5):763–793. doi:10.1210/endrev/bnac003
3. Wang H, Li N, Chivese T, et al. IDF diabetes atlas: Estimation of global and regional gestational diabetes mellitus prevalence for 2021 by international association of diabetes in pregnancy study group's criteria. *Diabet Res Clin Pract*. 2022;183:109050. doi:10.1016/j.diabres.2021.109050
4. Gao C, Sun X, Lu L, Liu F, Yuan J. Prevalence of gestational diabetes mellitus in mainland China: A systematic review and meta-analysis. *J Diabetes Investig*. 2019;10(1):154–162. doi:10.1111/jdi.12854
5. Daly B, Toulis KA, Thomas N, et al. Correction: Increased risk of ischemic heart disease, hypertension, and type 2 diabetes in women with previous gestational diabetes mellitus, a target group in general practice for preventive interventions: A population-based cohort study. *PLoS Med*. 2019;16(7):e1002881. doi:10.1371/journal.pmed.1002488
6. Chen S, Li N, Mei Z, et al. Micronutrient supplementation during pregnancy and the risk of pregnancy-induced hypertension: A randomized clinical trial. *Clin Nutr*. 2019;38(1):146–151. doi:10.1016/j.clnu.2018.01.029
7. Magee LA, von Dadelszen P, Singer J, et al. The CHIPS randomized controlled trial (control of hypertension in pregnancy study): Is severe hypertension just an elevated blood pressure? *Hypertension*. 2016;68(5):1153–1159. doi:10.1161/HYPERTENSIONAHA.116.07862
8. Yonkers KA, Gilstad-Hayden K, Forray A, Lipkind HS. Association of panic disorder, generalized anxiety disorder, and benzodiazepine treatment during pregnancy with risk of adverse birth outcomes. *JAMA Psych*. 2017;74(11):1145–1152. doi:10.1001/jamapsychiatry.2017.2733
9. Farrar D, Simmonds M, Bryant M, et al. Hyperglycaemia and risk of adverse perinatal outcomes: Systematic review and meta-analysis. *BMJ*. 2016;354(i4694). doi:10.1136/bmj.i4694
10. Muche AA, Olayemi OO, Gete YK. Gestational diabetes mellitus increased the risk of adverse neonatal outcomes: A prospective cohort study in Northwest Ethiopia. *Midwifery*. 2020;87:102713. doi:10.1016/j.midw.2020.102713
11. Nally LM, Bondy N, Doiev J, Buckingham BA, Wilson DM. A feasibility study to detect neonatal hypoglycemia in infants of diabetic mothers using real-time continuous glucose monitoring. *Diabet Technol Ther*. 2019;21(4):170–176. doi:10.1089/dia.2018.0337
12. Werner EF, Romano ME, Rouse DJ, et al. Association of gestational diabetes mellitus with neonatal respiratory morbidity. *Obstet Gynecol*. 2019;133(2):349–353. doi:10.1097/AOG.0000000000003053
13. Lin N, Cai Y, Zhang L, Chen Y. Identification of key genes associated with congenital heart defects in embryos of diabetic mice. *Mol Med Rep*. 2018;17(3):3697–3707. doi:10.3892/mmr.2017.8330
14. Yu Y, Arah OA, Liew Z, et al. Maternal diabetes during pregnancy and early onset of cardiovascular disease in offspring: Population based cohort study with 40 years of follow-up. *BMJ*. 2019;367(l6398). doi:10.1136/bmj.l6398
15. Metzger BE, Lowe LP, Dyer AR, et al. Hyperglycemia and adverse pregnancy outcomes. *N Engl J Med*. 2008;358(19):1991–2002. doi:10.1056/NEJMoa0707943
16. Koivusalo SB, Rönö K, Klemetti MM, et al. Gestational diabetes mellitus can be prevented by lifestyle intervention: the Finnish Gestational Diabetes Prevention Study (RADIEL): A randomized controlled trial. *Diabetes Care*. 2016;39(1):24–30. doi:10.2337/dc15-0511

17. Sharma AK, Singh S, Singh H, et al. Deep insight of the pathophysiology of gestational diabetes mellitus. *Cells*. 2022;11(17):2672. doi:10.3390/cells11172672
18. Liang JW, Chen MX, Hu XA, Zhou M, Zhang Y, Wang LL. Potential biomarkers in early pregnancy for predicting gestational diabetes mellitus and adverse pregnancy outcomes. *Clin Lab*. 2021;67(8). doi:10.7754/Clin.Lab.2021.201022
19. National Collaborating Centre for Ws, Children's H. National institute for health and care excellence: Clinical guidelines. *Diabetes in Pregnancy: Management of Diabetes and Its Complications from Preconception to the Postnatal Period*. London: National Institute for Health and Care Excellence (UK) Copyright © 2015 National Collaborating Centre for Women's and Children's Health.; 2015. PMID: 25950069.
20. Aune D, Sen A, Henriksen T, Saugstad OD, Tonstad S. Physical activity and the risk of gestational diabetes mellitus: A systematic review and dose-response meta-analysis of epidemiological studies. *Eur J Epidemiol*. 2016;31(10):967–997. doi:10.1007/s10654-016-0176-0
21. Sanabria-Martínez G, García-Hermoso A, Poyatos-León R, Álvarez-Bueno C, Sánchez-López M, Martínez-Vizcaíno V. Effectiveness of physical activity interventions on preventing gestational diabetes mellitus and excessive maternal weight gain: A meta-analysis. *BJOG*. 2015;122(9):1167–1174. doi:10.1111/1471-0528.13429
22. Dahlen HG, Barnett B, Kohlhoff J, Drum ME, Munoz AM, Thornton C. Obstetric and psychosocial risk factors for Australian-born and non-Australian born women and associated pregnancy and birth outcomes: A population based cohort study. *BMC Pregnancy Childbirth*. 2015;15:292. doi:10.1186/s12884-015-0681-2
23. Engberg E, Stach-Lempinen B, Sahrakorpi N, et al. A cross-sectional study of antenatal depressive symptoms in women at high risk for gestational diabetes mellitus. *J Psychosom Res*. 2015;79(6):646–650. doi:10.1016/j.jpsychores.2015.05.015
24. Cai S, Tan S, Gluckman PD, et al. Sleep quality and nocturnal sleep duration in pregnancy and risk of gestational diabetes mellitus. *Sleep*. 2017;40(2). doi:10.1093/sleep/zsw058
25. Nicolì F, Prete A, Citro F, et al. Short sleep duration and risk of gestational diabetes. *Gynecol Endocrinol*. 2022;38(8):672–675. doi:10.1080/09513590.2022.2089105
26. Yang SH, Kim C, An HS, An H, Lee JS. Prediction of gestational diabetes mellitus in pregnant Korean women based on abdominal subcutaneous fat thickness as measured by ultrasonography. *Diabetes Metab J*. 2017;41(6):486–491. doi:10.4093/dmj.2017.41.6.486
27. De Souza LR, Berger H, Retnakaran R, et al. First-trimester maternal abdominal adiposity predicts dysglycemia and gestational diabetes mellitus in midpregnancy. *Diabetes Care*. 2016;39(1):61–64. doi:10.2337/dc15-2027
28. Liu B, Lamerato LE, Misra DP. A retrospective analysis of the relationship between race/ethnicity, age at delivery and the risk of gestational diabetes mellitus. *J Matern Fetal Neonatal Med*. 2020;33(17):2961–2969. doi:10.1080/14767058.2019.1566310
29. Wang WZ, Wang CY, Cheng YT, et al. Tracing the origins of Hakka and Chaoshanese by mitochondrial DNA analysis. *Am J Phys Anthropol*. 2010;141(1):124–130. doi:10.1002/ajpa.21124
30. Metzger BE, Gabbe SG, Persson B, et al. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care*. 2010;33(3):676–682. doi:10.2337/dc09-1848
31. He W, Li Q, Yang M, et al. Lower BMI cutoffs to define overweight and obesity in China. *Obesity*. 2015;23(3):684–691. doi:10.1002/oby.20995
32. Tang J, Zhu X, Chen Y, et al. Association of maternal pre-pregnancy low or increased body mass index with adverse pregnancy outcomes. *Sci Rep*. 2021;11(1):3831. doi:10.1038/s41598-021-82064-z
33. Betrains A, Staels F, Schrijvers R, et al. Systemic autoinflammatory disease in adults. *Autoimmun Rev*. 2021;20(4):102774. doi:10.1016/j.autrev.2021.102774
34. Ma H, Liu M, Fu R, et al. Phase separation in innate immune response and inflammation-related diseases. *Front Immunol*. 2023;14:1086192. doi:10.3389/fimmu.2023.1086192
35. Kautzky-Willer A, Winhofer Y, Kiss H, et al. Gestational diabetes mellitus (Update 2023). *Wien Klin Wochenschr*. 2023;135(Suppl 1):115–128. doi:10.1007/s00508-023-02181-9
36. Chen S, Wang X, Lee BK, Gardner RM. Associations between maternal metabolic conditions and neurodevelopmental conditions in offspring: The mediating effects of obstetric and neonatal complications. *BMC Med*. 2023;21(1):422. doi:10.1186/s12916-023-03116-x
37. Dabelea D, Snell-Bergeon JK, Hartsfield CL, Bischoff KJ, Hamman RF, McDuffie RS. Increasing prevalence of gestational diabetes mellitus (GDM) over time and by birth cohort: Kaiser Permanente of Colorado GDM Screening Program. *Diabetes Care*. 2005;28(3):579–584. doi:10.2337/diacare.28.3.579
38. Ferrara A, Kahn HS, Quesenberry CP, Riley C, Hedderson MM. An increase in the incidence of gestational diabetes mellitus: Northern California, 1991-2000. *Obstet Gynecol*. 2004;103(3):526–533. doi:10.1097/01.AOG.0000113623.18286.20
39. Xiang AH, Li BH, Black MH, et al. Racial and ethnic disparities in diabetes risk after gestational diabetes mellitus. *Diabetologia*. 2011;54(12):3016–3021. doi:10.1007/s00125-011-2330-2
40. Nguyen CL, Pham NM, Binns CW, Duong DV, Lee AH. Prevalence of gestational diabetes mellitus in Eastern and Southeastern Asia: A systematic review and meta-analysis. *J Diabetes Res*. 2018;2018:6536974. doi:10.1155/2018/6536974
41. Tan J, Chen L, Wu Y, Zhu X, Knowledge FH. Attitude and practice of patients with gestational diabetes mellitus regarding gestational diabetes mellitus: A cross-sectional study. *Int J Gen Med*. 2023;16:4365–4376. doi:10.2147/IJGM.S423565
42. Wang C, Jin L, Tong M, et al. Prevalence of gestational diabetes mellitus and its determinants among pregnant women in Beijing. *J Matern Fetal Neonatal Med*. 2022;35(7):1337–1343. doi:10.1080/14767058.2020.1754395
43. Li F, Hu Y, Zeng J, et al. Analysis of risk factors related to gestational diabetes mellitus. *Taiwan J Obstet Gynecol*. 2020;59(5):718–722. doi:10.1016/j.tjog.2020.07.016
44. Kalok A, Peraba P, Shah SA, et al. Screening for gestational diabetes in low-risk women: Effect of maternal age. *Horm Mol Biol Clin Investig*. 2018;34(1). doi:10.1515/hmbci-2017-0071
45. Wu L, Han L, Zhan Y, et al. Prevalence of gestational diabetes mellitus and associated risk factors in pregnant Chinese women: A cross-sectional study in Huangdao, Qingdao, China. *Asia Pac J Clin Nutr*. 2018;27(2):383–388. doi:10.6133/apjcn.032017.03
46. Li Y, Ren X, He L, Li J, Zhang S, Chen W. Maternal age and the risk of gestational diabetes mellitus: A systematic review and meta-analysis of over 120 million participants. *Diabet Res Clin Pract*. 2020;162:108044. doi:10.1016/j.diabres.2020.108044
47. Das S, Behera MK, Misra S, Baliarsihna AK. Beta-cell function and insulin resistance in pregnancy and their relation to fetal development. *Metab Syndr Relat Disord*. 2010;8(1):25–32. doi:10.1089/met.2009.0017

48. Szoke E, Shrayyef MZ, Messing S, et al. Effect of aging on glucose homeostasis: Accelerated deterioration of beta-cell function in individuals with impaired glucose tolerance. *Diabet Care*. 2008;31(3):539–543. doi:10.2337/dc07-1443
49. Song X, Wang C, Wang T, Zhang S, Qin J. Obesity and risk of gestational diabetes mellitus: A two-sample Mendelian randomization study. *Diabet Res Clin Pract*. 2023;197:110561. doi:10.1016/j.diabres.2023.110561
50. Xu H, Hutcheon JA, Liu X, Stephansson O. Risk of gestational diabetes mellitus in relation to early pregnancy and gestational weight gain before diagnosis: A population-based cohort study. *Acta Obstet Gynecol Scand*. 2022;101(11):1253–1261. doi:10.1111/aogs.14450
51. Huang J, Chu X, Chen Y. Correlation and diagnostic value of maternal serum alpha-fetoprotein level, predelivery age and body mass with gestational diabetes mellitus. *Gynecol Endocrinol*. 2021;37(1):83–87. doi:10.1080/09513590.2020.1751112
52. Zhang Y, Xiao CM, Zhang Y, et al. Factors associated with gestational diabetes mellitus: A meta-analysis. *J Diabet Res*. 2021;2021:6692695. doi:10.1155/2021/6692695
53. Yong HY, Mohd Shariff Z, Mohd yusof BN, et al. Independent and combined effects of age, body mass index and gestational weight gain on the risk of gestational diabetes mellitus. *Sci Rep*. 2020;10(1):8486. doi:10.1038/s41598-020-65251-2
54. Giannakou K, Evangelou E, Yiallouros P, et al. Risk factors for gestational diabetes: An umbrella review of meta-analyses of observational studies. *PLoS One*. 2019;14(4):e0215372. doi:10.1371/journal.pone.0215372
55. Ouyang J, Lai Y, Wu L, et al. Association between prepregnancy weight change and risk of gestational diabetes mellitus in Chinese pregnant women. *Am J Clin Nutr*. 2023;117(6):1353–1361. doi:10.1016/j.ajcnut.2023.04.016
56. James DE, Stöckli J, Birnbaum MJ. The aetiology and molecular landscape of insulin resistance. *Nat Rev Mol Cell Biol*. 2021;22(11):751–771. doi:10.1038/s41580-021-00390-6
57. Suren Garg S, Kushwaha K, Dubey R, Gupta J. Association between obesity, inflammation and insulin resistance: Insights into signaling pathways and therapeutic interventions. *Diabet Res Clin Pract*. 2023;200:110691. doi:10.1016/j.diabres.2023.110691
58. Njete HI, John B, Mlay P, Mahande MJ, Msuya SE. Prevalence, predictors and challenges of gestational diabetes mellitus screening among pregnant women in northern Tanzania. *Trop Med Int Health*. 2018;23(2):236–242. doi:10.1111/tmi.13018
59. Lee KW, Ching SM, Ramachandran V, et al. Prevalence and risk factors of gestational diabetes mellitus in Asia: A systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2018;18(1):494. doi:10.1186/s12884-018-2131-4
60. Wang YA, Nikravan R, Smith HC, Sullivan EA. Higher prevalence of gestational diabetes mellitus following assisted reproduction technology treatment. *Hum Reprod*. 2013;28(9):2554–2561. doi:10.1093/humrep/det270
61. Cozzolino M, Serena C, Maggio L, et al. Analysis of the main risk factors for gestational diabetes diagnosed with international association of diabetes and pregnancy study groups (IADPSG) criteria in multiple pregnancies. *J Endocrinol Invest*. 2017;40(9):937–943. doi:10.1007/s40618-017-0646-6
62. Xuan nguyen K, Bui Minh T, Dinh HT. Low-grade inflammation in gestational diabetes mellitus and its correlation with maternal insulin resistance and fetal growth indices. *Int J Gen Med*. 2023;16:1429–1436. doi:10.2147/IJGM.S408856
63. Kansu-Celik H, Ozgu-Erdinc AS, Kisa B, Findik RB, Yilmaz C, Tasci Y. Prediction of gestational diabetes mellitus in the first trimester: Comparison of maternal fetuin-A, N-terminal proatrial natriuretic peptide, high-sensitivity C-reactive protein, and fasting glucose levels. *Arch Endocrinol Metab*. 2019;63(2):121–127. doi:10.20945/2359-3997000000126
64. Pattanathaiyanon P, Phaloprakarn C, Tangjitgamol S. Comparison of gestational diabetes mellitus rates in women with increased and normal white blood cell counts in early pregnancy. *J Obstetrics Gynaecol Res*. 2014;40(4):976–982. doi:10.1111/jog.12306
65. Huang X, Zha B, Zhang M, et al. Decreased monocyte count is associated with gestational diabetes mellitus development, macrosomia, and inflammation. *J Clin Endocrinol Metab*. 2022;107(1):192–204. doi:10.1210/clinem/dgab657
66. Saucedo R, Ortega-Camarillo C, Ferreira-Hermosillo A, Díaz-Velázquez MF, Meixueiro-Calderón C, Valencia-Ortega J. Role of oxidative stress and inflammation in gestational diabetes mellitus. *Antioxidants*. 2023;12(10):1812. doi:10.3390/antiox12101812
67. Zhang D, Sheng J, Chen L, et al. Effects of dietary fiber on the risk of gestational diabetes mellitus in advanced maternal age women: Study protocol for a randomized controlled trial. *Mol Nutr Food Res*. 2023;67(3):e2200437. doi:10.1002/mnfr.202200437