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ORIGINAL RESEARCH

Insulin Resistance as a Biomarker for Pelvic Organ Prolapse in Gestational Diabetes Mellitus: Stratification by Delivery Modes

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Objective: This study was to observe the assessment value of insulin and insulin resistance level on pelvic organ prolapse (POP) in women with gestational diabetes mellitus (GDM) who experienced different delivery modes, and to analyze the association between insulin and insulin resistance level and pelvic organ prolapse in GDM.

Methods: 150 GDM patients were selected as the observation group, with 150 healthy pregnant women as the control group. PG and HOMA-IR levels were compared between groups. Correlation analysis was conducted with Pearson method. Logistic regression was used to analyze the relationship between serum insulin and insulin resistance levels and POP in patients with GDM. The value of serum insulin and insulin resistance levels in predicting POP in patients with GDM was analyzed by ROC curves, and area under the curve (AUC) was compared by the Z test.

Results: POP was detected in 148 out of 300 cases (49.3%), with a prevalence of 62.0% in the GDM group compared to 36.7% in the control group. PG and HOMA-IR levels were higher in GDM patients with POP. BMI $\geq$ 24 kg/m^2, number of deliveries > 2, number of pregnancies > 2, gestational week $\geq$ 37 weeks, fetal weight $\geq$ 4 kg, mode of delivery, PG and HOMA-IR were risk factors for POP in patients with GDM. The AUC of PG for predicting POP in patients with GDM was 0.835 (95% CI: 0.702~0.845), and the AUC of HOMA-IR was 0.848 (95% CI: 0.768~0.922).

Conclusion: Insulin and insulin resistance levels are associated with POP in women with GDM with different modes of delivery, and their combined assessment may increase the predictive value for POP.

Keywords: gestational diabetes mellitus, insulin resistance, pelvic organ prolapse, vaginal birth, cesarean section

Introduction

Gestational diabetes mellitus (GDM) rates have increased steadily along with obesity and type 2 diabetes mellitus incidence worldwide.[1] Pregnant women are susceptible to GDM, which is a metabolic disorder specific to pregnancy that can lead to short- and long-term health problems.[2,3] This condition in pregnancy is influenced by the body's high glucose demand, insulin resistance, and relatively low insulin secretion.[4] Although blood glucose levels typically return to normal after delivery for most patients, the risk of future type 2 diabetes is elevated.[5] GDM is characterized by insulin resistance, which can adversely affect pelvic muscle function in pregnant women, potentially leading to pelvic organ prolapse (POP).[6] POP is a significant health concern for women, affecting approximately 25% of all women at some point in their lives.[7] It occurs when the supporting structures of the pelvic floor, including muscles and connective tissues, become weakened or damaged, leading to the descent of pelvic organs such as the bladder, uterus, or rectum into or outside the vaginal canal.[8] This condition can result in various symptoms, including urinary incontinence, sexual dysfunction, pelvic

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pain, and impaired quality of life.[9] The pelvic floor is vertically divided into three compartments: anterior, middle, and posterior, with the position and movement of these organs reflecting pelvic floor integrity and function.[10] While it is recognized that diabetes is associated with musculoskeletal complications, there is still a shortage of research on the specific link between insulin resistance from GDM and POP.[11] Most studies have targeted the general population or women who already have diabetes, ignoring the specific physiological changes and risks. Furthermore, there is a lack of detailed research on how different delivery modes may modulate the risk of POP in women with GDM, especially in the context of insulin resistance.[12] There is converging evidence that insulin resistance may be a factor in pelvic floor dysfunction through pathways such as collagen metabolism, persistent inflammation, and microvascular modifications.[13] Nonetheless, these pathways are not well comprehended, and there have been no studies so far that have measured insulin levels or insulin resistance concerning POP severity across different delivery modes in GDM patients.

This study aimed to address the knowledge gap by measuring insulin and insulin resistance in GDM patients with various delivery methods, examining their connection with POP, and offering a foundation for clinical prevention and treatment strategies tailored to this high-risk population.

Materials and Methods

General Information

150 cases of GDM patients who delivered in The No.2 Hospital of Baoding from January 2023 to March 2024 were selected as the observation group, and 150 healthy pregnant women who had medical checkups in The No.2 Hospital of Baoding during the same period were selected as the control group. The age of pregnant women was 20–38 (28.85 ± 4.32) years old, and the gestational age was 29.40 (38.98 ± 1.56) weeks.

Inclusion criteria: ① Pregnant women with normal results of prenatal checkups during pregnancy without serious complications; ② No history of POP; ③ Pregnant women aged 20–38 years; ④ Gestational age of 28–40 weeks; ⑤ Pregnant women with cognitive and communication abilities to cooperate the instructions.

Exclusion criteria: ① women with uterine malignant lesions and severe atrophy of the reproductive system that affect the treatment of POP; ② women with cigarette or alcohol consumption; ③ women who were mentally ill and other conditions that affect their cognitive and communication abilities.

Comparison of maternal age, gestational week, and other data between the two groups showed no statistically significant difference ($P > 0.05$). The study was approved by the Medical Ethics Committee of The No.2 Hospital of Baoding, and the pregnant women voluntarily participated and signed an informed consent form.

Diagnostic Criteria

A 75 g oral glucose tolerance test (OGTT) was performed at 24–28 weeks of gestation. GDM was diagnosed based on fasting blood glucose ≥ 5.1 mmol/L, blood glucose ≥ 10.0 mmol/L after 1 hour, or blood glucose ≥ 8.5 mmol/L after 2 hours.[14] POP was assessed with reference to the Niermeijer staging system.[15] POP was categorized into stages 0-IV using vaginal examination and 3D ultrasound imaging, with stage I and above indicating prolapse symptoms. Insulin resistance was assessed using the HOMA-IR index, calculated as [fasting insulin (μU/mL) × fasting glucose (mmol/L)]/22.5. All diagnostic and assessment criteria were standardized to ensure the reliability and comparability of the study.

Statistical Analysis

Data analysis was performed with SPSS 25.0 software. The measurement data were expressed as mean ± standard deviation, and the two groups were compared using a *t*-test. Count data were represented as cases (percent), and the comparison between the two groups was made using the chi-square test. Correlation analysis was conducted with Pearson method. To assess the relationship between serum insulin, insulin resistance, and POP outcomes in GDM patients, logistic regression was applied. The value of serum insulin and insulin resistance levels in predicting POP in patients with GDM was analyzed by ROC curves, and the comparison of area under the curve (AUC) was performed by the Z test. $P < 0.05$ was regarded as a statistically significant difference.

Results

POP Rates Between the Two Groups

POP was detected in 148 out of 300 cases (49.3%), with a prevalence of 62.0% in the GDM group compared to 36.7% in the control group. The prevalence of POP in the GDM group was significantly higher than that in the control group (Table 1).

Univariate Analysis of General Clinical Characteristics of GDM Patients with and without POP

According to univariate analysis, age, newborn gender, and pregnancy weight gain did not influence the occurrence of POP in GDM patients (all $P > 0.05$). BMI ≥ 24 kg/m^2, number of deliveries > 2, number of pregnancies > 2, gestational week of delivery ≥ 37 weeks, fetal weight ≥ 4 kg, and mode of delivery were the risk factors affecting the occurrence of POP after delivery in patients with GDM (Table 2 and Figure 1).

PG and HOMA-IR Levels in GDM Patients

PG (mmol/L) and HOMA-IR levels were higher in GDM patients with POP compared with those without POP ($P < 0.05$) (Table 3, Figure 2A and B).

Table 1 Comparison of the Rate of Maternal Pelvic Organ Prolapse Between the Two Groups

Groups	Cases	Pelvic Organ Prolapse	Pelvic Organ Prolapse Rate	Incidence
GDM group	150	93	62.00%	49.30%
Control group	150	55	36.70%	

Table 2 Univariate Analysis of the Occurrence of Pelvic Organ Prolapse in the Postpartum Period in Patients with GDM [Cases (%)]

Factors		Cases	With Pelvic Organ Prolapse	Without Pelvic Organ Prolapse	χ^2 Value	P Value
Age/years	< 25	17	9 (52.9)	8 (47.1)	0.022	0.085
	25~29	68	43 (63.2)	25 (36.8)		
	> 30	65	41 (63.1)	24 (36.9)		
Pre-pregnancy BMI (kg/m^2)	18.5~24	80	61 (76.3)	19 (23.7)	5.652	0.016
	≥ 24	70	32 (45.7)	38 (54.3)		
Number of deliveries	≤ 2	125	80 (64.0)	45 (36.0)	18.569	< 0.001
	> 2	25	13 (52.0)	12 (48.0)		
Number of pregnancies	≤ 2	78	56 (71.2)	22 (28.2)	16.256	< 0.001
	> 2	72	37 (51.3)	35 (48.7)		
Mode of delivery	Caesarean section	35	31 (88.5)	4 (11.5)	0.035	0.042
	Vaginal delivery	115	62 (53.9)	53 (46.1)		
Gestational week (weeks)	< 37	25	18 (72.0)	7 (28.0)	12.849	< 0.001
	≥37	125	72 (60.0)	53 (40.0)		
Fetal weight (kg)	< 4	85	56 (65.9)	29 (34.1)	7.023	< 0.001
	≥4	65	37 (56.9)	26 (43.1)		
Gender of newborns	Male	78	49 (62.8)	39 (37.2)	1.494	0.222
	Female	72	44 (66.1)	32 (33.9)		
Weight gain during pregnancy (kg)	< 12	85	47 (54.1)	38 (45.9)	0.096	0.756
	≥12	65	46 (70.8)	19 (29.2)		

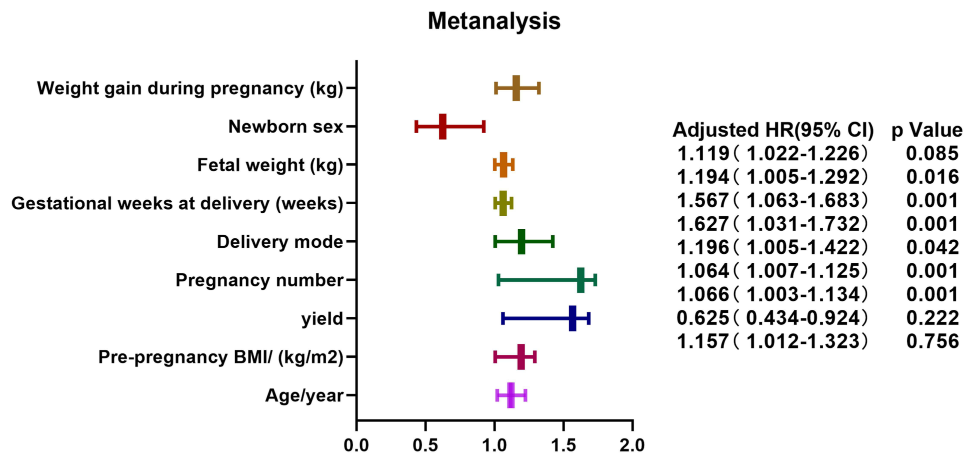

Figure 1 Forest plot of univariate analysis of the occurrence of POP in GDM patients.

Modes of Delivery in GDM Patients with POP

The threshold values for analyzing the mode of delivery were based on the median fasting PG and HOMA-IR levels. No difference was found in the mode of delivery between the two groups (all $P > 0.05$) (Table 4).

Multifactorial Logistic Analysis of the Risk of POP in GDM Patients

With POP (yes = 1, no = 0) as the dependent variable, multifactorial analysis was conducted, demonstrating that BMI ≥ 24 kg/m^2, number of deliveries > 2, number of pregnancies > 2, gestational week ≥ 37 weeks, fetal weight ≥ 4 kg, mode of delivery, PG (mmol/L), and HOMA-IR were the risk factors for the occurrence of POP in patients with GDM (Table 5 and Figure 3).

ROC Curves of PG and HOMA-IR Levels in GDM Patients

ROC curves were used to plot the predictive value of PG and HOMA-IR levels for POP in GDM, with PG and HOMA-IR levels serving as test variables. The results revealed that the predictive efficacy was higher when the two were combined than when used individually (Table 6 and Figure 4).

Discussion

Pelvic floor dysfunction has a high incidence in China, with an incidence rate of about 20%-40%, mainly including POP and urinary incontinence.[16] While pelvic floor dysfunction is not life-threatening for mothers, it significantly affects their daily activities and work.[17] The normal positioning of pelvic floor organs is ensured by the supportive structure of the pelvic floor. When the pelvic floor tissues are injured, these organs may move out of place, causing POP.[10] POP arises from complex causes, with the main contributors being pregnancy and childbirth.[18] The reasons may be: ① As pregnancy progresses, the uterus enlarges and the abdomen protrudes, causing the pelvic floor tissues to endure prolonged gravitational pressure and varying levels of damage; ② The estrogen levels in pregnant women fluctuate during pregnancy, impacting metabolism and causing the pelvic floor tissues to thin, leading to damage.[19,20]

Table 3 Insulin and Insulin Resistance Levels in GDM Patients with and without Pelvic Organ Prolapse

Groups	Cases	PG (mmol/L)	HOMA-IR
With pelvic organ prolapse	93	13.65±1.76	5.68±0.71
Without pelvic organ prolapse	57	9.67±1.57	3.25±0.55
χ2 value	-	19.67**	24.25**
P value	-	< 0.001	< 0.001

Note: ***P* < 0.01; data in the table are expressed as x ± s.

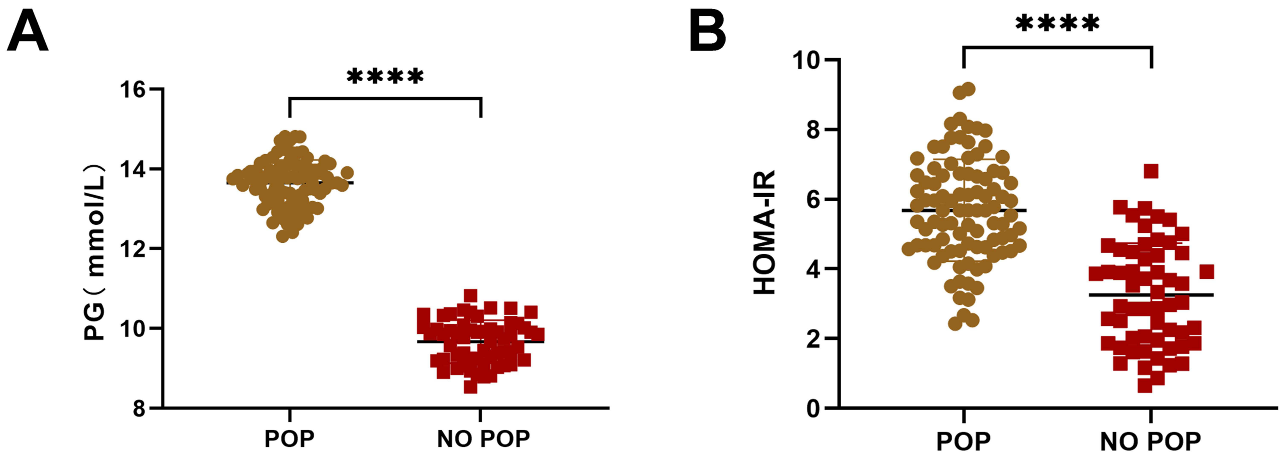

Figure 2 Quantification of PG and HOMA-IR levels.
Notes: (**A**) PG level (mmol/L). (**B**) HOMA-IR level. The data are expressed as mean ± SEM. ****P < 0.0001.

Research[21] reveals that in women with GDM at 38 to 40 weeks, there is an increase in the size of the systolic anorectal fissure and a marked decrease in its contraction and mobility. Women with GDM show lower rapid contraction peaks and hand-measured pelvic floor muscle strength at 6–8 weeks postpartum, implying that pelvic floor function is more severely compromised in the early postpartum period.[21] This study showed that among the 300 women included, the prevalence of POP was significantly higher in the GDM group (62.0%) than in the healthy control group (36.7%), indicating that GDM is a major risk factor for POP.[22] This is because prolonged hyperglycemia in pregnant women may negatively affect the pelvic floor muscles and nerves, while the increased risk of macrosomia and increased pelvic floor loading lead to varying degrees of pelvic floor muscle damage.[23] Meanwhile, the main pathophysiologic mechanisms of

Table 4 Comparison of Mode of Delivery for Pelvic Organ Prolapse in Patients with GDM

Factors	Median Value	Mode of Delivery [Cases (%)]		t/χ^2	*P*
		Vaginal delivery	Caesarean section		
PG	> 13.04	42 (58.3)	33 (41.7)	0.598	0.128
	≤ 13.04	39 (52.0)	36 (48.0)	0.962	0.756
HOMA-IR	> 4.74	40 (53.3)	35 (46.7)	0.416	0.519
	≤ 4.74	37 (49.3)	38 (50.7)	0.021	0.886

Table 5 Multifactorial Logistic Analysis of Postpartum Pelvic Organ Prolapse in Patients with GDM

Variables	B	SE	Wald χ^2	P	OR (95% CI)
BMI ≥ 24 kg/m^2	1.142	0.282	16.455	< 0.001	1.892 (1.800~5.423)
Number of deliveries > 2	−1.167	0.87	16.401	< 0.001	0.453 (0.179~0.553)
Number of pregnancies > 2	−0.573	0.264	4.593	0.034	0.782 (0.330~0.956)
Gestational week ≥ 37	−2.857	1.025	7.793	0.005	0.156 (0.008~0.429)
Fetal weight ≥ 4 kg	−0.669	0.298	5.073	0.026	0.365 (0.282~ 0.923)
Mode of delivery	0.143	0.053	9.165	0.004	1.245 (1.065~1.435)
PG	1.768	0.46	14.743	< 0.001	3.658 (2.376~14.440)
HOMA-IR	0.156	0.049	10.061	0.002	1.248 (1.061~1.287)
Constant	−25.294	5.036	25.223	< 0.001	

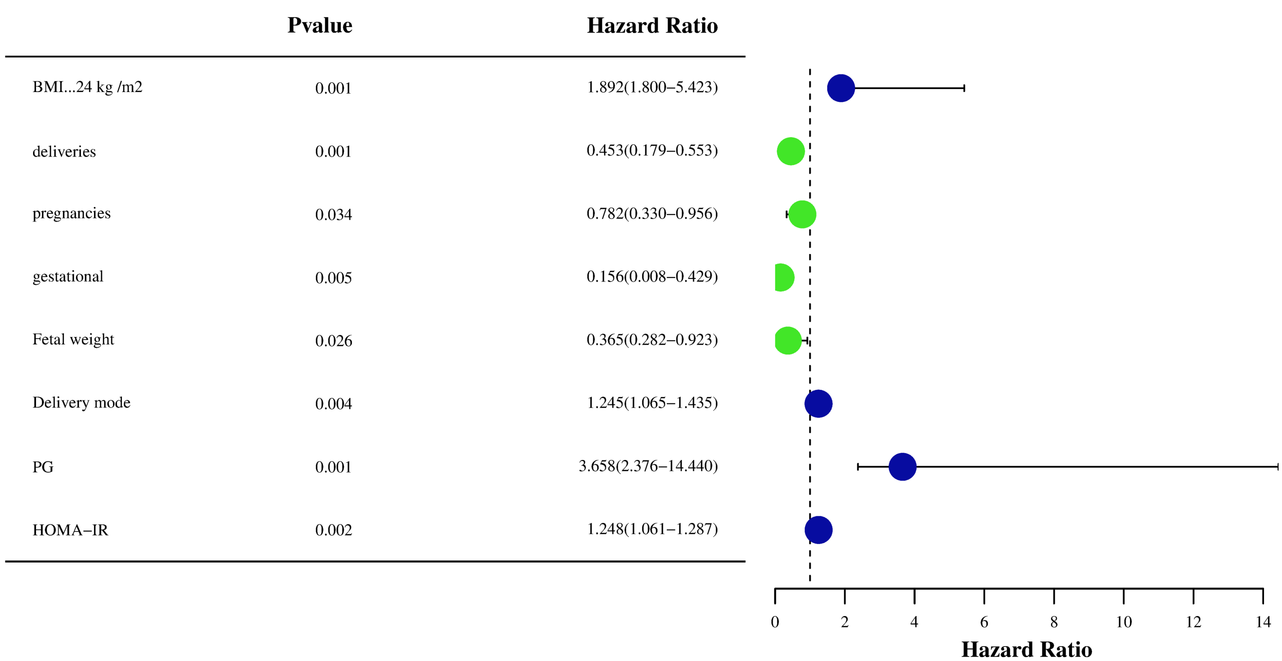

Figure 3 Multifactorial logistic forest plot for the occurrence of POP in GDM patients.

GDM involve insulin resistance and relative insulin secretion deficiency.[24] Insulin resistance not only affects glucose metabolism, but may also influence pelvic muscle function through multiple pathways.[25] Specifically, a hyperglycemic state may impair collagen and elastin through non-enzymatic glycation, leading to weakened pelvic floor support structures. In addition, insulin resistance may further exacerbate pelvic floor muscle atrophy and dysfunction by affecting vascular endothelial function and reducing blood supply to pelvic tissues.[26,27] Together, these mechanisms increase the risk of POP in patients with GDM.

This study showed that BMI, number of deliveries, number of pregnancies, gestational week, fetal weight and mode of delivery were all risk factors for the occurrence of POP in the early postpartum period. The probability of POP increased significantly when the number of pregnancies and deliveries increased, indicating that the increase in the number of pregnancies and deliveries changed the function and structure of the pelvic floor tissues, and the degree of damage to the pelvic floor tissues increased, and in severe cases, perineal tearing was caused, which destroyed the integrity of the pelvic floor tissues and led to the increase in the incidence of POP.[28,29] Excessive maternal BMI increases abdominal pressure, which is not conducive to the nutrient supply of pelvic floor tissues and increases the degree of damage to pelvic tissues. The increase in gestational weeks increases the gravitational force on the maternal pelvic floor, and persistent compression damages the pelvic floor tissues, causing an increase in the incidence of POP.[30] When fetal weight increases, notably in macrosomia, it enhances the compressibility of the maternal pelvic floor tissues and elevates the risk of POP. The incidence of POP was higher in vaginal deliveries than in cesarean deliveries. The reason for this is mainly due to the fact that during vaginal delivery, the pelvic floor tissues are forced to stretch, which can cause pelvic floor tears in severe cases and increase the probability of POP.[31]

Table 6 Predictive Value of PG and HOMA-IR Levels for Postpartum Pelvic Organ Prolapse in GDM Patients

Indicators	AUC (95% CI)	Optimal Threshold	Sensitivity/%	Specificity/%
PG (mmol/L)	0.835 (0.770–0.901)	3.952	75	85.9
HOMA-IR	0.809 (0.731–0.887)	3.015	80	71.4
Combined	0.891 (0.847~0.936)	0.225	77.5	87.4

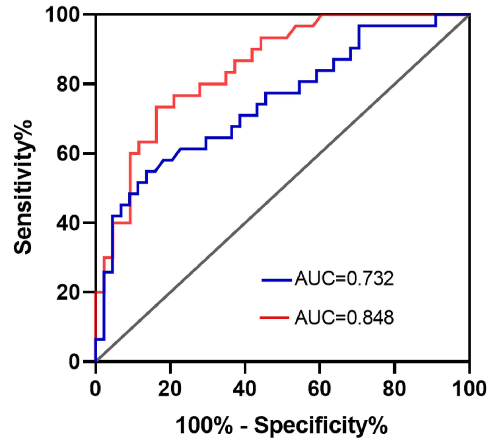

Figure 4 ROC curves of serum PG and HOMA-IR for predicting the occurrence of POP in GDM patients.

Insulin resistance affects not only glucose metabolism but also lipid metabolism. Triglycerides and total cholesterol are elevated 2–3 times in normal pregnant women during pregnancy, and low-density lipoprotein increases 2.0–2.5 times in late pregnancy. Patients suffering from GDM have more significant insulin resistance and higher lipid levels.[32,33] The relationship between insulin resistance and POP in patients with GDM may involve multiple biological mechanisms. First, insulin resistance may lead to a chronic inflammatory state that increases the activity of extracellular matrix-degrading enzymes, such as metalloproteinases, thereby weakening pelvic floor supportive structures and promoting the development of POP.[34] Second, hyperinsulinemia, commonly associated with GDM, stimulates adrenocorticotropic hormone secretion and affects collagen metabolism, leading to alterations in pelvic floor tissues and reducing their mechanical properties.[35] In addition, insulin resistance may affect estrogen and progesterone sensitivity, two hormones that play a key role in maintaining normal function of pelvic floor muscles and connective tissues.[36,37] Patients with GDM may suffer from pelvic floor tissue laxity and dysfunction due to hormonal imbalances. Further, the increased stress load during pregnancy, such as persistent hyperglycemia due to insulin resistance, may exacerbate the burden on the pelvic floor and promote POP.[38] ROC assessment showed that the efficacy of the combination of PG and HOMA-IR levels in predicting POP in GDM mothers was higher than that of individual prediction. This suggests that PG and HOMA-IR have a synergistic effect in predicting POP. Combined testing of these two indicators can improve the accuracy and sensitivity of prediction, help early identification of high-risk groups, and provide a basis for clinical intervention. By detecting PG and HOMA-IR levels, healthcare providers can promptly modify treatment strategies and improve pregnancy care to lower the risk of POP.

There are some limitations to this study. First, the sample size is relatively limited, which may affect the generalizability and accuracy of the results. Future studies may expand the sample size to further validate the results of this study. Second, this study was a cross-sectional study, which made it difficult to determine the causal relationship between factors and POP. A prospective cohort study could be conducted in follow-up to investigate the pathogenesis in depth. In addition, this study only focused on some of the clinical and metabolic indicators, and more factors, such as genetic factors and lifestyle, can be included for comprehensive analysis in the future.

In summary, this study clarified the relationship between multiple factors and POP in GDM patients, especially the important effects of PG and HOMA-IR levels. These results provide a theoretical basis for the clinical prevention and treatment of POP in patients with GDM, and help to improve maternal postnatal quality of life. Future studies should further explore the pathogenesis in depth to support the development of more effective interventions.

Data Sharing Statement

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Ethics Approval

The present study was approved by the Ethics Committee of The No.2 Hospital of Baoding (No. 202204BD-030) and written informed consent was provided by all patients prior to the study start. All procedures were performed in accordance with the ethical standards of the Institutional Review Board and The Declaration of Helsinki, and its later amendments or comparable ethical standards.

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Disclosure

The authors have no conflicts of interest to declare in this work.

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