Article

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Associated Factors and Development of a Risk-Estimation Nomogram for Clinically Relevant Depressive Symptoms in Pregnant Women With Gestational Diabetes Mellitus

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Abstract

Background: This study aimed to identify factors associated with clinically relevant depressive symptoms among pregnant women with gestational diabetes mellitus (GDM) and to develop and internally validate a risk-estimation nomogram for early psychological risk stratification.

Methods: In this single-centre retrospective observational study, 870 pregnant women with GDM treated at the Department of Obstetrics of The Fourth Hospital of Shijiazhuang between January 2023 and June 2025 were consecutively enrolled. After GDM diagnosis, all participants completed routine surveys and underwent assessment with the 17-item Hamilton Depression Rating Scale (HAMD-17). A HAMD-17 score of $\geq$8 was used to define clinically relevant depressive symptoms for this study, rather than a formal psychiatric diagnosis. Among the included women, 178 had clinically relevant depressive symptoms (case group) and 692 did not (control group). Medical records were reviewed to collect demographic, metabolic, pregnancy-related, and psychosocial information. Multivariable logistic regression was used to identify factors associated with depressive symptoms among pregnant women with GDM, and a nomogram was constructed. Model discrimination was assessed using the area under the curve (AUC) of receiver operating characteristic (ROC), and internal validation was performed using 1000 bootstrap resamples to obtain the optimism-corrected C-index. Calibration was evaluated using the calibration slope and Brier score, alongside the Hosmer–Lemeshow test.

Results: Compared with the control group, the case group had higher proportions of family history of depression/anxiety, abnormal pregnancy history, a history of vaginal bleeding, a history of tocolytic therapy, insomnia during pregnancy, and adverse life events during pregnancy, and a lower proportion of planned pregnancy. Multivariable logistic regression showed that adverse life events during pregnancy (odds ratio [OR] = 1.647), family history of depression/anxiety (OR = 2.487), abnormal pregnancy history (OR = 1.900), history of tocolytic therapy (OR = 1.879), and insomnia during pregnancy (OR = 1.781) were independently associated with clinically relevant depressive symptoms (all $p < 0.05$). The apparent AUC of the nomogram was 0.875 (95% confidence interval [CI]: 0.827–0.923), and the bootstrap-corrected C-index was 0.871 (95% CI: 0.819–0.917). The calibration slope was 0.943 (95% CI: 0.821–1.065) and the Brier score was 0.118, indicating acceptable calibration.

Conclusions: Family history of depression/anxiety showed the strongest association with clinically relevant depressive symptoms among pregnant women with GDM, followed by abnormal pregnancy history, tocolytic therapy, insomnia, and adverse life events during pregnancy. The nomogram may help identify women who require further psychological evaluation after GDM diagnosis within the current hospital setting; however, external validation in an independent cohort and prospective validation are essential before routine clinical implementation.

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Keywords

gestational diabetes mellitus; pregnant women; depressive symptoms; associated factors; risk-estimation nomogram

Introduction

Gestational diabetes mellitus (GDM), one of the most common metabolic complications of pregnancy, is defined as glucose intolerance first identified during pregnancy [1]. The International Diabetes Federation estimated that hyperglycaemia in pregnancy affected approximately 21.1 million live births worldwide in 2021, with most cases attributable to GDM [2]. Perinatal depression is also a clinically important public health concern. A systematic review and meta-regression reported an overall pooled prevalence of perinatal depression of 11.9%, with higher estimates in low- and middle-income settings and in studies using symptom scales [3]. In women with GDM, depressive symptoms may be more frequent because the diagnosis requires rapid dietary adjustment, repeated glucose monitoring, increased concern about fetal outcomes, and additional obstetric follow-up [4].

Previous studies have reported that GDM-related depressive symptoms may be associated with adverse obstetric history, perceived stress, sleep disturbance, inadequate social support, and family psychiatric history [2,4,5]. Nevertheless, existing studies have several limitations. Some studies have focused on postpartum depression, whereas evidence on depressive symptoms assessed after GDM diagnosis remains insufficient; others used a limited set of psychosocial or obstetric variables, and several nomogram studies lacked clear information on the timing of depression assessment in relation to GDM diagnosis [5,6]. In addition, the 17-item Hamilton Depression Rating Scale (HAMD-17) is a symptom-severity scale rather than a formal diagnostic interview, so studies using scale cutoffs should avoid implying a formal psychiatric diagnosis.

Compared with previous nomogram studies on GDM-related depression [7], this single-centre retrospective study explicitly defines the assessment window as within one week after oral glucose tolerance test (OGTT)-based GDM diagnosis, incorporates both pregnancy-related and psychosocial variables, and developed an internally validated nomogram for early psychological risk stratification. The intended incremental contribution is to provide a pragmatic outpatient risk-stratification tool based on routinely available variables while explicitly acknowledging the temporal and validation limitations of the retrospective design.

Materials and Methods

Baseline Data and Grouping

This single-centre retrospective observational study consecutively included 870 pregnant women with GDM who registered for antenatal care at the Obstetrics Department of The Fourth Hospital of Shijiazhuang between January 2023 and June 2025. All participants completed routine antenatal questionnaires and HAMD-17 assessment after the OGTT-based GDM diagnosis. Data collection was completed in June 2025. Among them, 178 women had clinically relevant depressive symptoms (case group), and 692 women had HAMD-17 scores below the predefined cutoff (control group).

Diagnostic Criteria and Assessment Timeline

GDM was diagnosed according to the Chinese Ministry of Health standard "Diagnosis of Gestational Diabetes Mellitus (WS 331-2011)" [8]. During a 75 g OGTT, GDM was diagnosed when any of the following thresholds were reached or exceeded: fasting plasma glucose (FPG) $\geq$5.1 mmol/L, 1-hour glucose $\geq$10.0 mmol/L, or 2-hour glucose $\geq$8.5 mmol/L.

Depressive symptoms were assessed using the HAMD-17 [9] within one week after the diagnosis of GDM. A total HAMD-17 score of $\geq$8 was used to define clinically relevant depressive symptoms for grouping [9,10]. This scale-based definition was not regarded as equivalent to a formal diagnosis of major depressive disorder according to Diagnostic and Statistical Manual of Mental Disorders (DSM) or International Classification of Diseases (ICD) criteria.

Early-pregnancy anxiety/depression screening before 13 weeks of gestation was used to identify baseline mental health status and to support exclusion of women with pre-pregnancy anxiety or depression, whereas the grouping in the present study was based on the HAMD-17 assessment performed after GDM diagnosis.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) age 22–39 years; (2) completed antenatal registration and anxiety/depression scale testing at the obstetrics outpatient clinic before 13 weeks of gestation; and (3) underwent OGTT as scheduled. Exclusion criteria were as follows: (1) diabetes diagnosed before pregnancy; (2) History of anxiety

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or depression before pregnancy; (3) cognitive impairment; (4) malignant tumours; (5) human immunodeficiency virus (HIV) infection; or (6) missing relevant scale results, laboratory tests, or medical history records.

Sample Size Estimation

Due to the retrospective design, all eligible pregnant women with GDM during the study period were consecutively included rather than determined by an a priori sample size calculation. The final sample comprised 870 participants, including 178 women with clinically relevant depressive symptoms. This number of outcome events met the commonly used events-per-variable principle for multivariable logistic regression and nomogram construction [11,12]. Considering all variables entered in the multivariable model (five final significant predictors, six adjustment covariates, and two non-significant variables retained from univariate screening—planned pregnancy and history of vaginal bleeding—for a total of 13 variables), the number of events per variable remained above 10 ($178/13 \approx 13.7$), supporting the stability of the multivariable modelling in the available dataset.

Assessment Tool for Depressive Symptoms

The HAMD-17 [9] was administered by trained obstetric or mental health staff and includes 17 items covering depressed mood, guilt feelings, suicide, insomnia (initial, middle, and late). Most items are rated on a 5-point scale (0 = absent, 1 = mild, 2 = moderate, 3 = severe, 4 = very severe), and a few items are rated on a 3-point scale. In the present study, a total score of $\geq$8 indicated clinically relevant depressive symptoms requiring further psychological attention [9,10]. The Cronbach's α coefficient in this study sample was 0.844, indicating acceptable internal consistency for the present dataset.

Data Collection

Baseline Information

Demographic information was extracted from the hospital electronic medical record system, including age, height, weight, body mass index (BMI), educational level, pre-pregnancy alcohol use, pre-pregnancy smoking, family history of diabetes, household registration type (urban/rural), ethnicity, occupation, monthly household income, and adverse life events during pregnancy. Monthly household income was categorised using a cutoff of 6000 CNY (1 CNY $\approx$ 0.142 USD), based on the distribution of the present sample and local economic data [13]. Adverse life events during pregnancy were defined as major negative events recorded in the antenatal questionnaire or medical record during the current pregnancy, including serious illness or death of a family member, marital breakdown, sudden financial difficulty, major family conflict, or other comparable events requiring marked psychological adaptation.

Pregnancy and Obstetric History

Information related to pregnancy and obstetric history was obtained through the electronic medical record system, including number of pregnancies, parity, planned pregnancy, abnormal pregnancy history, regular exercise during pregnancy, folic acid supplementation, presence of early pregnancy reactions, history of vaginal bleeding, history of tocolytic therapy, insomnia during pregnancy, and presence of gestational hypertension or anaemia. Abnormal pregnancy history was defined as any previous spontaneous abortion, stillbirth, preterm birth, ectopic pregnancy, fetal malformation, or other documented adverse pregnancy outcome. Insomnia during pregnancy was recorded as present when the questionnaire or medical record documented difficulty initiating sleep, difficulty maintaining sleep, early-morning awakening, or poor sleep quality occurring repeatedly during the current pregnancy and accompanied by daytime fatigue or distress. Because no dedicated sleep scale (e.g., Pittsburgh Sleep Quality Index or Insomnia Severity Index) was used, this variable was interpreted as a clinical-record-based symptom variable rather than a formal diagnosis of insomnia.

Data entry was performed independently by two persons with cross-checking to build the database. For key variables with missing values, telephone follow-up was conducted to supplement.

Statistical Analysis

All collected data were analysed using R software version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were tested for normality using the Kolmogorov–Smirnov test. Normally distributed variables were expressed as mean $\pm$ standard deviation and compared using the independent samples *t*-test. Categorical variables are expressed as frequencies (%) and compared using the χ^2 test. Variables with $p < 0.05$ in univariate analysis and clinically relevant covariates were entered into multivariable logistic regression model. Multi-

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collinearity was assessed using the variance inflation factor (VIF). A nomogram was constructed to estimate the probability of clinically relevant depressive symptoms after GDM diagnosis. Discrimination was evaluated by the area under the curve (AUC) of receiver operating characteristic (ROC), and internal validation was performed using 1000 bootstrap resamples to obtain the optimism-corrected C-index. Calibration was evaluated using the calibration slope, Brier score, and Hosmer–Lemeshow test, together with calibration plots. Decision curve analysis (DCA) was used to evaluate clinical net benefit. A two-sided p value < 0.05 was considered statistically significant; extremely small p values were reported as $p < 0.001$.

Results

Comparison of Demographic Data Between the Two Groups

The two groups differed significantly in the proportion of adverse life events during pregnancy ($\chi^2 = 22.674$, $p < 0.001$). The proportion of women with adverse life events was higher in the case group (14.61%, 26/178) than in the control group (4.62%, 32/692). No significant differences were found in other demographic variables (all $p > 0.05$). (Table 1)

Comparison of Pregnancy-Related Data Between the Two Groups

The proportion of family history of depression/anxiety was higher in the case group (17.98%) than in the control group (2.75%; $\chi^2 = 59.525$, $p < 0.001$). The proportion of planned pregnancy was lower in the case group (62.92% vs. 73.84%; $\chi^2 = 8.308$, $p = 0.004$). The proportions of abnormal pregnancy history (17.98% vs. 7.80%; $\chi^2 = 16.452$, $p < 0.001$), history of vaginal bleeding (18.54% vs. 8.96%; $\chi^2 = 13.358$, $p < 0.001$), history of tocolytic therapy (13.48% vs. 6.21%; $\chi^2 = 10.525$, $p = 0.001$), and insomnia during pregnancy (37.64% vs. 27.31%; $\chi^2 = 7.237$, $p = 0.007$) were higher in the case group. (Table 2)

Factors Associated With Clinically Relevant Depressive Symptoms in Pregnant Women With GDM

Variables with statistical significance in univariate analysis (adverse life events during pregnancy, family history of depression/anxiety, planned pregnancy, abnormal pregnancy history, history of vaginal bleeding, history of tocolytic therapy, and insomnia during pregnancy) and clinically relevant covariates were entered into the multivariable logistic regression model. The coding was as follows: no = 0 and yes = 1 for binary variables. The results showed that adverse life events during pregnancy (odds ratio [OR] = 1.647, $p = 0.045$), family history of depression/anxiety (OR = 2.487, $p < 0.001$), abnormal pregnancy history (OR = 1.900, $p = 0.028$), history of tocolytic therapy (OR = 1.879, $p = 0.046$), and insomnia during pregnancy (OR = 1.781, $p = 0.024$) were independently associated with clinically relevant depressive symptoms in pregnant women with GDM. Planned pregnancy and history of vaginal bleeding, which were significant in univariate analyses, did not remain significant after multivariable adjustment. Additionally, the number of women with vaginal bleeding was limited, and the confidence interval was close to the null value (Table 3).

Internal Validation and Clinical Utility of the Risk-Estimation Nomogram

A nomogram was constructed to visualise the factors retained in the multivariable logistic regression model (Fig. 1). The score for each factor corresponds to a point on the upper axis; the total score across factors is then mapped to the estimated probability of clinically relevant depressive symptoms. The maximum total score in the model was 240 points, corresponding to an estimated probability of approximately 90%. Based on DCA results and risk distribution, tentative cut-off scores were established: low risk (<80 points, predicted probability <15%), medium risk (80–140 points, predicted probability 15%–35%), and high risk (>140 points, predicted probability >35%).

A calibration curve was used to evaluate agreement between predicted and observed probabilities (Fig. 2). In the calibration plot, the diagonal reference line represents perfect calibration, and the bias-corrected curve after bootstrap resampling approximates the observed calibration of the model. The bootstrap-corrected C-index was 0.871 (95% confidence interval [CI]: 0.819–0.917) based on 1000 bootstrap resamples. The calibration slope was 0.943 (95% CI: 0.821–1.065), and the Brier score was 0.118, indicating acceptable overall calibration. The Hosmer–Lemeshow test showed $\chi^2 = 1.296$ and $p = 0.401$, indicating no evidence of significant lack of fit. DCA (Fig. 3) showed that the nomogram provided a higher net benefit than the "treat all" and "treat none" strategies when the threshold probability ranged from 0.21 to 1.00. The DCA lower threshold of 0.21 is notably higher than the sample prevalence of clinically relevant depressive symptoms (approximately 20.5%), indicating that the nomogram does not demonstrate superior net benefit at very low threshold probabilities. The receiver operating characteristic curve (Fig. 4) showed an apparent AUC of 0.875 (95% CI: 0.827–0.923) for identifying

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Table 1. Comparison of demographic data between the two groups of pregnant women with GDM.

Demographic information	Case group (n = 178)	Control group (n = 692)	t/χ^2	p
Age (years)	31.81 ± 3.90	31.66 ± 4.40	0.415	0.678
Pre-pregnancy BMI (kg/m^2)	21.83 ± 1.67	21.95 ± 1.70	−0.843	0.400
FPG (mmol/L)	6.04 ± 0.66	6.13 ± 0.58	−1.793	0.073
HbA1c (%)	5.98 ± 0.57	6.01 ± 0.60	−0.601	0.548
Gestational weight gain rate (%)			0.740	0.390
<20.0%	98 (55.06)	356 (51.45)		
≥20.0%	80 (44.94)	336 (48.55)		
Education level (%)			2.905	0.088
Middle school or below	102 (57.30)	347 (50.14)		
High school or above	76 (42.70)	345 (49.86)		
Household registration (%)			1.925	0.165
Urban	113 (63.48)	477 (68.93)		
Rural	65 (36.52)	215 (31.07)		
Ethnicity (%)			0.422	0.516
Han	154 (86.52)	611 (88.29)		
Others	24 (13.48)	81 (11.71)		
Pre-pregnancy alcohol use (%)			3.116	0.078
Yes	21 (11.80)	53 (7.66)		
No	157 (88.20)	639 (92.34)		
Pre-pregnancy smoking (%)			1.420	0.233
Yes	14 (7.87)	38 (5.49)		
No	164 (92.13)	654 (94.51)		
Family history of diabetes (%)			3.034	0.082
Yes	43 (24.16)	127 (18.35)		
No	135 (75.84)	565 (81.65)		
Occupation (%)			5.021	0.081
Mental work	113 (63.48)	456 (65.9)		
Manual work	45 (25.28)	192 (27.75)		
Unemployed	20 (11.24)	44 (6.36)		
Monthly household income (%)			0.386	0.535
<6000 CNY	81 (45.51)	297 (42.92)		
≥6000 CNY	97 (54.49)	395 (57.08)		
Adverse life events during pregnancy (%)			22.674	<0.001
Yes	26 (14.61)	32 (4.62)		
No	152 (85.39)	660 (95.38)		

Note: Data are presented as mean ± standard deviation or n (%). 1 CNY ≈ 0.142 USD. BMI, body mass index; FPG, fasting plasma glucose; HbA1c, glycated haemoglobin; GDM, gestational diabetes mellitus.

clinically relevant depressive symptoms among pregnant women with GDM. These performance estimates should be interpreted as internal validation results because no external validation cohort was available.

Discussion

The present study found that family history of depression/anxiety had the strongest association among the included variables (OR = 2.487), indicating that familial psychiatric vulnerability was associated with clinically relevant depressive symptoms after GDM diagnosis. This finding should not be interpreted as direct evidence of a genetic causal mechanism, because family history also reflects shared family environment, parenting patterns, illness awareness, and help-seeking behaviour [14,15]. Nevertheless, a previous population-based study showed that family history of depression was associated with increased risk of lifetime and current depressive symptoms and may involve both inherited vulnerability and environmental exposure [16]. In the context of GDM, women with familial vulnerability may have lower psychological resilience when

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Table 2. Comparison of pregnancy-related data between the two groups of pregnant women with GDM.

Item	Case group (n = 178)	Control group (n = 692)	t/χ^2	p
Family history of depression/anxiety (%)			59.525	<0.001
Yes	32 (17.98)	19 (2.75)		
No	146 (82.02)	673 (97.25)		
Planned pregnancy (%)			8.308	0.004
Yes	112 (62.92)	511 (73.84)		
No	66 (37.08)	181 (26.16)		
Number of pregnancies (%)			2.256	0.133
1	77 (43.26)	343 (49.57)		
>1	101 (56.74)	349 (50.43)		
Parity (%)			0.519	0.471
Primipara	82 (46.07)	298 (43.06)		
Multipara	96 (53.93)	394 (56.94)		
Abnormal pregnancy history (%)			16.452	<0.001
Yes	32 (17.98)	54 (7.80)		
No	146 (82.02)	638 (92.2)		
Regular exercise during pregnancy (%)			0.854	0.356
Yes	77 (43.26)	273 (39.45)		
No	101 (56.74)	419 (60.55)		
Folic acid supplementation (%)			2.683	0.101
Yes	156 (87.64)	634 (91.62)		
No	22 (12.36)	58 (8.38)		
Early pregnancy reaction (%)			0.444	0.505
Yes	122 (68.54)	456 (65.90)		
No	56 (31.46)	236 (34.10)		
History of vaginal bleeding (%)			13.358	<0.001
Yes	33 (18.54)	62 (8.96)		
No	145 (81.46)	630 (91.04)		
History of tocolytic therapy (%)			10.525	0.001
Yes	24 (13.48)	43 (6.21)		
No	154 (86.52)	649 (93.79)		
Insomnia during pregnancy (%)			7.237	0.007
Yes	67 (37.64)	189 (27.31)		
No	111 (62.36)	503 (72.69)		
Gestational hypertension (%)			3.625	0.057
Yes	10 (5.62)	19 (2.75)		
No	168 (94.38)	673 (97.25)		
Anaemia (%)			1.981	0.159
Yes	31 (17.42)	92 (13.29)		
No	147 (82.58)	600 (86.71)		

Note: Data are presented as n (%). GDM, gestational diabetes mellitus.

facing dietary restriction, glucose monitoring, and concerns about fetal outcomes. These findings suggest that family history of depression/anxiety is a simple but clinically significant screening item that may be considered for inclusion in antenatal psychological screening after GDM diagnosis.

Abnormal pregnancy history (OR = 1.900) and history of tocolytic therapy (OR = 1.879) were also independently associated with depressive symptoms. The similar magnitude of these two odds ratios suggests that both previous adverse obstetric experience and current pregnancy-related complications may contribute to psychological vulnerability. Women with a history of miscarriage, stillbirth, preterm birth, ectopic pregnancy, or fetal abnormality may enter the current pregnancy with heightened threat perception. After GDM diagnosis, this background may amplify concerns about fetal growth, preterm delivery, neonatal metabolic

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Table 3. Factors associated with clinically relevant depressive symptoms in pregnant women with GDM.

Variables	β	SE	Wald χ^2	p	OR	95% CI
Adverse life events during pregnancy	0.499	0.229	4.748	0.045	1.647	1.051–2.580
Family history of depression/anxiety	0.911	0.356	6.548	<0.001	2.487	1.238–4.997
Planned pregnancy	−0.391	0.211	3.434	0.112	0.676	0.447–1.023
Abnormal pregnancy history	0.642	0.281	5.220	0.028	1.900	1.096–3.296
History of vaginal bleeding	0.177	0.094	3.546	0.091	1.194	0.993–1.435
History of tocolytic therapy	0.631	0.298	4.484	0.046	1.879	1.048–3.371
Insomnia during pregnancy	0.577	0.250	5.327	0.024	1.781	1.091–2.907
Age (per year)	0.008	0.022	0.132	0.716	1.008	0.965–1.053
Pre-pregnancy BMI (per kg/m^2)	0.041	0.055	0.556	0.456	1.042	0.935–1.161
Fasting plasma glucose (per mmol/L)	−0.221	0.167	1.751	0.186	0.802	0.578–1.112
HbA1c (per %)	−0.083	0.159	0.272	0.602	0.920	0.674–1.257
Education level (high school or above vs. middle school or below)	−0.254	0.195	1.697	0.193	0.776	0.529–1.136
Monthly household income (≥6000 CNY vs. <6000 CNY)	−0.215	0.191	1.266	0.261	0.807	0.555–1.174
Constant	1.438	0.819	3.083	0.128		

Note: All variables were entered simultaneously into the multivariable model. Age, pre-pregnancy BMI, FPG, and HbA1c were entered as continuous variables; education level and monthly household income were entered as binary variables. All six adjustment covariates were non-significant (all $p > 0.05$). No obvious multicollinearity was detected among the entered variables (all VIF <2.5, range: 1.08–2.37). 1 CNY ≈ 0.142 USD. SE, standard error; OR, odds ratio; CI, confidence interval; VIF, variance inflation factor; BMI, body mass index; FPG, fasting plasma glucose; HbA1c, glycated haemoglobin; GDM, gestational diabetes mellitus.

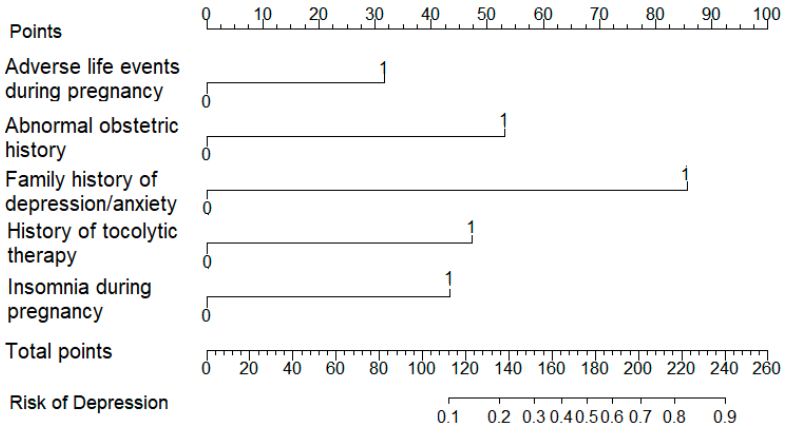

Fig. 1. Nomogram of factors associated with clinically relevant depressive symptoms. Each predictor is assigned a point value, and the total points correspond to the estimated individual probability.

problems, and treatment safety. Tocolytic therapy often follows threatened abortion, threatened preterm labour, or other obstetric complications and may increase medical visits, activity restriction, and uncertainty regarding pregnancy continuation. Previous studies in GDM populations have similarly reported that adverse obstetric experience and perceived stress are associated with antenatal or postpartum depressive symptoms [5,6,17,18]. These findings suggest that combined obstetric and psychological follow-up may be warranted for pregnant women with GDM with adverse pregnancy history or current pregnancy instability, rather than focusing solely on glucose control.

Adverse life events during pregnancy were independently associated with depressive symptoms (OR = 1.647). This association is consistent with the biopsychosocial model, however, the retrospective design prevents confirmation of a causal sequence. Major negative life events may reduce coping resources, increase perceived stress, and weaken adherence to the daily self-management requirements of GDM [19,20]. From a neuroendocrine perspective, sustained stress may activate the hypothalamic–pituitary–adrenal axis and increase cortisol exposure, which could theoretically be associated with both depressive symptoms and insulin resistance [21,22]. However, the present study did not measure cortisol or other

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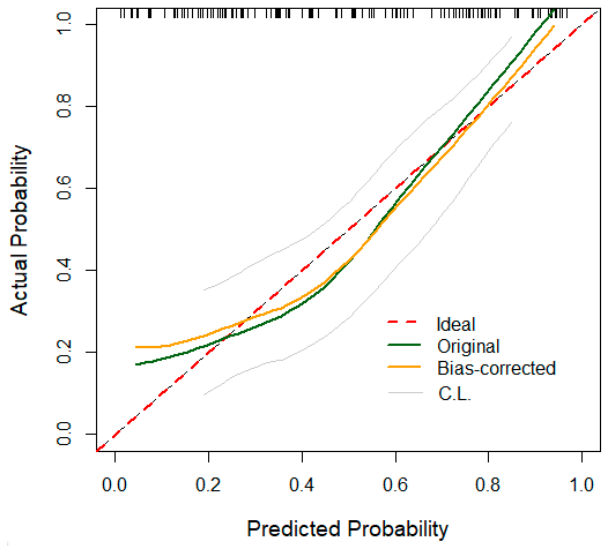

Fig. 2. Calibration curve of the nomogram. The diagonal line represents ideal calibration, and the bias-corrected curve shows the agreement between predicted and observed probabilities after bootstrap resampling. C.L., confidence limit.

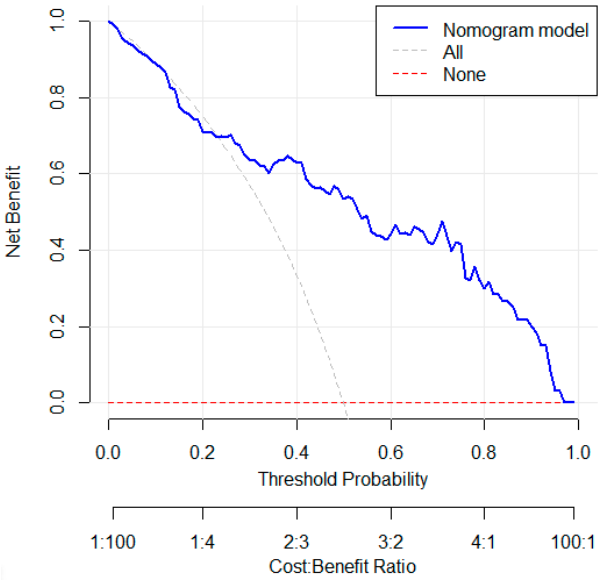

Fig. 3. DCA of the nomogram. The curve illustrates the net clinical benefit across different threshold probabilities compared with treat-all and treat-none strategies. DCA, decision curve analysis.

stress biomarkers, so this mechanism remains inferential. A practical implication is that antenatal assessment in women with GDM may benefit from including recent life stressors, especially when adherence to dietary control, sleep monitoring, and glucose management become difficult.

Insomnia during pregnancy was another independent

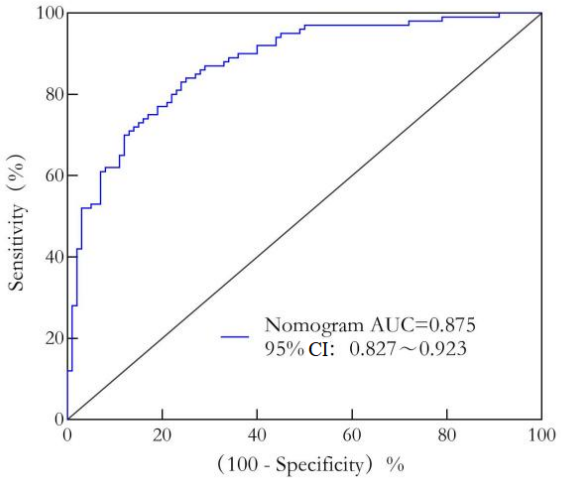

Fig. 4. Receiver operating characteristic curve of the nomogram. The apparent AUC was 0.875 (95% CI: 0.827–0.923). AUC, area under the curve; CI, confidence interval.

factor associated with depressive symptoms (OR = 1.781). The association between insomnia and subsequent depression has been supported by longitudinal meta-analyses [23, 24]; however, in the present study, insomnia may function both as an associated factor and a symptom overlapping with depression. In women with GDM, nocturnal discomfort, anxiety about glucose fluctuations, dietary changes, and frequent urination may disrupt sleep [25,26]. Conversely, poor sleep may increase daytime fatigue, impair self-management capacity, and intensify worry or self-blame when glycaemic targets are not achieved [23]. Because insomnia in this study was identified from medical records and antenatal questionnaires rather than a validated sleep scale, the findings should be interpreted as suggesting that documented sleep disturbance is a clinically useful warning signal. To assess whether the association was driven primarily by overlapping depressive symptoms, a sensitivity analysis was conducted excluding 87 women (10.0% of the total sample) with HAMD-17 insomnia subscores ≥2. In the remaining 783 women, the adjusted OR for insomnia during pregnancy remained 1.562 (95% CI: 1.012–2.411, $p = 0.044$), consistent with the primary analysis and supporting the robustness of the association.

Planned pregnancy and history of vaginal bleeding were significant in univariate comparisons but did not remain statistically significant in the multivariable model. As noted in the Results, planned pregnancy may reflect broader socioeconomic status, health literacy, marital stability, and antenatal care engagement; after adjustment for education, income, and other variables, its independent contribution was attenuated. Similarly, vaginal bleeding is closely re-

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lated to threatened miscarriage, tocolytic therapy, and abnormal pregnancy history; therefore, its association may be attenuated after adjustment for these related obstetric variables. The limited number of women with vaginal bleeding also reduced statistical power, and the confidence interval for this variable was close to the null value. These findings suggest that planned pregnancy and vaginal bleeding may still warrant clinical attention, but their independent associations with depressive symptoms were not confirmed in this dataset.

The present study constructed a nomogram for clinically relevant depressive symptoms assessed within one week after GDM diagnosis, a defined and clinically relevant assessment window. Compared with a previous nomogram developed for postpartum depression in GDM [7], the current model focused on the antenatal period immediately following GDM diagnosis, incorporated pregnancy-related variables such as tocolytic therapy and vaginal bleeding, and used the HAMD-17 rather than the Edinburgh Postnatal Depression Scale. However, the model did not include several variables included in prior studies (e.g., social support, marital satisfaction, glycaemic control indicators), limiting direct comparison of predictive performance. Compared with a simple clinical checklist, the nomogram provides individualised risk probabilities based on weighted factors, which may facilitate more individualised risk stratification. However, whether this approach provides additional benefit over simpler screening approach remains to be determined in prospective comparative studies with external validation.

This study has several limitations. First, it was a singlecentre retrospective analysis, and all participants were from the obstetrics outpatient system of one hospital. The demographic and socioeconomic profile of this population (predominantly Han ethnicity, urban residents) may limit generalisability to other regions and populations. Selection bias may also arise from the exclusion of women with missing data, although telephone follow-up was conducted to minimise data loss. Second, the retrospective design introduces temporal ambiguity in the sequence of variables; depressive symptoms, insomnia, and adverse life events were assessed concurrently, so the directionality of associations cannot be established. Third, depressive symptoms were defined using HAMD-17 scores $\geq$8 rather than a structured DSM/ICD diagnostic interview, so the outcome should be interpreted as clinically relevant depressive symptoms rather than confirmed depressive disorder. Fourth, because data on adverse life events and insomnia were obtained from medical records or antenatal questionnaires without standardised validated instruments, both variables are subject to recall and recording bias. Although a sensitivity analysis was conducted to partially address the insomnia measurement issue, prospective studies with validated scales are still needed. Fifth, important confounding factors were not available for analysis. Marital status, social support, physical activity intensity, gestational glycaemic control trajectory (e.g., HbA1c or glucose profiles after diagnosis), medication use, and coping style were not systematically recorded in the electronic medical record system and could not be included. The absence of these variables may result in residual confounding, and future studies should incorporate standardised measures of social support and glycaemic control. Sixth, the DCA lower threshold of 0.21 was higher than the sample prevalence (~20.5%), indicating that the nomogram did not demonstrate net benefit at very low threshold probabilities. This limits its utility for screening in very low-risk settings. Finally, the nomogram was only internally validated by bootstrap resampling and lacked external or temporal validation; therefore, the performance of this model may be overestimated. Future prospective studies should use structured diagnostic interviews, validated scales for sleep and life events, comprehensive covariate assessment, and independent external cohorts to confirm generalisability and clinical utility.

Conclusions

In pregnant women with GDM, clinically relevant depressive symptoms were associated with family history of depression/anxiety, abnormal pregnancy history, history of tocolytic therapy, insomnia during pregnancy, and adverse life events during pregnancy. The internally validated nomogram based on these factors may help obstetric clinicians identify women who may benefit from more detailed psychological assessment after GDM diagnosis within the current hospital setting. Given the single-centre retrospective design, non-standardised measurement of psychosocial variables, absence of key confounders such as social support and glycaemic control, and lack of external validation, the model should not be applied in routine clinical practice until prospective multicentre validation is completed.

Availability of Data and Materials

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

Author Contributions

XPC and LXW conceived and designed the research framework. All authors participated in data collection

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and the clinical implementation of the research procedures. WHC and LL sorted out research data and completed statistical analysis. JLY finished the initial writing of the manuscript. All authors revised and polished the manuscript together, supplemented key academic viewpoints and revised core content. All authors confirmed and agreed on the final version to be officially published. Every participant took charge of their respective research segments, bore corresponding academic responsibilities, and promised to timely verify and solve all doubts concerning the authenticity, accuracy and integrity of this research achievement.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of The Fourth Hospital of Shijiazhuang (institution review board number, 20250070) and was performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

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Conflict of Interest

The authors declare no conflict of interest.

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