

Original Research

Effect of Combined Gestational Diabetes Mellitus and Preeclampsia on Pregnancy Outcomes

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Abstract

Background: Gestational diabetes mellitus (GDM) and preeclampsia (PE) significantly increase the risk of adverse pregnancy outcomes. However, the effect on the risk of adverse pregnancy outcomes of GDM in combination with PE remains undetermined. Therefore, this study aimed to investigate the risk of adverse outcomes in pregnant women with GDM and PE. **Methods:** This retrospective cohort study was conducted at a single center. To explore the correlations between the occurrence of PE and adverse pregnancy outcomes, the enrolled population was divided into two groups: GDM and non-GDM. Risk factors associated with PE were analyzed using a binary logistic regression model. **Results:** This study comprised 27,181 pregnant women (5412 GDM cases and 21,769 non-GDM cases). The prevalence of PE was significantly higher in the GDM group than in the non-GDM group ($p < 0.05$). The presence of GDM, pre-pregnancy body mass index (pp-BMI) $>24 \text{ kg/m}^2$, and excessive gestational weight gain (GWG) were demonstrated to contribute to an increased risk of developing PE ($p < 0.05$). Pregnant women with GDM exhibited a significantly higher risk of preterm birth. Additionally, the risk of preterm birth, cesarean section, and fetal growth restriction increased further when PE occurred alongside GDM. **Conclusions:** Overall, pp-BMI $>24 \text{ kg/m}^2$ and excessive GWG were risk factors for PE. Pregnant women with GDM have a higher risk of developing PE, and co-occurrence of PE further increases the risk of adverse pregnancy outcomes. Therefore, attention and management of this population are needed during pregnancy.

Keywords: gestational diabetes mellitus; preeclampsia; risk factor; pregnancy outcomes

1. Introduction

Gestational diabetes mellitus (GDM) is a disorder that affects glucose metabolism during pregnancy, affecting approximately 9%–26% of pregnancies. The prevalence of GDM in China can be as high as 14.8% [1]. The abnormal glucose metabolism associated with GDM can lead to several complications during pregnancy, including gestational obesity and hypertensive disorders of pregnancy (HDP) [2]. Preeclampsia (PE) represents a serious type of HDP, which affects approximately 4.4%–5.57% of pregnant women and can have negative consequences for both maternal and neonatal health [3]. The development of PE involves a complex interplay of multiple factors. Current research has identified several key mechanisms contributing to the development and progression of PE, including abnormal placental function, vascular endothelial dysfunction, immune imbalances, and genetic factors [4]. Moreover, evidence indicates that the pathological process of PE in pregnant women is irreversible [5]. Therefore, a timely termination of the pregnancy is currently the only method to prevent further deterioration outcomes during pregnancy. Meanwhile, no routine screening test can accurately predict the risk of PE, prompting ongoing clinical research to identify more reliable predictive methods [6]. This uncertainty in prediction underscores the significance of preventing PE.

The combination of GDM and PE significantly increases health risks for both mother and infants [7], which can lead to adverse pregnancy outcomes, such as preterm birth and fetal growth restriction. Additionally, both GDM and PE are independent risk factors for cardiovascular disease, which poses a threat to the long-term cardiovascular health of pregnant women [8]. While existing studies have shown a notable increase in PE among pregnant women with GDM [1], the independent association between GDM and PE remains debated [9]. Therefore, further research is necessary to understand this relationship better and identify controllable factors. Additionally, identifying factors associated with PE in pregnant women with GDM is crucial for improving perinatal outcomes. Thus, this study aimed to investigate the factors linked to the occurrence of PE in pregnant women with GDM to enable early identification of those at high risk for developing PE.

2. Materials and Methods

2.1 Study Population and Data Collection

This single-center retrospective study involved 27,181 pregnant women who delivered at Women's Hospital Zhejiang University School of Medicine between January 2018 and December 2019. The ages of the pregnant women ranged from 18 to 54 years old, averaging 31.13 years.



The study excluded individuals who experienced multiple births, had pre-pregnancy diabetes mellitus, chronic hypertension or heart disease, abortions or stillbirths, or missing primary pregnancy data. All participants underwent regular antenatal examinations between the 24th and 28th week of pregnancy. At this time, the participants were tested for various biochemical markers, including fasting glucose (FG), hemoglobin A1c (HbA1c), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglyceride (TG), to minimize the potential impact of variations in gestational age on the test results. The hospital ethics committee approved the study (IRB-20200183-R). The enrolled cases were divided into GDM and non-GDM based on the GDM diagnosis criteria [10] and then into PE and control groups according to the PE diagnosis criteria [11]. Gestational weight gain (GWG) was assessed according to the Chinese criteria (WS/T 801-2022). Then, the enrolled cases were classified into three groups based on their GWG: inadequate GWG, appropriate GWG, and excessive GWG.

2.2 Definitions

Pre-pregnancy body mass index (pp-BMI) was calculated as the ratio of a woman's pre-pregnancy weight (kg) versus her height squared (m^2). The categories were assigned according to Chinese classification standards, as follows: underweight ($<18.5 \text{ kg/m}^2$), normal weight ($18.5\text{--}24 \text{ kg/m}^2$), overweight ($24.1\text{--}28 \text{ kg/m}^2$), and obese ($>28 \text{ kg/m}^2$).

GWG was calculated as the weight before delivery (kg) minus pre-pregnancy weight (kg). According to the Chinese standards (WS/T 801-2022), the recommended GWG varies for women based on their pp-BMI: 11.0–16.0 kg for underweight women, 8.0–14.0 kg for normal weight, 7.0–11.0 kg for overweight, and 5.0–9.0 kg for obese. For pregnant women with different pp-BMIs, those below the above criteria were classified as having inadequate GWG, those meeting the above criteria were classified as having adequate GWG, and those exceeding the above criteria were classified as having excessive GWG.

HDP is a high blood pressure symptom during pregnancy, which includes various types of gestational hypertension, PE, eclampsia, chronic hypertension complicated by PE, and chronic hypertension [11].

GDM represents a diagnosis of GDM, which can be applied if any of the glucose values from the 75 g oral glucose tolerance test (OGTT) during 24–28 weeks of pregnancy are reached or exceeded: fasting, 5.1 mmol/L; 1-hour, 10.0 mmol/L; 2-hour, 8.5 mmol/L [10].

2.3 Pregnancy Outcomes

Our obstetricians used the latest clinical practice guidelines to diagnose adverse pregnancy outcomes. We included various adverse pregnancy outcomes, including preterm birth (delivery before 37 completed weeks of gestation) [12], cesarean section, macrosomia (birth weight $\geq 4000 \text{ g}$), and fetal growth restriction [13].

2.4 Statistical Analysis

The statistical software used was SPSS version 23.0 (IBM, Armonk, NY, USA). Continuous data are expressed as the mean $\pm$ standard deviation (SD), while categorical data are expressed as numbers or percentages. We assessed differences between groups using *t*-tests for continuous variables and χ^2 or Fisher's exact tests for categorical variables. Risk factor analyses were conducted using binary logistic regression models, with results expressed as odds ratios (ORs) and 95% confidence intervals (CIs). We adjusted for potential confounding variables, including maternal age and pp-BMI. Statistical significance was defined as $p < 0.05$ (two-sided).

3. Results

3.1 Demographic and Clinical Characteristics between GDM and Non-GDM

A total of 27,181 cases were included in the study. Table 1 summarizes the demographic and clinical characteristics between the GDM and non-GDM groups. The data were divided into two groups [10]: 5412 cases in the GDM group (139 PE cases and 5273 non-PE cases) and 21,769 cases in the non-GDM group (362 PE cases and 21,407 non-PE cases). The prevalence of PE in the GDM group was 2.56% (139/5412), significantly higher than the prevalence of 1.66% (362/21,769) found in the non-GDM group ($p < 0.05$). The presence/absence of GDM in pregnant women and whether pp-weight, FG, HbA1c, and TG levels were higher were observed in the PE group ($p < 0.05$). The incidence of PE was highest among women with excessive GWG.

3.2 Factors Associated with PE

Table 2 presents the factors associated with PE. After adjustment for confounders, logistic regression analyses indicated that pp-BMI $>24 \text{ kg/m}^2$ and excess GWG elevated the risk of developing PE. In addition, women with pp-BMI $<18.5 \text{ kg/m}^2$ in the non-GDM group exhibited a lower risk of developing PE ($p < 0.05$).

3.3 Risk Analysis of Hypertensive Complications in Pregnant Women with GDM

Table 3 outlines the risk analysis of hypertensive complications during pregnancy in pregnant women with GDM. After adjusting for age, pp-BMI, GWG, and gestational age, the risk of HDP and PE remained significantly higher in pregnant women with GDM than those without ($p < 0.05$).

3.4 Pregnancy Outcomes in Pregnant Women with GDM and Those with GDM and PE

Table 4 presents the adverse pregnancy outcomes for women with GDM and those with GDM and PE. Compared to pregnant women without GDM, those with GDM had a

Table 1. Clinical characteristics of the GDM and non-GDM groups.

Variables	GDM				Non-GDM			
	Non-PE (n = 5273)	PE (n = 139)	t/χ^2	p -value	Non-PE (n = 21,407)	PE (n = 362)	t/χ^2	p -value
Age (years)	32.57 ± 4.46	32.86 ± 4.60	−0.737	0.461	30.77 ± 4.13	30.64 ± 4.50	0.599	0.549
Gestational age (weeks)	38.49 ± 1.56	37.59 ± 1.94	6.672	<0.001	38.83 ± 1.47	37.79 ± 2.28	13.195	<0.001
pp-weight (kg)	55.54 ± 8.42	60.23 ± 10.37	−6.442	<0.001	53.34 ± 7.29	57.32 ± 9.13	−10.232	<0.001
GWG (kg)	12.50 ± 4.34	14.63 ± 5.46	−5.606	<0.001	14.56 ± 4.13	16.66 ± 4.88	−9.462	<0.001
Infant weight (g)	3293.14 ± 479.50	3027.16 ± 8.42	6.393	<0.001	3307.21 ± 436.88	3001.81 ± 703.79	13.018	<0.001
FG (mmol/L)	4.66 ± 0.56	4.94 ± 0.70	−5.824	<0.001	4.35 ± 0.31	4.41 ± 0.34	−3.392	0.001
HbA1c (%)	5.15 ± 0.36	5.37 ± 0.42	−6.943	<0.001	4.96 ± 0.28	5.12 ± 0.31	−10.598	<0.001
HDL (mmol/L)	1.87 ± 0.37	1.72 ± 0.39	4.820	<0.001	1.92 ± 0.36	1.84 ± 0.35	4.059	<0.001
LDL (mmol/L)	2.92 ± 0.83	2.85 ± 0.78	1.024	0.306	2.96 ± 0.79	2.97 ± 0.84	−0.327	0.744
TG (mmol/L)	2.45 ± 0.99	2.73 ± 1.05	−3.280	0.001	2.20 ± 0.80	2.51 ± 0.88	−7.445	<0.001
Infant weight (g)	N = 5273	N = 139	50.879	<0.001	N = 21,407	N = 362	314.240	<0.001
<2500	230 (4.4)	24 (17.3)			672 (3.1)	73 (20.2)		
2500–4000	4742 (89.9)	110 (79.1)			19,714 (92.1)	269 (74.3)		
>4000	301 (5.7)	5 (3.6)			1021 (4.8)	20 (5.5)		
Age (years)	N = 5273	N = 139	3.804	0.051	N = 21,407	N = 362	2.163	0.141
<34	3563 (67.6)	83 (59.7)			17,332 (81.0)	282 (77.9)		
≥35	1710 (32.4)	56 (40.3)			4075 (19.0)	80 (22.1)		
pp-BMI (kg/m ²)	N = 5271	N = 135	54.399	<0.001	N = 21,399	N = 355	110.492	<0.001
<18.5	717 (13.6)	9 (6.7)			4388 (20.5)	38 (10.7)		
18.5–24	3564 (67.6)	67 (49.6)			14,976 (70)	230 (64.8)		
24.1–28	841 (16.0)	48 (35.6)			1780 (8.3)	69 (19.4)		
>28	149 (2.8)	11 (8.1)			255 (1.2)	18 (5.1)		
GWG group	N = 5220	N = 135	27.769	<0.001	N = 21,131	N = 355	78.291	<0.001
Inadequate	707 (13.6)	7 (5.2)			1261 (6.0)	12 (3.4)		
Appropriate	2747 (52.6)	54 (40.0)			9396 (44.5)	83 (23.4)		
Excessive	1766 (33.8)	74 (54.8)			10,474 (49.5)	260 (73.2)		
Gestational age (weeks)	N = 5273	N = 139	39.302	<0.001	N = 21,407	N = 362	97.901	<0.001
<28	7 (0.1)	0 (0)			22 (0.1)	1 (0.3)		
28–31	27 (0.5)	0 (0)			77 (0.3)	9 (2.5)		
32–36	338 (6.4)	32 (23.0)			940 (4.4)	59 (16.3)		
≥37	4901 (93.0)	107 (77.0)			20,368 (95.2)	293 (80.9)		

Abbreviations: GDM, gestational diabetes mellitus; PE, preeclampsia; pp-weight, pre-pregnancy weight; pp-BMI, pre-pregnancy body mass index; GWG, gestational weight gain; FG, fasting glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; HbA1c, hemoglobin A1c; N, number. Gestational age: weeks of delivery.

Table 2. Factors associated with PE.

Variables	GDM				Non-GDM			
	c-OR (95% CI)	<i>p</i> -value	a-OR	<i>p</i> -value	c-OR (95% CI)	<i>p</i> -value	a-OR	<i>p</i> -value
Age (years)								
<34	Ref.		Ref.		Ref.		Ref.	
≥35 #	1.406 (0.997–1.983)	0.052	1.255 (0.887–1.775)	0.200	1.207 (0.939–1.550)	0.142	1.035 (0.804–1.332)	0.792
pp-BMI (kg/m ²)								
<18.5 ##	0.668 (0.331–1.345)	0.258	0.665 (0.328–1.346)	0.237	0.564 (0.399–0.796)	0.001	0.555 (0.392–0.786)	0.001
18.5–24	Ref.		Ref.		Ref.		Ref.	
24.1–28 ##	3.306 (2.080–4.431)	<0.001	3.046 (2.085–4.450)	<0.001	2.524 (1.920–3.318)	<0.001	2.566 (1.950–3.376)	<0.001
>28 ##	3.927 (2.033–7.586)	<0.001	3.941 (2.040–7.6113)	<0.001	4.596 (2.801–7.543)	<0.001	4.612 (2.810–7.570)	<0.001
GWG group								
Inadequate ##	0.504 (0.228–1.112)	0.090	0.499 (0.226–1.101)	0.085	1.077 (0.586–1.979)	0.810	1.078 (0.587–1.981)	0.808
Appropriate	Ref.		Ref.		Ref.		Ref.	
Excessive ##	2.132 (1.493–3.043)	<0.001	2.146 (1.503–3.065)	0.001	2.810 (2.191–3.603)	<0.001	2.808 (2.189–3.601)	<0.001

#Adjusted for pp-BMI. ##Adjusted for maternal age. Abbreviations: GDM, gestational diabetes mellitus; PE, preeclampsia; pp-BMI, pre-pregnancy body mass index; c-OR, crude odds ratio; a-OR, adjusted odds ratio; CI, confidence interval; Ref., reference.

significantly higher risk of preterm birth ($p < 0.001$). Among GDM-positive women, the risk of preterm birth, cesarean section, and fetal growth restriction was significantly higher in women with PE than in those without ($p < 0.001$).

4. Discussion

In this retrospective study, we found that both pp-BMI >24 kg/m² and excessive GWG increased the risk of PE, regardless of whether the woman has GDM. Furthermore, pregnant women diagnosed with GDM had a significantly higher risk of preterm birth, which increased for those with GDM who also experience comorbid PE.

Our study provides evidence to evaluate the risk factors for PE mentioned earlier. Obesity is a well-known risk factor for both GDM and PE. Meanwhile, pp-BMI evaluates nutritional status before pregnancy, while GWG assesses nutritional status during pregnancy. Research from various studies indicates that GWG and pp-BMI are independent risk factors for PE; however, the extent of their effects remains a topic of debate [7]. Our study indicates that pre-pregnancy overweight (pp-BMI >24 kg/m²) and excessive GWG both contribute to an increased risk of PE. Thus, pregnant women must pay close attention to GWG since it is a factor that can be managed during pregnancy [14,15]. For pregnant women with GDM, actively managing their weight is not only beneficial for controlling the progress of GDM but also for preventing more serious adverse pregnancy outcomes [16], such as PE.

After adjusting for age, pp-BMI, and GWG, our study found that pregnant women with GDM are significantly more likely to experience a combination of HDP and PE. This finding supports the notion that GDM is an independent risk factor for PE, aligning with previously conducted research [8]. However, conflicting research has been published on the causal relationship between GDM and PE [9].

Additionally, our study observed that pregnant women with PE had significantly higher levels of biochemical indicators, including FG, HbA1c, and TG, compared with the non-PE group. These abnormalities may be closely related to placental metabolic disorders caused by glucose and fatty acid levels during placental development, which may be an important mechanism leading to PE [17]. Meanwhile, GDM and PE not only share similar risk factors but are also closely related in terms of pathophysiological processes. The common pathogenesis of the two conditions is reflected in the following aspects: (1) Insulin resistance [18], which is associated with placental ischemia and hypoxia in both GDM and PE. (2) Oxidative stress [19]: in GDM, hyperglycemia leads to increased oxidative stress; in PE, metabolic changes caused by placental ischemia and hypoxia produce excess reactive oxygen species (ROS). (3) Vascular endothelial dysfunction [20]: in GDM, excessive glycosylation products harm vascular endothelial cells; in PE, toxins resulting from placental ischemia and hypoxia have a similar damaging effect. These common threads reveal an intrinsic link between the pathogenesis of GDM and PE, providing valuable clues and insights for exploring effective preventive measures.

As a study has shown, the association between GDM and hypertension subtypes differs across different races [1]. Genetic background, lifestyle, dietary habits, and environmental conditions contribute to these differences, which may affect the association between GDM and hypertension subtypes through multiple pathways and possibly bias the study's findings. Our study is limited to the Chinese population; thus, these data may not apply to other regions or ethnicities. Therefore, subsequent studies should expand the samples for further differential analyses.

Finally, our study found that the risk of preterm birth was significantly increased in pregnant women with GDM, consistent with similar studies [21]. When women with

Table 3. Risk analysis of hypertensive complications in pregnant women with GDM.

Variables	GDM			
	c-OR (95% CI)	p-value	a-OR	p-value#
HDP	Ref. 1.642 (1.455–1.853)	<0.001	Ref. 1.428 (1.251–1.631)	<0.001
PE	Ref. 1.559 (1.279–1.900)	<0.001	Ref. 1.508 (1.219–1.864)	<0.001

#Adjusted for maternal age, pp-BMI, GWG, gestational age, and parity. Abbreviations: GDM, gestational diabetes mellitus; HDP, hypertensive disorders of pregnancy; PE, preeclampsia; c-OR, crude odds ratio; a-OR, adjusted odds ratio; CI, confidence interval; pp-BMI, pre-pregnancy body mass index; Ref., reference. Gestational age: weeks of delivery.

Table 4. Effect of PE on pregnancy outcome in pregnant women with GDM.

Variables	N	Preterm birth#	Caesarean delivery#	Macrosomia#	Fetal growth restriction#
Total	27,181	N = 1503	N = 8996	N = 1455	N = 151
Non-GDM (%)	21,769 (80.1)	1102 (5.1)	7013 (32.2)	1129 (5.2)	124 (0.6)
GDM (%)	5412 (19.9)	401 (7.4)	1983 (36.6)	326 (6.0)	27 (0.5)
a-OR (95% CI)*		1.309 (1.158–1.478)	0.938 (0.878–1.001)	1.002 (0.879–1.142)	0.907 (0.591–1.391)
p-value		<0.001	0.054	0.977	0.653
GDM	5412	N = 401	N = 1983	N = 326	N = 27
GDM + non-PE (%)	5273 (97.4)	369 (7.0)	1899 (36.0)	321 (6.1)	19 (0.4)
GDM + PE (%)	139 (2.6)	32 (23.0)	84 (60.4)	5 (3.6)	8 (5.8)
a-OR (95% CI)**		3.597 (2.368–5.464)	2.378 (1.668–3.393)	0.407 (0.164–1.011)	18.925 (7.935–45.137)
p-value		<0.001	<0.001	0.053	<0.001

*compared with the non-GDM group. **compared with the GDM + non-PE group. #Adjusted for maternal age, pp-BMI. Abbreviations: GDM, gestational diabetes mellitus; PE, preeclampsia; a-OR, adjusted odds ratio; CI, confidence interval; N, number; pp-BMI, pre-pregnancy body mass index.

GDM also experience PE, the risk of preterm birth, cesarean section, and fetal growth restriction further escalates, as supported by a recent United States (US) cohort study [22]. Preterm birth is one of the leading causes of neonatal morbidity and mortality worldwide [23], while fetal growth restriction seriously affects neonatal growth and development. When mothers have PE, it can lead to placental hypoperfusion, which is characterized by intrauterine fetal growth restriction oligoamniotic fluid and a 5% lower birth weight [24]. A Canadian study has shown that PE is strongly associated with various adverse outcomes, including cesarean section, preterm placental abruption, fetal growth restriction, and preterm birth [25]. The co-occurrence of GDM and PE will seriously threaten the health of both mothers and infants [1,7]. Therefore, early detection and prevention of PE is vital to reduce obstetric complications and adverse pregnancy outcomes.

The findings of this study can provide valuable guidance to clinicians. Indeed, more active interventions should be adopted for high-risk pregnant women diagnosed with GDM, such as intensive glycemic control, regular obstetric examination, and mother-infant monitoring. Comparatively, health education and pregnancy weight management should be strengthened for pregnant women with

pre-pregnancy overweight and excessive GWG. Increased awareness of PE combined with GDM can lead to more effective treatment strategies and interventions to improve maternal and infant health.

Currently, there remain relatively few studies on the impact of GDM combined with PE on pregnancy outcomes in the Chinese population. Therefore, the latest GWG guidelines established by the Chinese Nutrition Society in 2021 are currently adopted, which provide precise and relevant guidance for pregnant women in China. In contrast, many previous studies relied on the 2009 Institute of Medicine (IOM) standards; however, these international recommendations may not apply to all countries due to population differences. Subsequently, by adapting the GWG standard to Chinese characteristics, the aim is to provide more substantial clinical data for pregnant women with GDM and PE. The clinical data for this study were collected before the outbreak of the coronavirus disease 2019 (COVID-19) pandemic. Consequently, we avoided the missing data caused by the lack of regular antenatal care due to the public health crisis during the pandemic and the impact of COVID-19 infection on pregnancy outcomes.

However, our study has some limitations. The clinical presentation of PE is highly variable and classified as

early-onset PE (onset before 34 weeks of gestation) or late-onset PE (onset at or after 34 weeks of gestation) [26]. Due to challenges in accurately determining the onset of PE at diagnosis in this study, we did not conduct typing and comparative analyses of different types of PE. Subsequent studies will provide a more detailed breakdown of cases, enabling a more in-depth differential analysis of the various subtypes of PE. In addition, some studies have indicated that anxiety or depression during pregnancy may contribute to an increased incidence of GDM [27,28]. Thus, psychological stress during the antenatal period should also be considered a potential risk factor for the development of GDM and hypertension. However, limited data availability meant this study could not account for psychological factors.

5. Conclusions

In conclusion, pp-BMI >24 kg/m² and excessive GWG increased the risk of PE. Pregnant women with GDM are at a heightened risk of developing PE. Furthermore, the co-occurrence of PE further amplifies the risk of adverse pregnancy outcomes. Therefore, this population requires special attention and management during pregnancy.

Availability of Data and Materials

The datasets utilized and analyzed in the current study are available from the corresponding author upon reasonable request.

Author Contributions

HL and BBY contributed to the study's conception and design, execution of the experiments, statistical analysis of the data, and writing of the paper. NJ and BZ were involved in the design, data analysis, and manuscript revision. All authors read and approved the final manuscript. All authors participated fully in the work and agreed to be accountable for all aspects.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki and the Medical Ethics Committee of Women's Hospital Zhejiang University School of Medicine approved the study (IRB-20200183-R), and no special informed consent was required because anonymous patient records were used.

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Conflict of Interest

The authors declare no conflict of interest.

References

- [1] Jiang L, Tang K, Magee LA, von Dadelszen P, Ekeroma A, Li X, *et al.* A global view of hypertensive disorders and diabetes mellitus during pregnancy. *Nature Reviews. Endocrinology.* 2022; 18: 760–775. <https://doi.org/10.1038/s41574-022-00734-y>.
- [2] 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 (Clinical Research Ed.).* 2022; 377: e067946. <https://doi.org/10.1136/bmj-2021-067946>.
- [3] Elgazzaz M, Woodham PC, Maher J, Faulkner JL. Implications of pregnancy on cardiometabolic disease risk: preeclampsia and gestational diabetes. *American Journal of Physiology. Cell Physiology.* 2024; 327: C646–C660. <https://doi.org/10.1152/ajpcell.00293.2024>.
- [4] Nirupama R, Divyashree S, Janhavi P, Muthukumar SP, Ravindra PV. Preeclampsia: Pathophysiology and management. *Journal of Gynecology Obstetrics and Human Reproduction.* 2021; 50: 101975. <https://doi.org/10.1016/j.jogoh.2020.101975>.
- [5] Kornacki J, Olejniczak O, Sibiak R, Gutaj P, Wender-Ozegowska E. Pathophysiology of Pre-Eclampsia-Two Theories of the Development of the Disease. *International Journal of Molecular Sciences.* 2023; 25: 307. <https://doi.org/10.3390/ijms25010307>.
- [6] Stepan H, Galindo A, Hund M, Schlembach D, Sillman J, Surbek D, *et al.* Clinical utility of sFlt-1 and PlGF in screening, prediction, diagnosis and monitoring of pre-eclampsia and fetal growth restriction. *Ultrasound in Obstetrics & Gynecology: The Official Journal of the International Society of Ultrasound in Obstetrics and Gynecology.* 2023; 61: 168–180. <https://doi.org/10.1002/uog.26032>.
- [7] Yang Y, Wu N. Gestational Diabetes Mellitus and Preeclampsia: Correlation and Influencing Factors. *Frontiers in Cardiovascular Medicine.* 2022; 9: 831297. <https://doi.org/10.3389/fcvm.2022.831297>.
- [8] Liu X, Nianogo RA, Janzen C, Fei Z, Seamans MJ, Wen R, *et al.* Association Between Gestational Diabetes Mellitus and Hypertension: A Systematic Review and Meta-Analysis of Cohort Studies with a Quantitative Bias Analysis of Uncontrolled Confounding. *Hypertension (Dallas, Tex.: 1979).* 2024; 81: 1257–1268. <https://doi.org/10.1161/HYPERTENSIONA.123.22418>.
- [9] Yang X, QimeiZhong, Huang M, Li L, Tang C, Luo S, *et al.* Causal relationship between gestational diabetes and preeclampsia: A bidirectional mendelian randomization analysis. *Diabetes Research and Clinical Practice.* 2024; 210: 111643. <https://doi.org/10.1016/j.diabres.2024.111643>.
- [10] Yang HX. Diagnostic criteria for gestational diabetes mellitus (WS 331-2011). *Chinese Medical Journal.* 2012; 125: 1212–1213.
- [11] Magee LA, Brown MA, Hall DR, Gupte S, Hennessy A, Karumanchi SA, *et al.* The 2021 International Society for the Study of Hypertension in Pregnancy classification, diagnosis & management recommendations for international practice. *Pregnancy Hypertension.* 2022; 27: 148–169. <https://doi.org/10.1016/j.preghy.2021.09.008>.
- [12] Prediction and Prevention of Spontaneous Preterm Birth: ACOG Practice Bulletin, Number 234. *Obstetrics and Gynecology.* 2021; 138: e65–e90. <https://doi.org/10.1097/AOG.0000000000004479>.
- [13] Lees CC, Romero R, Stampalija T, Dall'Asta A, DeVore GA, Prefumo F, *et al.* Clinical Opinion: The diagnosis and management of suspected fetal growth restriction: an evidence-based approach. *American Journal of Obstetrics and Gynecology.* 2022; 226: 366–378. <https://doi.org/10.1016/j.ajog.2021.11.1357>.

- [14] Obstetrics Subgroup, Chinese Society of Obstetrics and Gynecology, Chinese Medical Association, Chinese Society of Perinatal Medicine, Chinese Medical Association, Committee of Pregnancy with Diabetes Mellitus, China Maternal and Child Health Association. Guideline of diagnosis and treatment of hyperglycemia in pregnancy (2022) [Part one]. *Zhonghua Fu Chan Ke Za Zhi*. 2022; 57: 3–12. <https://doi.org/10.3760/cma.j.cn112141-20210917-00528>. (In Chinese)
- [15] Lima Ferreira J, Voss G, Dória M, Sá Couto A, Príncipe RM. Benefit of insufficient gestational weight gain in obese women with gestational diabetes mellitus: A multicenter study in Portugal. *Diabetes & Metabolic Syndrome*. 2021; 15: 419–424. <https://doi.org/10.1016/j.dsx.2021.01.020>.
- [16] Li M, Zhang CY, Yue CY. Effects of pre-pregnancy BMI and gestational weight gain on adverse pregnancy outcomes and complications of GDM. *Journal of Obstetrics and Gynaecology: The Journal of the Institute of Obstetrics and Gynaecology*. 2022; 42: 630–635. <https://doi.org/10.1080/01443615.2021.1945009>.
- [17] Hu M, Li J, Baker PN, Tong C. Revisiting preeclampsia: a metabolic disorder of the placenta. *The FEBS Journal*. 2022; 289: 336–354. <https://doi.org/10.1111/febs.15745>.
- [18] Modzelewski R, Stefanowicz-Rutkowska MM, Matuszewski W, Bandurska-Stankiewicz EM. Gestational Diabetes Mellitus-Recent Literature Review. *Journal of Clinical Medicine*. 2022; 11: 5736. <https://doi.org/10.3390/jcm11195736>.
- [19] Phoswa WN, Khaliq OP. The Role of Oxidative Stress in Hypertensive Disorders of Pregnancy (Preeclampsia, Gestational Hypertension) and Metabolic Disorder of Pregnancy (Gestational Diabetes Mellitus). *Oxidative Medicine and Cellular Longevity*. 2021; 2021: 5581570. <https://doi.org/10.1155/2021/5581570>.
- [20] Bolatai A, He Y, Wu N. Vascular endothelial growth factor and its receptors regulation in gestational diabetes mellitus and eclampsia. *Journal of Translational Medicine*. 2022; 20: 400. <https://doi.org/10.1186/s12967-022-03603-4>.
- [21] Dalfra' MG, Burlina S, Lapolla A. Weight gain during pregnancy: A narrative review on the recent evidences. *Diabetes Research and Clinical Practice*. 2022; 188: 109913. <https://doi.org/10.1016/j.diabres.2022.109913>.
- [22] Onuoha C, Schulte CCM, Thaweethai T, Hsu S, Pant D, James KE, *et al*. The simultaneous occurrence of gestational diabetes and hypertensive disorders of pregnancy affects fetal growth and neonatal morbidity. *American Journal of Obstetrics and Gynecology*. 2024; 231: 548.e1–548.e21. <https://doi.org/10.1016/j.ajog.2024.03.009>.
- [23] Cao G, Liu J, Liu M. Global, Regional, and National Incidence and Mortality of Neonatal Preterm Birth, 1990–2019. *JAMA Pediatrics*. 2022; 176: 787–796. <https://doi.org/10.1001/jamapediatrics.2022.1622>.
- [24] Dimitriadis E, Rolnik DL, Zhou W, Estrada-Gutierrez G, Koga K, Francisco RPV, *et al*. Pre-eclampsia. *Nature Reviews. Disease Primers*. 2023; 9: 8. <https://doi.org/10.1038/s41572-023-00417-6>.
- [25] Yang Y, Le Ray I, Zhu J, Zhang J, Hua J, Reilly M. Preeclampsia Prevalence, Risk Factors, and Pregnancy Outcomes in Sweden and China. *JAMA Network Open*. 2021; 4: e218401. <https://doi.org/10.1001/jamanetworkopen.2021.8401>.
- [26] Aneman I, Pienaar D, Suvakov S, Simic TP, Garovic VD, McClements L. Mechanisms of Key Innate Immune Cells in Early- and Late-Onset Preeclampsia. *Frontiers in Immunology*. 2020; 11: 1864. <https://doi.org/10.3389/fimmu.2020.01864>.
- [27] OuYang H, Chen B, Abdulrahman AM, Li L, Wu N. Associations between Gestational Diabetes and Anxiety or Depression: A Systematic Review. *Journal of Diabetes Research*. 2021; 2021: 9959779. <https://doi.org/10.1155/2021/9959779>.
- [28] Mersha AG, Tollosa DN, Bagade T, Eftekhari P. A bidirectional relationship between diabetes mellitus and anxiety: A systematic review and meta-analysis. *Journal of Psychosomatic Research*. 2022; 162: 110991. <https://doi.org/10.1016/j.jpsychores.2022.110991>.