Diabetes, Metabolic Syndrome and Obesity

Dovepress
Taylor & Francis Group

Open Access Full Text Article

REVIEW

Risk Factors for Gestational Diabetes Mellitus in Mainland China: A Systematic Review and Meta-Analysis

Linjuan Xia[1], Zehua Yang[2], Qincai Mu[3], Yulin Ji[1], Juncheng Lyu[4]

[1]College of Nursing, Dali University, Dali, Yunnan, 671000, People's Republic of China; [2]Department of Obstetrics and Gynecology, The Second People's Hospital of Dali City, Dali, Yunnan, 671003, People's Republic of China; [3]Department of Obstetrics, The First Affiliated Hospital of Dali University, Dali, Yunnan, 671000, People's Republic of China; [4]School of Public Health, Shandong Second Medical University, Weifang, Shandong, 261053, People's Republic of China

Correspondence: Juncheng Lyu, Email cheng_china@163.com

Diabetes, Metabolic Syndrome and Obesity downloaded from https://www.dovepress.com/
For personal use only.

Objective: This study aimed to identify and evaluate risk factors associated with gestational diabetes mellitus (GDM) in mainland China.

Methods: Eight electronic databases were searched for literature published from January 2010 until December 2023. Heterogeneity was quantified using I^2. Data were pooled by fixed or random effects models and expressed as odds ratio and 95% confidence intervals.

Results: A total of 69 observational studies with an overall sample size of 2,138,032 Chinese women and 219,303 patients with GDM were included in the analysis. After adjusting confounders, older maternal age (OR = 1.12, 95% CI: 1.09–1.15), maternal age ≥35 years (OR = 1.96, 95% CI: 1.74–2.21), higher pre-pregnancy body mass index (OR = 1.24, 95% CI: 1.17–1.32), pre-pregnancy overweight (OR = 1.78, 95% CI: 1.64–1.92) or obesity (OR 2.52, 95% CI: 2.06–3.08), family history of diabetes (OR = 1.85, 95% CI: 1.58–2.17), history of GDM (OR = 4.09, 95% CI: 2.13–7.82), and elevated levels of fasting plasma glucose (OR = 2.54, 95% CI: 2.13–3.01), hemoglobin (OR = 1.47, 95% CI: 1.14–1.89) and serum triglycerides (OR = 1.69, 95% CI: 1.31–2.16) in early pregnancy were associated with an increased risk of GDM in mainland China. But gravidity ≥2 (OR = 1.06, 95% CI: 0.89–1.27), conception by assisted reproductive technology analyses (OR = 1.54, 95% CI: 0.95–2.51) were not associated with GDM, and parity ≥1 (OR = 0.88, 95% CI: 0.82–0.94) was related to lower risk of GDM. In available unadjusted studies, history of abortion (OR = 1.34, 95% CI: 1.31–1.37) increased risk of GDM, non-Han ethnicity (OR = 0.78, 95% CI: 0.59–1.03) and high school or lower education level (OR1.09, 95% CI: 0.94–1.26) showed no correlation with GDM.

Conclusion: The key risk factors for GDM in mainland China included older maternal age, maternal age ≥35 years, pre-pregnancy overweight or obesity, family history of diabetes, history of GDM, elevated levels of FPG, Hb, and serum TG in early pregnancy. Early identification and intervention for women at high risk should be performed to prevent the development of GDM.

Keywords: gestational diabetes mellitus, risk factors, mainland China, systematic review, meta-analysis

Introduction

Gestational diabetes mellitus (GDM) refers to diabetes being diagnosed in the second or third trimester of pregnancy without significant diabetes before pregnancy.[1] The incidence of GDM has been increasing in recent years. In 2021, the International Diabetes Federation reported that 16.7% of women aged 20–49 in the world had varying degrees of blood sugar elevation during pregnancy, of which 80.3% were caused by GDM.[2] In 2008, Hyperglycemia and Adverse Pregnancy Outcomes (HAPO) study indicated that mild hyperglycemia during pregnancy could increase the risk of adverse pregnancy outcomes such as, large for gestational age, cesarean delivery, neonatal hypoglycemia, preterm birth, shoulder dystocia and preeclampsia.[3] Based on these findings, in 2010, the International Association of Diabetes and Pregnancy Study Groups (IADPSG) recommended a new diagnostic criterion for GDM by performing a 75-gram 2-hour oral glucose tolerance (OGTT) at 24–28 weeks of gestation.[4] According to IADPSG criteria, when 1 or more glucose

Received: 24 October 2024
Accepted: 28 January 2025
Published: 22 February 2025

© 2025 Xia et al. This work is published and licensed by Dove Medical Press Limited. The full terms of this license are available at https://www.dovepress.com/terms.php and incorporate the Creative Commons Attribution – Non Commercial (unported, v3.0) License (http://creativecommons.org/licenses/by-nc/3.0/). By accessing the work you hereby accept the Terms. Non-commercial uses of the work are permitted without any further permission from Dove Medical Press Limited, provided the work is properly attributed. For permission for commercial use of this work, please see paragraphs 4.2 and 5 of our Terms (https://www.dovepress.com/terms.php).

indexes met or exceeded the following cut-offs: fasting, 5.1 mmol/L; 1 hour, 10.0 mmol/L; 2 hours, 8.5 mmol/L, the pregnant women should be diagnosed with GDM.

Since then, many studies have shown that GDM is strongly associated with adverse maternal and infant outcomes.[5–7] In 2021, a systematic review about GDM and adverse pregnancy outcomes showed that the risks of cesarean section, preterm birth, macrosomia, and large for gestational age were 1.5 to 2 folds in women with GDM compared to those without GDM.[8] Additionally, women with GDM history had higher risk of suffering from diabetes and cardiovascular diseases after delivery.[9,10] Offsprings of mothers with GDM were at increased risk of becoming overweight or obese during childhood[11,12] and were more likely to develop abnormal glucose metabolism and hypertension.[13,14] It has been confirmed that early assessment of the risk of developing GDM among pregnant women and timely lifestyle intervention can reduce the occurrence of GDM.[9,15] GDM typically is diagnosed between 24 and 28 weeks of gestation. Therefore, the risk factors related to the onset of GDM and their significance should be clearly identified.

Pregnancy care in China has undergone significant transformation over the past decades.[16] Currently, more than 98% of births occur in hospitals, driven by government initiatives to reduce maternal and neonatal mortality rates. Home births, once common in rural areas, have become exceedingly rare due to improvements in healthcare infrastructure and the implementation of hospital-based birth policies.[17] In mainland China, the prevalence of GDM reached 14.8%,[18] indicating that this country might have the largest number of GDM patients worldwide. Globally, the prevalence of GDM varies significantly, influenced by differences in genetic predisposition, environmental exposures, lifestyle factors, and diagnostic criteria.[19] For example, the prevalence of GDM in Europe and North America typically ranges between 5% and 10%, whereas Asian populations, including Chinese women, tend to exhibit higher rates of GDM due to a combination of genetic and lifestyle factors.[20] These distinctions underline the importance of focusing on GDM risk factors in mainland China, where rapid economic development, urbanization, and dietary changes have further compounded the issue.[21,22] Understanding the unique risk profiles of Chinese women can provide critical insights for targeted prevention and intervention strategies. Thus, this study aims to identify key risk factors for GDM among pregnant women in mainland China through meta-analysis, with the goal of enhancing early identification and preventive strategies, ultimately reducing the incidence and adverse outcomes associated with GDM in this population.

Methods

This systematic review was reported according to and under the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement.[23] The protocol was registered in PROSPERO (CRD42024496696).

Search Strategy

The following databases including PubMed, Embase, Web of Science, Cochrane library, CBM, China National Knowledge Infrastructure (CNKI), Wang Fang Data and Chongqing VIP were systematically searched from January 2010 until December 2023. The references of included studies and relevant systematic review were manually searched to obtain additional literature. The search strategy combined with medical subject words and free text words related to risk factors of GDM. The detailed search strategies of PubMed and Embase were shown in Supplementary Table S1.

Eligibility Criteria

Studies were included if they meet the following criteria: (1) Case-control or cohort studies conducted in mainland China; (2) Participants: pregnant women aged 18 years or older; (3) Outcome measures: pregnant women in the studies should undergo an 75 g Oral Glucose Tolerance Test (OGTT) at 24–28 weeks of gestation; (4) Diagnosis of GDM: the diagnostic criteria established by IADPSG in 2010; (5) Studies reported one of the following risk factors: maternal age, ethnicity, educational level, pre-pregnancy body mass index (BMI), family history of diabetes, history of GDM, gravidity, parity, history of abortion, use of assisted reproductive technology (ART), early pregnancy fasting plasma glucose (FPG), hemoglobin (Hb) levels, serum triglycerides (TG) levels; (6) Studies reported risk ratios (RR) or odds ratios (OR) and their confidence interval (CI) for the risk factors, or provided sufficient data to calculate these metrics.

Studies were excluded if: (1) Studies included participants with pregestational diabetes; (2) Studies only focused on specific populations (such as, advanced maternal age pregnancy, multiple pregnancies, or individuals diagnosed with

specific diseases); (3) Studies lacking a clear diagnostic standard for gestational diabetes; (4) Intervention studies, cross-sectional studies, systematic review, meta-analysis, conference abstracts, case reports, letters, guidelines, reviews and animal studies; (5) Total sample size less than 1000; (6) Duplicated data; (7) Studies published not in English or Chinese.

Data Extraction

Two researchers independently screened the literature, extracted the data, and cross-checked it. Any disagreement was resolved through discussion or consultation with a third review author. The extracted data included including author, publication year, year of recruitment, study design, region, sample size, number of women with GDM, risk factors, crude and adjusted OR and RR, and 95% CI. For studies adopting multivariate regression, we extracted adjusted ORs or RRs, which account for confounding variables such as maternal age, pre-pregnancy BMI, family history of diabetes, and other relevant factors reported by the original authors. Adjusted estimates were used for meta-analysis when available, and unadjusted estimates were analyzed separately to evaluate their consistency. For unadjusted studies, we calculated risk ratios and 95% confidence intervals based on the extracted data. The unadjusted and adjusted data were meta-analyzed separately.

Risk of Bias Assessment

Risk of bias assessment was independently evaluated by two reviewers using the Newcastle Ottawa Scale (NOS).[24] For each study, the item scores were collated and an overall risk of bias (low, moderate, and high) was determined. A lower risk of bias denotes higher quality. Scores above 5 indicate moderate-to-high quality study.

Statistical Analysis

A flow diagram illustrated the literature search and article selection process. The Cochran's Q test and I^2 was applied to detect heterogeneity between the studies. Subgroup analyses were performed for factors that could potentially affect GDM: study design, BMI classification standard and region. Next, we performed sensitivity analyses by omitting each study individually and recalculating the pooled effect size estimates for the remaining studies to assess the effect of individual studies on the pooled result. The publication bias was evaluated by using funnel plot and Egger's test (≥10 studies). All analyses were performed using Stata 14.0. $P < 0.05$ indicates statistical significance.

Results

Characteristics of Included Studies

Of the 4291 studies identified, 69 studies with a total of 2,138,032 women and 219,303 patients with GDM were included in the present study. The flow diagram of the search process is shown in Figure 1. Characteristics of the included study were summarized in Supplementary Table S2.

Quality Assessment

Among the 69 published papers, 15 were written in Chinese and 54 were written in English. The NOS results for 56 cohort studies and 13 case–control studies were summarized in Supplementary Table S3 and Table S4. Eight studies were judged as medium risk of bias, while 61 articles had a lower risk of bias and were assessed as high-quality study.

Risk Factors for GDM

Maternal Age

Data on maternal age (as a continuous variable) were provided by eight cohort studies[22,26–32] and seven case–control studies[33–39] with sample sizes ranging from 1136 to 12,870. In adjusted analysis, each one-unit increase in maternal age was associated with a slight increase in the odds of developing GDM (OR = 1.12,95% CI: 1.09–1.15, Supplementary Figure S1).

Twenty-two studies[22,28,31,40–58] reported the risk of GDM stratified by maternal age into specific age groups. The most commonly used strata were <25 years, 25–29 years, 30–34 years, 35–39 years, and ≥40 years, although some studies grouped ages more broadly, such as <35 years and ≥35 years, depending on their research objectives. The pooled estimate of GDM risk for mothers aged ≥35 years showed significantly increased odds for GDM in unadjusted analyses (OR = 2.30; 95% CI

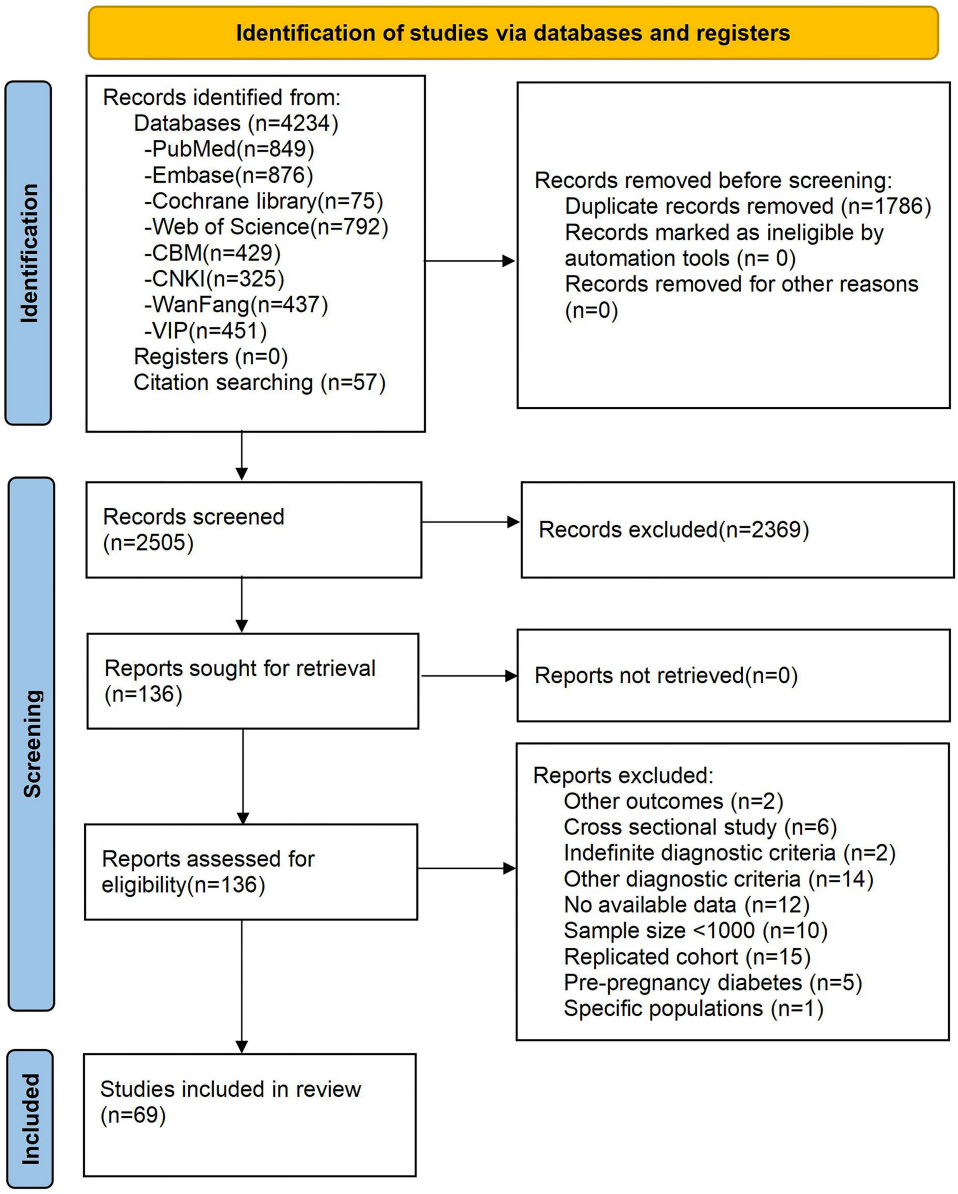

Figure 1 PRISMA flow diagram of study selection.
Notes: PRISMA figure adapted from Liberati A, Altman D, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Journal of clinical epidemiology. 2009;62(10). Creative Commons.[25]

2.12–2.49, Figure 2) compared to mothers aged <35 years (reference group). The overall adjusted effects of maternal age categories on the risk of GDM are summarized in Table 1. Inspection of the forest plot for other maternal age groups suggested a consistent trend of increasing GDM risk with advancing maternal age (Supplementary Figure S2).

Ethnicity

Only three studies including 880 non-Han ethnic and 23064 han ethnicity women provided data on ethnicity.[22,42,59] There were no significant differences in risk of developing GDM between non-Han ethnic and Han nationality (OR = 0.78 95% CI: 0.59–1.03, Figure 3) in unadjusted analyses.

Education Level

Fourteen studies reported on education background and GDM.[22,26,41,43,46,49,50,53,54,60–64] Sample sizes ranged from 1360 to 114986. The pooled estimate of developing GDM had no statistical significance in women with high school or lower

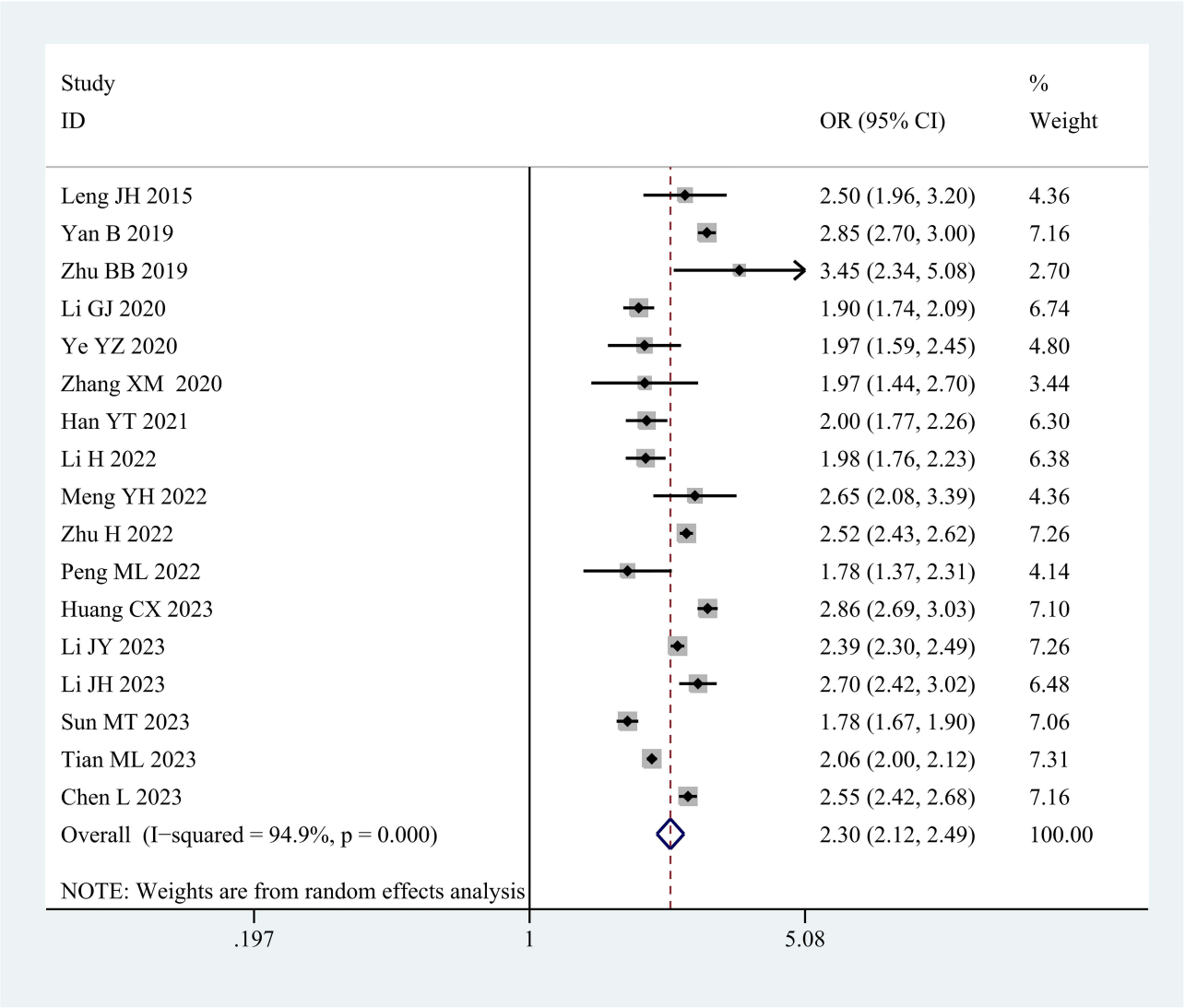

Figure 2 Forest plot of unadjusted association between maternal age≥35 years versus <35 years and gestational diabetes mellitus.

educational attainment when women with college or higher educational attainment as reference groups (OR = 1.09, 95% CI: 0.94–1.26, Figure 4) in unadjusted analyses.

Pre-Pregnancy BMI

Seven cohort studies[22,27–30,32,61] and six case–control studies[33,37–39,42,65] with continuous pre-pregnancy BMI (kg/m^2) were included in the meta-analyses. For every unit increase in BMI, there was a significant increase in odds for GDM in adjusted analysis (OR = 1.24, 95% CI: 1.17–1.32, Figure 5).

Three classification criteria were used to divide pre-pregnancy BMI into four groups: underweight, normal weight, overweight and obese populations in the included articles. Eight studies[28,41,43,48,54,66–68] reported BMI category according to the World Health Organization (WHO) cut-points (underweight: <18.5; normal weight: 18.5–24.9; overweight: 25.0–29.9; obese: ≥30.0). Twenty-four studies[22,26,29–31,40,44–46,51,53,61,63–65,69–77] defined BMI based on Chinese adult BMI classification criteria (underweight: <18.5; normalweight: 18.5–23.9; overweight: 24.0–27.9; obese: ≥28.0). One study[78] adopted definition from WHO BMI classification criteria for Asians (underweight: <18.5; normal weight: 18.5–22.9; overweight: 23.0–24.9; obese: ≥25.0). The pooled effect of GDM in the underweight, overweight, and obese pregnant women was 0.61, 1.94, and 2.99 in unadjusted analysis and 0.65, 1.78, and 2.52 after adjusting for confounders compared with women with normal weight (Table 2).

https://doi.org/10.2147/DMSO.S502043

Table 1 The Adjusted Effect of Maternal Age Categories on the Risk of GDM

Maternal Age Group	Reference Group	Studies(n)	OR (95%)	I^2 (%)	P for Heterogeneity
25–29 years	<25 years	4	1.70(1.36–2.13)	77.8	0.004
30–34 years	<25 years	7	1.58(1.42–1.74)	69.6	0.003
≥35 years	<25 years	5	2.48(2.23–2.77)	47.8	0.105
35–39 years	<25 years	2	1.85(1.62–2.12)	88.8	0.003
30–34 years	<30 years	4	2.81(2.20–3.59)	80.2	0.002
35–39 years	<30 years	2	4.59(3.39–6.21)	81.5	0.02
≥40 years	<30 years	2	6.73(5.87–7.72)	0.5	0.316
≥35 years	<30 years	2	6.32(3.98–10.04)	0.00	0.822
≥35 years	<35 years	4	1.96(1.74–2.21)	81.9	<0.001
35–39 years	<35 years	2	1.59(1.13–2.23)	89.1	0.002
≥40 years	<35 years	2	2.09(1.72–2.53)	56.9	0.128

Forest plot of association between pre-pregnancy underweight, overweight and obese and GDM stratified by classification criteria could be seen in Supplemental Figures S3-S5.

Family History of Diabetes

Twenty-two studies reported data on the family history of diabetes[22,26–33,35,37,41,42,45,46,49,53,59,63,64,67,79] and demonstrated 1.85-fold increased odds for GDM in adjusted analyses (OR = 1.85, 95% CI: 1.58–2.17, Figure 6).

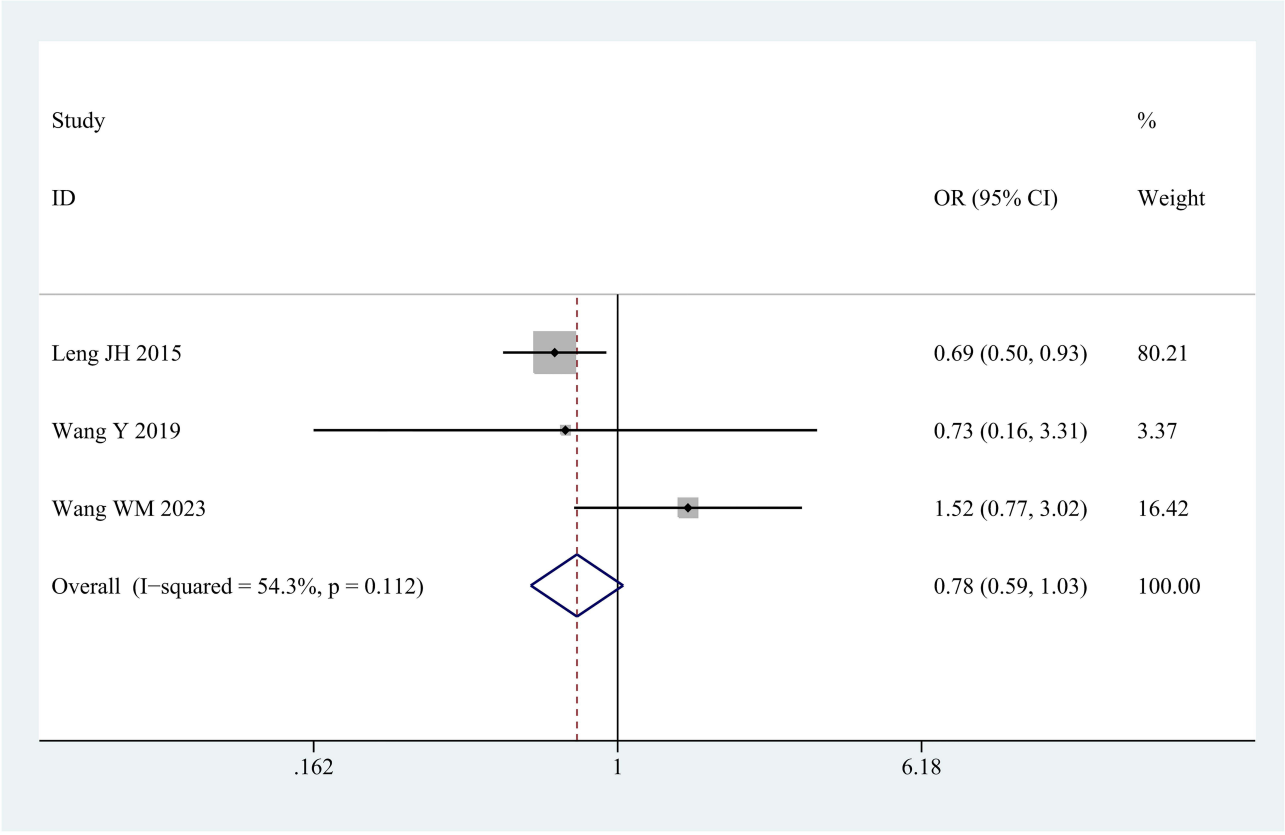

Figure 3 Forest plot of unadjusted association between other ethnic versus Han ethnicity and gestational diabetes mellitus.

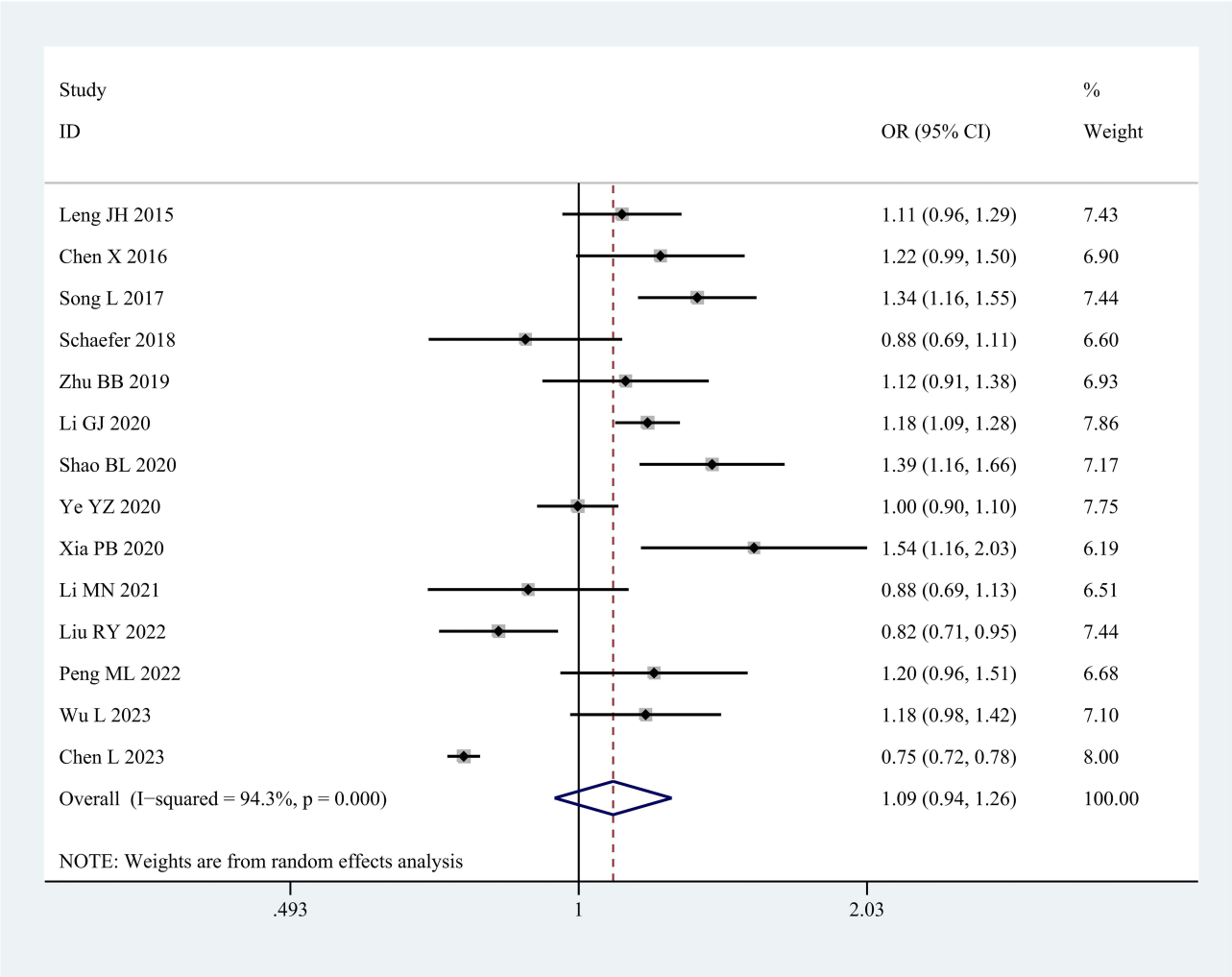

Figure 4 Forest plot of unadjusted association between education level and gestational diabetes mellitus.

History of GDM

The relationship between the history of GDM and GDM was studied in eleven papers.[26,30,31,37,41–43,49,63,64,79] The overall estimate of being diagnosed with the GDM was estimated at 4.09(95% CI 2.13–7.82, Figure 7) in adjusted analysis.

Gravidity

Seven papers reported an association between gravidity and GDM.[32,36,49,65,79–81] Compared with the reference group (gravidity = 1), gravidity ≥2 was associated with a higher risk of GDM in adjusted analysis (OR = 1.06, 95% CI: 0.89–1.27, Supplemental Figure S6), but was not statistically significant.

Parity

Additionally, twenty-four studies evaluated the relation between parity and GDM.[22,29,32,35–37,40,42–44,46,48–50,52,53,59–62,64,65,73,79] The pooled results showed that parity ≥1 was associated with lower risk of GDM in adjusted studies (OR 0.88,95% CI: 0.82–0.94, Supplemental Figure S7).

History of Abortion

The pooled OR based on result from three articles[50,82,83] addressed that there was high risk of GDM in women with history of abortion (OR1.34, 95% CI: 1.31–1.37, Supplemental Figure S8) by using crude OR.

https://doi.org/10.2147/DMSO.S502043

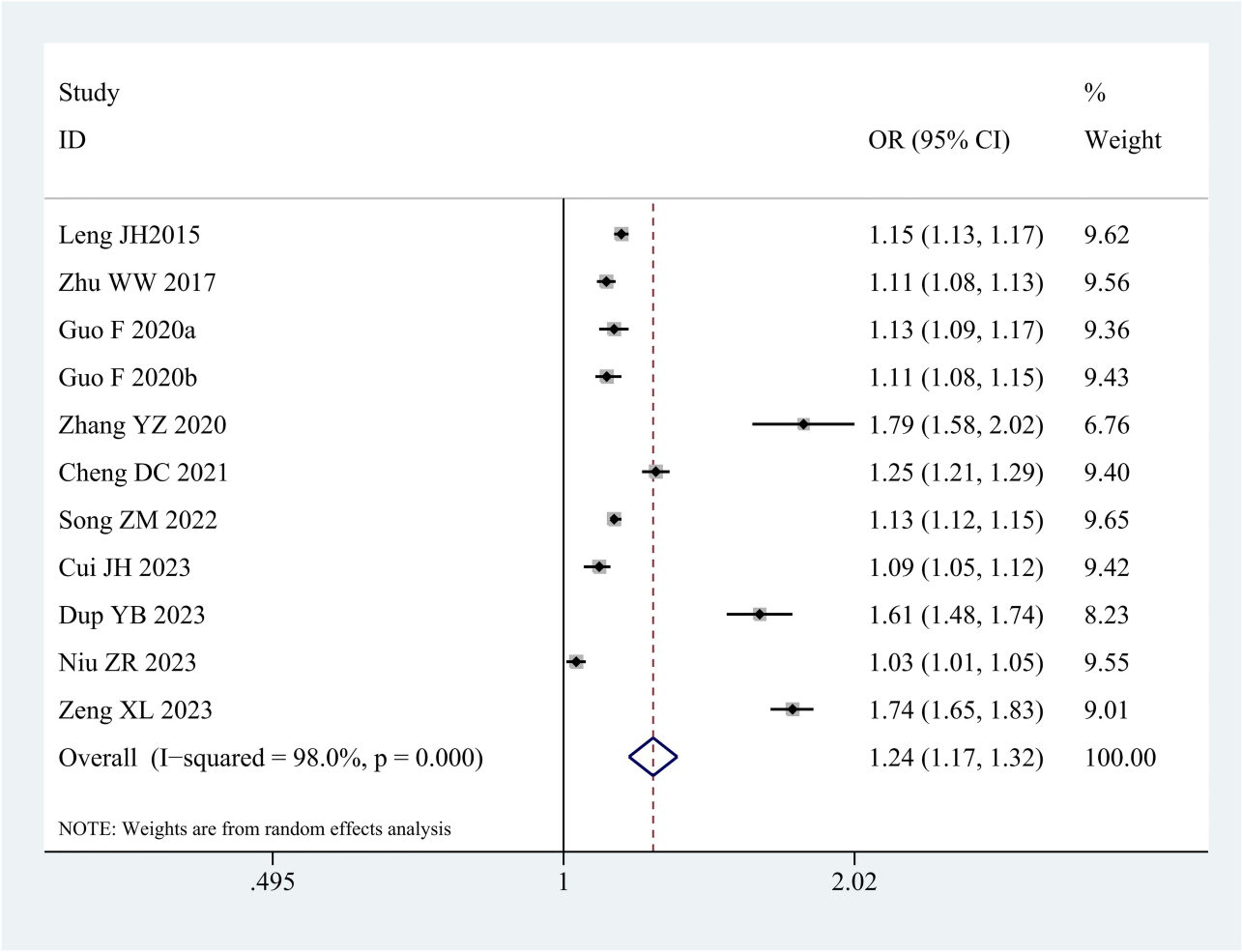

Figure 5 Forest plot of adjusted association between pre-pregnancy body mass index (as a continuous variable) and gestational diabetes mellitus.

Use of ART

Night papers provided data about ART.[31,37,39,42,43,73,84–86] Compared with spontaneous conception, using ART were related to higher GDM risk in adjusted analyses (OR 1.54, 95% CI: 0.95–2.51, Supplemental Figure S9), but there were no significant differences.

FPG in Early Pregnancy

Seven studies measured FPG in early pregnancy.[26,29,31,32,35,37,40] For every unit increase in FPG, there was an increase in odds for GDM (adjusted OR = 2.54, 95% CI: 2.13–3.01, Figure 8).

Hb Levels in Early Pregnancy

Seven studies were used in the meta-analysis[62,87–92] demonstrating an association between Hb in early pregnancy and GDM in adjusted analysis (OR = 1.47, 95% CI: 1.14–1.89, Figure 9).

Table 2 The Overall Effect of Pre-Pregnancy BMI Categories on the Risk of GDM

BMI Categories	Crude OR				Adjusted OR			
	Studies(n)	OR (95% CI)	I^2 (%)	p-value	Studies(n)	OR (95% CI)	I^2 (%)	p-value
Underweight	21	0.61(0.56–0.67)	78.1	<0.001	17	0.65(0.63–0.68)	8.3	0.357
Overweight	26	1.94(1.83–2.07)	74.6	<0.001	19	1.78(1.64–1.92)	73.4	<0.001
Obese	23	2.99(2.58–3.46)	84.1	<0.001	16	2.52(2.06–3.08)	76.9	<0.001

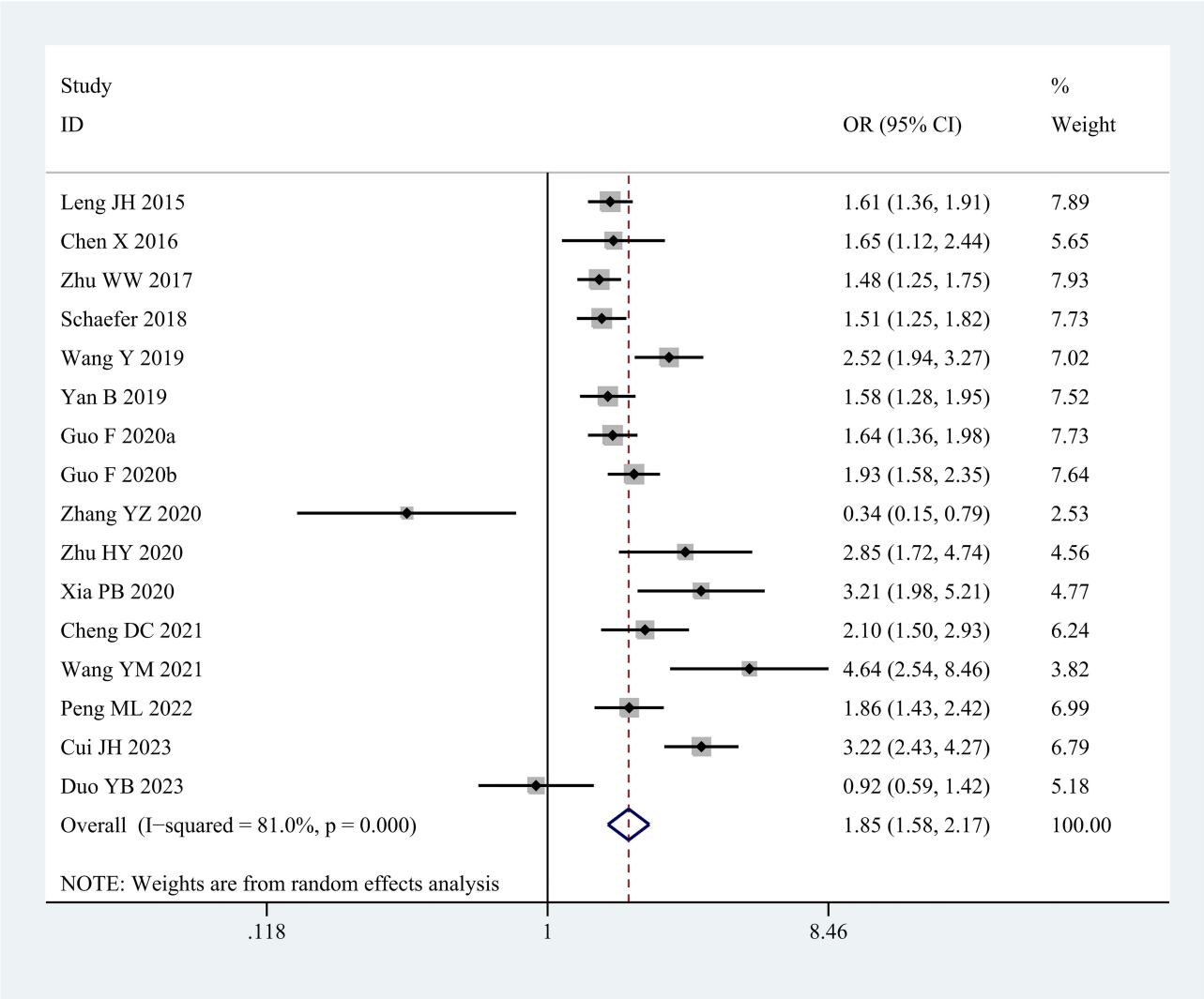

Figure 6 Forest plot of adjusted association between family history of diabetes and gestational diabetes mellitus.

TG Levels in Early Pregnancy

Four studies examined fasting TG in early pregnancy.[34,37,38,93] Increasing TG was associated with (OR = 1.69, 95% CI: 1.31–2.16, Figure 10) increased likelihood for GDM in adjusted analyses.

Subgroup and Sensitivity Analyses

Study design and BMI classification standard were not related to heterogeneity between studies. There were insufficient number of studies to perform subgroup analyses according to region. Sensitivity analyses were performed on adjusted analyses (Supplementary Item 1). Most pooled estimates were not significantly different when a study was omitted, suggesting that no one study had a large effect on the pooled estimate. Supplementary file showed the funnel plots of the included studies for GDM (≥10 studies).

Discussion

In this systematic review and meta-analysis, we identified several main risk factors for GDM among women in mainland China. Our findings highlighted that older maternal age, pre-pregnancy overweight or obesity, family history of diabetes, previous history of GDM, and elevated levels of FPG, Hb, and serum TG in early pregnancy were strongly associated with an increased risk of developing GDM. These associations remained robust in adjusted analyses.

https://doi.org/10.2147/DMSO.S502043

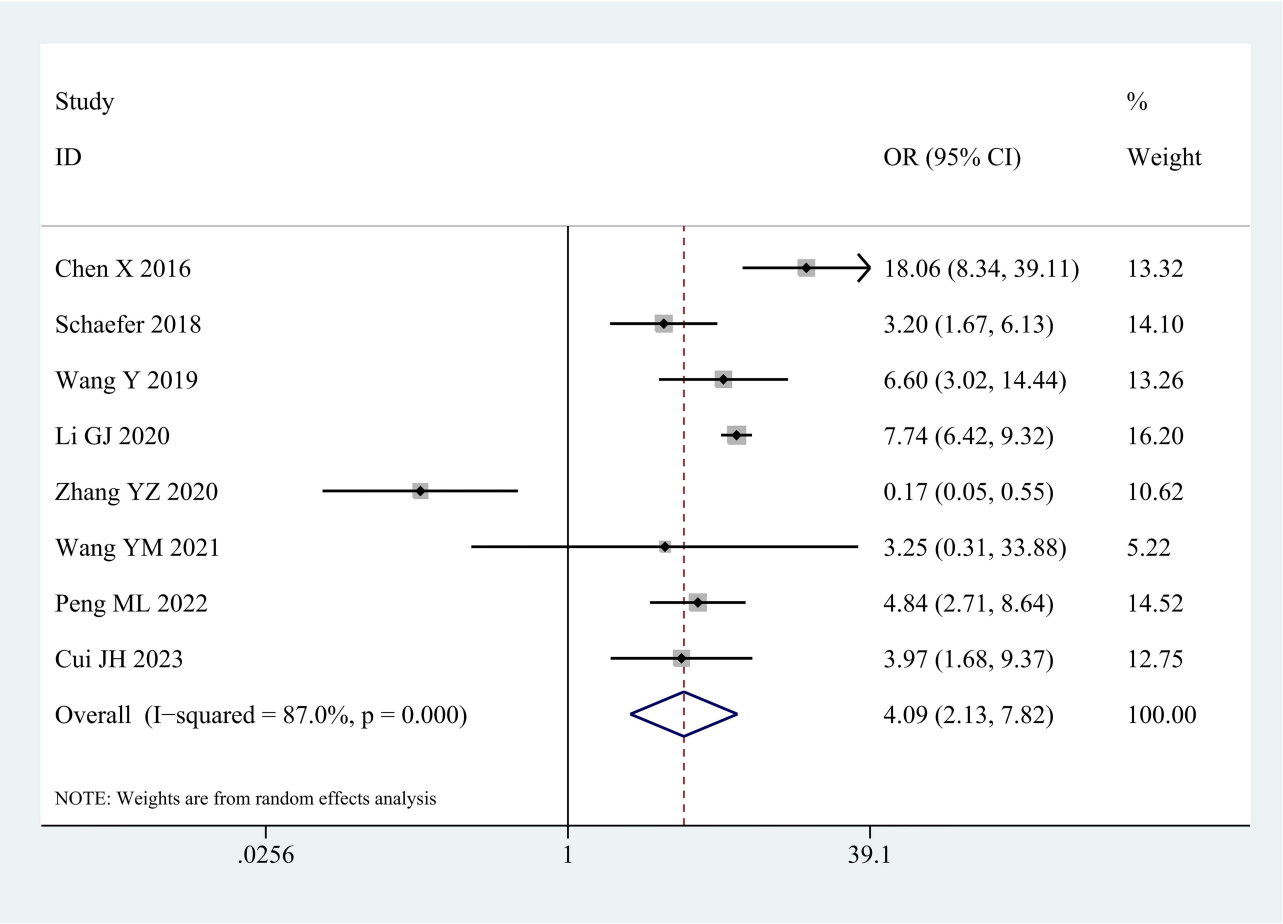

Figure 7 Forest plot of adjusted association between history of gestational diabetes mellitus (GDM) and GDM.

The present review first focused on populations from mainland China in evaluating multiple risk factors for GDM according to IADPSG criteria. A systematic review published in 2019 summarized the prevalence of GDM in mainland China but did not provide pooled estimates of risk factors related to GDM.[18] Another review focusing on Asian populations included a small subset of Chinese participants. However, the primary emphasis was on the broader Asian population,[94] which may not accurately reflect the unique risk profiles of women in mainland China.

Our findings are consistent with previous studies that advanced maternal age was a strong risk factor for GDM, and maternal age greater than 35 years was more prone to GDM.[95–97] However, other studies differed with this cutoff value of maternal age, women over 25 were identified as having a higher risk of GDM,[98] which was consistent with findings among Asian populations.[94] Conversely, reviews conducted in Europe and Middle East and North Africa typically indicated that the risk increased significantly for women over 30 years.[99,100] In mainland China, the shifting population policies (China's family planning) and the trend towards later marriage and childbirth are likely contributing factors to the observed age-related risk.

Similar to previous research, our study confirmed that pre-pregnancy overweight and obesity were independent risk factors for GDM.[96,100–104] In our analysis, we conducted subgroup analyses based on different BMI classification standards, and the results remained consistent, reinforcing the robustness of our findings. A higher BMI has been universally recognized as a risk factor, but the degree of risk associated with overweight and obesity could differ due to variations in genetic, lifestyle, and environmental factors among different populations.

Our unadjusted analyses demonstrated family history of diabetes were related with 2.13-fold increased odds for GDM, and even after adjusting for potential confounders, the odds remained significantly elevated at 1.85-fold.

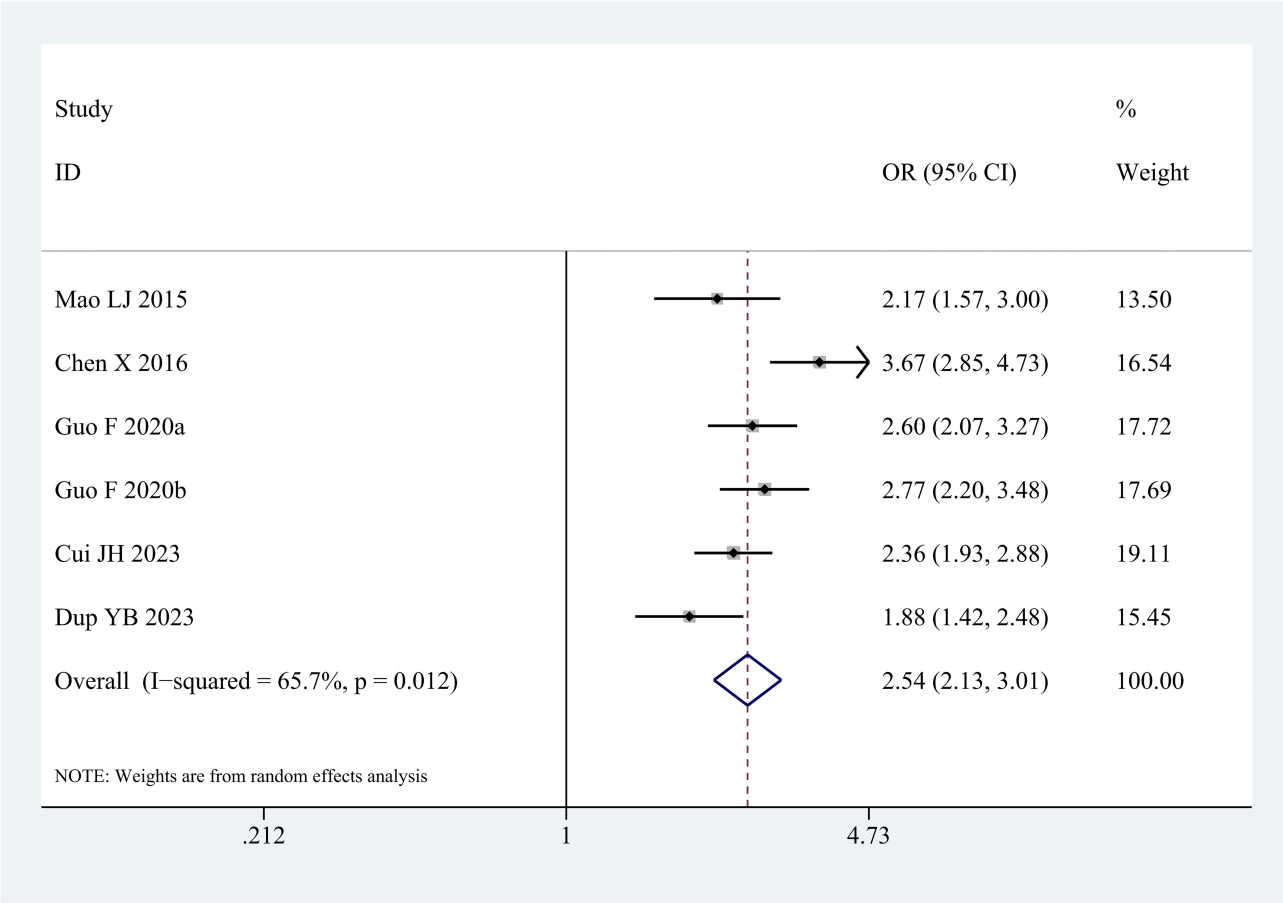

Figure 8 Forest plot of adjusted association between fasting plasma glucose and gestational diabetes mellitus.

A systematic review and meta-analysis suggested that women with family history of diabetes was estimated at 3.46-fold greater than those without.[105] Another study showed that the pooled odds of GDM was 2.326.[98]

Our study found that a history of GDM was a significant risk factor for the recurrence of GDM in subsequent pregnancies. Specifically, the overall OR of being diagnosed with GDM in women with history of GDM was 4.09 when adjusted for potential confounders. This finding aligned with numerous systematic reviews that had consistently identified a previous history of GDM as a prominent risk factor for GDM. A comprehensive review incorporating studies from various countries estimated the OR for history of GDM at 21.137, indicating a substantially higher risk of recurrence compared to women without a history of GDM. In the context of Asian populations, a meta-analysis demonstrated that the history of previous GDM was estimated with an OR of 8.42. Similarly, in sub-Saharan Africa, pooled analyses identified a history of GDM as one of the most important risk factors, with an RR of 5.9. In Ethiopia, the association was particularly strong, with women having a previous history of GDM showing an OR of 8.66. However, these studies did not provide information on whether the analyses were adjusted for confounding variables. The lower adjusted OR in our study compared to these studies might be due to adjustment of a wide range of confounding factors in primary studies.

Elevated FPG and serum TG levels in early pregnancy as predictors of GDM risk were supported by one review,[102] similar to our results. Also, we observed that elevated hemoglobin levels increased the risk of GDM, this finding aligned with the results of two systematic reviews that similarly identified elevated Hb levels as a significant risk factor for GDM.[106,107]

Interestingly, while gravidity ≥2 and conception via ART were associated with an increased incidence of GDM in univariable analysis, these associations were not significant after adjusting for potential confounders. Two other studies

https://doi.org/10.2147/DMSO.S502043

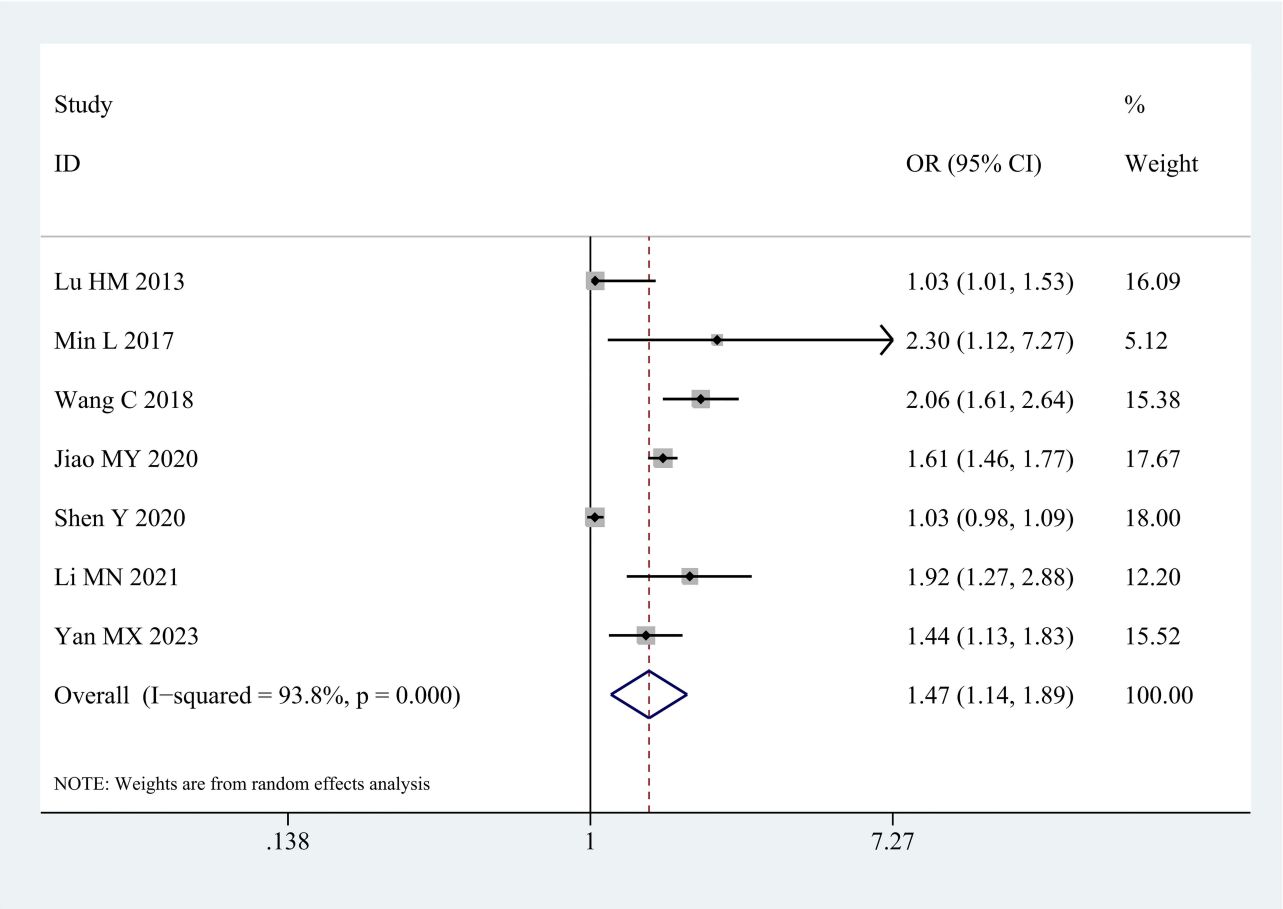

Figure 9 Forest plot of adjusted association between hemoglobin and gestational diabetes mellitus.

demonstrated that primigravida was associated with a lower risk of developing GDM.[94,98] It was reported that ART singleton pregnancies were associated with a higher risk of GDM compared with those of spontaneous conception by using crude OR.[108] The role of confounding factors could not be eliminated in these studies. This suggested that the observed associations in univariable analyses might be confounded by other factors.

Additionally, we observed that women with parity ≥1 had a higher likelihood of developing GDM based on crude odds ratios but appeared to reduce the risk of GDM after adjusting for confounders. This paradoxical finding might reflect the influence of parity-related physiological changes that are not fully accounted for by the confounders included in primary studies.

By summarizing unadjusted results, women with history of abortion were at higher risk of developing GDM, which was consistent with one study.[94] But it also was reported that history of abortion was not related to GDM.[98] Thus, the results about the relationship between the history of abortion and GDM were inconsistent. In this review, there was no significant difference in GDM between non-Han and Han ethnic groups. The small sample sizes in minority groups in our study might have limited the statistical power to detect any significant differences. Similarly, our analysis showed women with higher education (college or higher) did not have a different risk compared to those with lower education (high school or lower), these findings were different from some existing research. Those studies conducted in western countries had shown that low-educated women had an increased risk of GDM.[109,110]

One of the primary strengths of this study was its exclusive focus on populations from mainland China, providing a region-specific analysis of GDM risk factors. The inclusion of multiple risk factors and their assessment in both univariable and multivariable analyses provide a nuanced understanding of the independent and combined effects of these factors on GDM risk. However, several limitations should be noted. First, the possibility of residual confounding

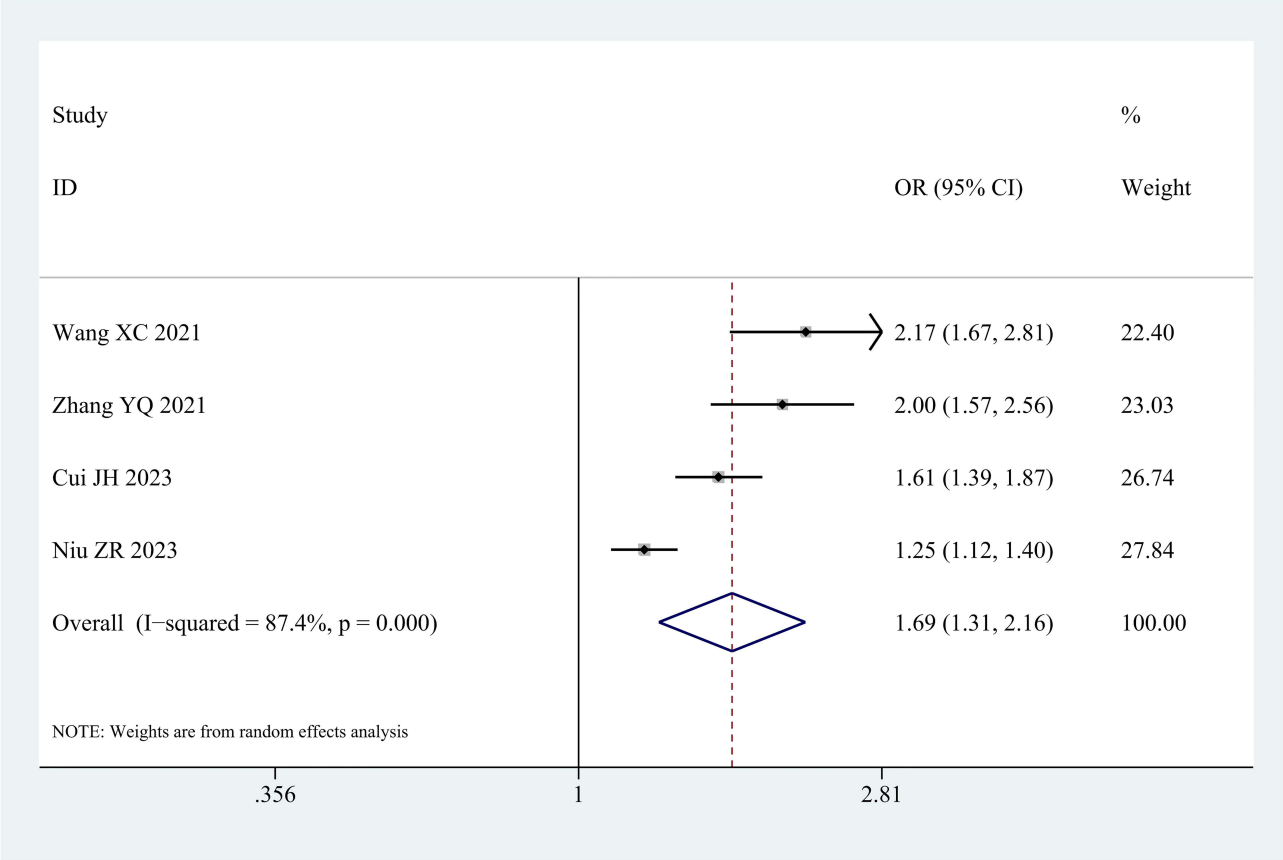

Figure 10 Forest plot of adjusted association between serum triglycerides and gestational diabetes mellitus.

cannot be entirely excluded. Additionally, while our focus on mainland China enhances the specificity of our results, it may limit the generalizability of these findings to other populations with different genetic, environmental, and lifestyle factors. Furthermore, as all data included in this meta-analysis were derived from published studies conducted in mainland China, comparisons with other countries or regions could not be made, which limits the ability to explore potential population-specific differences. Another important limitation is that our analysis primarily focused on the known maternal characteristics such as age, BMI and family history of diabetes. However, GDM risk was influenced by a multitude of factors, including lifestyle, diet, and physical activity, which were not comprehensively assessed in our review.

Conclusion

Overall, this meta-analysis identified key risk factors for GDM in mainland China, including advanced maternal age, pre-pregnancy obesity, family history of diabetes, and elevated early pregnancy biomarkers. The adjusted results were derived from multivariate regression models in the included studies, which accounted for confounders like age and BMI. However, variations in adjustment strategies across studies remain a limitation. Our findings emphasize the need for standardized methods and targeted interventions to reduce GDM risks in this population.

Data Sharing Statement

The data used and analyzed during the current study are available from the corresponding author upon reasonable request.

https://doi.org/10.2147/DMSO.S502043

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.

Funding

The study was supported by the Scientific Research Fund Project of the Department of Education of Yunnan Province, China (2024J0834,2022J0684).

Disclosure

No potential conflict of interest was reported by the authors.

References

1. ElSayed NA, Aleppo G, Aroda VR, et al. 2. classification and diagnosis of diabetes: standards of care in diabetes-2023. *Diabet Care*. 2023;46 (Suppl 1):S19–s40. doi:10.2337/dc23-S002
2. Magliano DJ, Boyko EJ. committee IDFDAtes. IDF diabetes atlas. In: *Idf Diabetes Atlas*. Brussels: International Diabetes Federation © International Diabetes Federation; 2021.
3. Group HSCR, Metzger BE, Lowe LP, et al. Hyperglycemia and adverse pregnancy outcomes. *New Engl J Med*. 2008;358(19):1991–2002.
4. 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/dc10-0719
5. Kim MH, Kwak SH, Kim SH, et al. Pregnancy outcomes of women additionally diagnosed as gestational diabetes by the international association of the diabetes and pregnancy study groups criteria. *Diabet Metabol J*. 2019;43(6):766–775. doi:10.4093/dmj.2018.0192
6. Liu B, Cai J, Xu Y, et al. early diagnosed gestational diabetes mellitus is associated with adverse pregnancy outcomes: a prospective cohort study. *J Clin Endocrinol Metab*. 2020;105(12):e4264–e4274. doi:10.1210/clinem/dgaa633
7. Mistry SK, Das Gupta R, Alam S, Kaur K, Shamim AA, Puthussery S. Gestational diabetes mellitus (GDM) and adverse pregnancy outcome in South Asia: a systematic review. *Endocrinol Diabetes Metabol*. 2021;4(4):e00285. doi:10.1002/edm2.285
8. 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
9. Song C, Li J, Leng J, Ma RC, Yang X. Lifestyle intervention can reduce the risk of gestational diabetes: a meta-analysis of randomized controlled trials. *Obesity Rev*. 2016;17(10):960–969. doi:10.1111/obr.12442
10. Kramer CK, Campbell S, Retnakaran R. Gestational diabetes and the risk of cardiovascular disease in women: a systematic review and meta-analysis. *Diabetologia*. 2019;62(6):905–914. doi:10.1007/s00125-019-4840-2
11. Mantzorou M, Papandreou D, Pavlidou E, et al. Maternal gestational diabetes is associated with high risk of childhood overweight and obesity: a cross-sectional study in pre-school children aged 2-5 years. *Medicina*. 2023;59(3):455. doi:10.3390/medicina59030455
12. Lowe WL Jr, Lowe LP, Kuang A, et al. Maternal glucose levels during pregnancy and childhood adiposity in the hyperglycemia and adverse pregnancy outcome follow-up study. *Diabetologia*. 2019;62(4):598–610. doi:10.1007/s00125-018-4809-6
13. Lowe WL Jr, Scholtens DM, Kuang A, et al. Hyperglycemia and Adverse Pregnancy Outcome Follow-up Study (HAPO FUS. *Mat Gest Diabet Mellitus Childhood Glucose Metabol Diabet Care*. 2019;42(3):372–380.
14. Tam WH, Ma RCW, Ozaki R, et al. In utero exposure to maternal hyperglycemia increases childhood cardiometabolic risk in offspring. *Diabetes Care*. 2017;40(5):679–686. doi:10.2337/dc16-2397
15. Bgeginski R, Ribeiro PAB, Mottola MF, Ramos JGL. Effects of weekly supervised exercise or physical activity counseling on fasting blood glucose in women diagnosed with gestational diabetes mellitus: a systematic review and meta-analysis of randomized trials. *J diabet*. 2017;9 (11):1023–1032. doi:10.1111/1753-0407.12519
16. Feng XL, Guo S, Hipgrave D, et al. China's facility-based birth strategy and neonatal mortality: a population-based epidemiological study. *Lancet*. 2011;378(9801):1493–1500. doi:10.1016/S0140-6736(11)61096-9
17. Li XF, Fortney JA, Kotelchuck M, Glover LH. The postpartum period: the key to maternal mortality. *Int J Obstetrics Gynaecology*. 1996;54 (1):1–10. doi:10.1016/0020-7292(96)02667-7
18. Gao CH, Sun X, Lu L, Liu FW, Yuan J. Prevalence of gestational diabetes mellitus in mainland China: a systematic review and meta-analysis. *J Diabetes Invest*. 2019;10(1):154–162. doi:10.1111/jdi.12854
19. 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. *Diabetes Res Clin Pract*. 2022;183:109050. doi:10.1016/j.diabres.2021.109050
20. Zhu Y, Zhang C. Prevalence of gestational diabetes and risk of progression to type 2 diabetes: a global perspective. *Curr Diab Rep*. 2016;16 (1):7. doi:10.1007/s11892-015-0699-x
21. Zhang F, Dong L, Zhang CP, et al. Increasing prevalence of gestational diabetes mellitus in Chinese women from 1999 to 2008. *Diabetic Med*. 2011;28(6):652–657. doi:10.1111/j.1464-5491.2010.03205.x
22. Leng J, Shao P, Zhang C, et al. Prevalence of gestational diabetes mellitus and its risk factors in Chinese pregnant women: a prospective population-based study in Tianjin, China. *PLoS One*. 2015;10(3):e0121029. doi:10.1371/journal.pone.0121029

23. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.
24. Wells GA, Wells G, Shea B, et al. The Newcastle-Ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2014.
25. Liberati A, Altman DG and Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;339(jul21 1). doi:10.1136/bmj.b2700), b2700–b2700.
26. Chen X. *The Risk Factors And Risk Assessment Model Of Gestational Diabetes Mellitus* [Master]. Soochow University; 2016.
27. Zhu WW, Yang HX, Wang C, Su RN, Feng H, Kapur A. High prevalence of gestational diabetes mellitus in Beijing: effect of maternal birth weight and other risk factors. *Chinese Med J*. 2017;130(9):1019–1025. doi:10.4103/0366-6999.204930
28. Yan B, Yu YX, Lin MZ, et al. High, but stable, trend in the prevalence of gestational diabetes mellitus: a population-based study in Xiamen, China. *J Diabetes Invest*. 2019;10(5):1358–1364. doi:10.1111/jdi.13039
29. Guo F, Yang S, Zhang Y, Yang X, Zhang C, Fan JX. Nomogram for prediction of gestational diabetes mellitus in urban, Chinese, pregnant women. *BMC Preg Childb*. 2020;20(1):43. doi:10.1186/s12884-019-2703-y
30. Zhang YZ, Zhou L, Tian LB, et al. A mid-pregnancy risk prediction model for gestational diabetes mellitus based on the maternal status in combination with ultrasound and serological findings. *Exp Ther Med*. 2020;20(1):293–300. doi:10.3892/etm.2020.8690
31. Wang YM, Ge ZJ, Chen L, et al. Risk prediction model of gestational diabetes mellitus in a Chinese population based on a risk scoring system. *Diabetes Therapy*. 2021;12(6):1721–1734. doi:10.1007/s13300-021-01066-2
32. Duo YB, Song SN, Qiao XL, et al. A simplified screening model to predict the risk of gestational diabetes mellitus in pregnant Chinese women. *Diabetes Therapy*. 2023;14(12):2143–2157. doi:10.1007/s13300-023-01480-8
33. Cheng DC, Li FF, Zhou XX, Xu XM. Opportunities for prevention of gestational diabetes before 24 weeks of gestation. *Diabetes Metab Syndr Obes*. 2021;14:813–819. doi:10.2147/DMSO.S294589
34. Wang XC, Zheng XQ, Yan JY, et al. The clinical values of afamin, triglyceride and plr in predicting risk of gestational diabetes during early pregnancy. *Front Endocrinol*. 2021;12:723650. doi:10.3389/fendo.2021.723650
35. Zhang S, Liu HK, Li N, et al. Relationship between gestational body mass index change and the risk of gestational diabetes mellitus: a community-based retrospective study of 41,845 pregnant women. *BMC Preg Childb*. 2022;22(1):336. doi:10.1186/s12884-022-04672-5
36. Zhu H, Zhao ZJ, Xu J, et al. The prevalence of gestational diabetes mellitus before and after the implementation of the universal two-child policy in China. *Front Endocrinol*. 2022;13:960877. doi:10.3389/fendo.2022.960877
37. Cui JH, Li P, Chen XJ, et al. Study on the relationship and predictive value of first-trimester pregnancy-associated plasma protein-a, maternal factors, and biochemical parameters in gestational diabetes mellitus: a large case-control study in southern China mothers. *Diabetes Metab Syndr Obes*. 2023;16:947–957. doi:10.2147/DMSO.S398530
38. Niu ZR, Bai LW, Lu Q. Establishment of gestational diabetes risk prediction model and clinical verification. *J Endocrinol Invest*. 2023;47(5):1281–1287. doi:10.1007/s40618-023-02249-3
39. Zeng XL, He ZY, Zhou NY, et al. The prevalence and risk factors of gestational diabetes mellitus among 23 869 pregnant women in Chongqing. *Chin J Dis Control Prev*. 2023;27(1):70.
40. Mao LJ, Ge X, Xu YQ, et al. Pregestational body mass index, weight gain during first half of pregnancy and gestational diabetes mellitus: a prospective cohort study. *Chin J Epidemiol*. 2015;36(5):416–420.
41. Schaefer KK, Xiao WQ, Chen QZ, et al. Prediction of gestational diabetes mellitus in the born in Guangzhou cohort study, China. *Int J Obstetrics Gynaecology*. 2018;143(2):164–171. doi:10.1002/ijgo.12627
42. Wang Y, Luo BR. Risk factors analysis of gestational diabetes mellitus based on international association of diabetes pregnancy study groups criteria. *Nan fang yi ke da xue xue bao*. 2019;39(5):572–578. doi:10.12122/j.issn.1673-4254.2019.05.12
43. Li GJ, Wei T, Ni W, et al. Incidence and risk factors of gestational diabetes mellitus: a prospective cohort study in Qingdao, China. *Front Endocrinol*. 2020;11:636. doi:10.3389/fendo.2020.00636
44. Zhang XM, Zhao X, Huo LL, et al. Risk prediction model of gestational diabetes mellitus based on nomogram in a Chinese population cohort study. *Sci Rep*. 2020;10(1):21223. doi:10.1038/s41598-020-78164-x
45. Zhu HY, He D, Liang N, Lai AL, Zeng JB, Yu HL. High serum triglyceride levels in the early first trimester of pregnancy are associated with gestational diabetes mellitus: a prospective cohort study. *J Diabetes Invest*. 2020;11(6):1635–1642. doi:10.1111/jdi.13273
46. Xia PB. *Analysis of Risk Factors and Adverse Pregnancy Outcomes of Gestational Diabetes Mellitus in Obstetric Inpatients of a Top Three Hospital in Nanjing* [Master]. Southeast University; 2020.
47. Li H, Nawsherwan, Fan CF, Mubarik S, Nabi G, Ping YX. The trend in delayed childbearing and its potential consequences on pregnancy outcomes: a single center 9-years retrospective cohort study in Hubei, China. *BMC Preg Childb*. 2022;22(1):514. doi:10.1186/s12884-022-04807-8
48. Meng YH, Qu YM, Zhan YL, et al. The influencing factors and perinatal outcomes of gestational diabetes. *Chin J Dis Control Prev*. 2022;26(9):1011–1016.
49. Peng ML, He C, Peng J, et al. Risk factors of gestational diabetes mellitus. *J Contemp Urol Reprod Oncol*. 2022;14(06):345–349.
50. Chen L, Zhang Y, Sun C, et al. Study of the risk factors for gestational diabetes mellitus and the effect of gestational hyperglycemia on adverse pregnancy outcomes. *Chin J Diabetes Mellitus*. 2023;15(10):933–940.
51. Sun MT, Luo MJ, Wang TT, et al. Effect of the interaction between advanced maternal age and pre-pregnancy BMI on pre-eclampsia and GDM in Central China. *BMJ Open Diabetes Res Care*. 2023;11(2):e003324. doi:10.1136/bmjdrc-2023-003324
52. Han YT, Tong MK, Jin L, Yu JH, Meng WY, Ren AG. Maternal age at pregnancy and risk for gestational diabetes mellitus among Chinese women with singleton pregnancies. *Int Diabetes Dev Ctries*. 2021;41(1):114–120. doi:10.1007/s13410-020-00859-8
53. Zhu BB, Liang CM, Xia X, et al. Iron-related factors in early pregnancy and subsequent risk of gestational diabetes mellitus: the Ma'anshan Birth Cohort (MABC) study. *Biol Trace Elem Res*. 2019;191(1):45–53. doi:10.1007/s12011-018-1595-4
54. Ye YZ, Xiong Y, Zhou QJ, Wu JN, Li XT, Xiao XR. Comparison of machine learning methods and conventional logistic regressions for predicting gestational diabetes using routine clinical data: a retrospective cohort study. *J Diabetes Res*. 2020;2020:4168340. doi:10.1155/2020/4168340

55. Huang C, Jiang Q, Su W, et al. Age-specific effects on adverse pregnancy outcomes vary by maternal characteristics: a population-based retrospective study in Xiamen, China. *BMC Public Health*. 2023;23(1):326. doi:10.1186/s12889-023-15235-4
56. Tian ML, Ma GJ, Du LY, et al. the Effect of 2016 Chinese second-child policy and different maternal age on pregnancy outcomes in Hebei Province, China. *BMC Preg Childb*. 2023;23(1):267. doi:10.1186/s12884-023-05552-2
57. Li J, Yan J, Jiang W. The role of maternal age on adverse pregnancy outcomes among primiparous women with singleton birth: a retrospective cohort study in urban areas of China. *J Matern Fetal Neonatal Med*. 2023;36(2):2250894. doi:10.1080/14767058.2023.2250894
58. Li J, Li Y, Duan Y, Xiao X, Luo J, Luo M. Dose-response associations of maternal age with pregnancy complications and multimorbidity among nulliparas and multiparas: a multicentric retrospective cohort study in southern China. *J Glob Health*. 2023;13:04117. doi:10.7189/jogh.13.04117
59. Wang WM, Li N, Wang XY, et al. Remnant cholesterol is associated with gestational diabetes mellitus: a cohort study. *J Clin Endocrinol Metab*. 2023;108(11):2924–2930. doi:10.1210/clinem/dgad262
60. Song L, Shen L, Li H, et al. Socio-economic status and risk of gestational diabetes mellitus among Chinese women. *Diabetic Med*. 2017;34(10):1421–1427. doi:10.1111/dme.13415
61. Shao BL, Mo MJ, Xin X, et al. The interaction between prepregnancy BMI and gestational vitamin D deficiency on the risk of gestational diabetes mellitus subtypes with elevated fasting blood glucose. *Clin Nutr*. 2020;39(7):2265–2273. doi:10.1016/j.clnu.2019.10.015
62. Li MN, Hu M, Yue ZJ, Zhang YD, Yang HL. The interactive effects of non-alcoholic fatty liver disease and hemoglobin concentration in the first trimester on the development of gestational diabetes mellitus. *PLoS One*. 2021;16(9):e0257391. doi:10.1371/journal.pone.0257391
63. Liu RY, Zhan YL, Liu X, et al. Stacking ensemble method for gestational diabetes mellitus prediction in Chinese pregnant women: a prospective cohort study. *J Healthc Eng*. 2022;2022:8948082. doi:10.1155/2022/8948082
64. Wu L, Ouyang J, Lai Y, et al. Combined healthy lifestyle in early pregnancy and risk of gestational diabetes mellitus: a prospective cohort study. *BJOG*. 2023;130(13):1611–1619. doi:10.1111/1471-0528.17548
65. Song ZM, Cheng Y, Li TT, Fan YF, Zhang QY, Cheng HD. Prediction of gestational diabetes mellitus by different obesity indices. *BMC Preg Childb*. 2022;22(1):8. doi:10.1186/s12884-022-04615-0
66. Li CM, Liu YJ, Zhang WY. Joint and independent associations of gestational weight gain and pre-pregnancy body mass index with outcomes of pregnancy in Chinese women: a retrospective cohort study. *PLoS One*. 2015;10(8):e0136850. doi:10.1371/journal.pone.0136850
67. Liu L, Hong ZX, Zhang LH. Associations of prepregnancy body mass index and gestational weight gain with pregnancy outcomes in nulliparous women delivering single live babies. *Sci Rep*. 2015;5:9.
68. Li JH, Yang L, Chen Q, Liu J, He Y. The prospective cohort study on the impact of pre-pregnancy body mass index and gestational weight gain on pregnancy complications and outcomes. *Chin J Obstet Gynecol*. 2019;54(3):184–188.
69. Xing MM, Wei G, Wang ZL, Ren LZ. Effect of pre-pregnancy body mass index and gestational weight gain on perinatal outcomes. *Chin J Child Health Care*. 2020;28(4):389–394.
70. Feng N, Huang XK. Effect of pre-pregnancy body mass index and gestational weight gain on perinatal outcomes. *Int J Clin Exp Med*. 2021;14(8):2180–2188.
71. Xie DH, Yang WZ, Wang AH, et al. Effects of pre-pregnancy body mass index on pregnancy and perinatal outcomes in women based on a retrospective cohort. *Sci Rep*. 2021;11(1):19863. doi:10.1038/s41598-021-98892-y
72. Zhang J, An WS, Lin L. The association of prepregnancy body mass index with pregnancy outcomes in Chinese women. *J Diabetes Res*. 2022;2022:1–7. doi:10.1155/2022/8946971
73. Gao Z, Yang XH. Influence of pre-pregnancy body mass index and gestational weight gain of pregnant women on their gestational diabetes mellitus and their interaction. *Chin J Fam Plann*. 2022;30(03):567–572.
74. Gu CM, Wu WX, Lai KF, et al. Maternal pre-pregnancy BMI, MTHFR polymorphisms, and the risk of adverse pregnancy outcomes in pregnant women from South China: a retrospective cohort study. *BMC Preg Childb*. 2023;23(1):295. doi:10.1186/s12884-023-05605-6
75. Wei Y, Guo Q, Sun W, Yang H. Characteristics of oral glucose tolerance test in 9803 pregnant women of different pre-pregnancy body mass index and its relationship with the incidence of gestational diabetes mellitus. *Zhonghua fu Chan ke za zhi*. 2015;50(11):830–833.
76. Wei YM, Yang HX, Zhu WW, et al. Risk of adverse pregnancy outcomes stratified for pre-pregnancy body mass index. *J Matern Fetal Neonatal Med*. 2016;29(13):2205–2209. doi:10.3109/14767058.2015.1081167
77. Zhao RF, Zhou L, Zhang WY. Identifying appropriate pre-pregnancy body mass index classification to improve pregnancy outcomes in women of childbearing age in Beijing, China: a retrospective cohort study. *Asia Pac J Clin Nut*. 2019;28(3):567–576. doi:10.6133/apjcn.201909_28(3).0016
78. Chen Y, Wan K, Gong YH, et al. Assessing the relationship between pregravid body mass index and risk of adverse maternal pregnancy and neonatal outcomes: prospective data in Southwest China. *Sci Rep*. 2021;11(1):7591. doi:10.1038/s41598-021-87135-9
79. Wu YT, Ma SY, Wang Y, et al. A risk prediction model of gestational diabetes mellitus before 16 gestational weeks in Chinese pregnant women. *Diabetes Res Clin Pract*. 2021;179:109001. doi:10.1016/j.diabres.2021.109001
80. Liu BQ, Song LL, Zhang LN, et al. Higher numbers of pregnancies associated with an increased prevalence of gestational diabetes mellitus: results from the healthy baby cohort study. *J Epidemiol*. 2020;30(5):208–212. doi:10.2188/jea.JE20180245
81. Li X, Luo C, Li Y, Wu YY, Xiong T. Relationship between previous gravidity and pregnancy outcomes of the primipara: a cohort study. *Acta Medicinae Universitatis Scientiae et Technologiae Huazhong*. 2021;50(4):516–521.
82. Zhao Y, Zhao YB, Fan KC, Jin LP. Association of history of spontaneous or induced abortion with subsequent risk of gestational diabetes. *JAMA Network Open*. 2022;5(3):e220944. doi:10.1001/jamanetworkopen.2022.0944
83. Sun HX, Mao J, Su XJ, Du QL. Impact of spontaneous abortion history and induced abortion history on perinatal outcomes of singleton pregnancies. *BMC public Health*. 2023;23(1):2360. doi:10.1186/s12889-023-17264-5
84. Yang XK, Li Y, Li CD, Zhang WY. Current overview of pregnancy complications and live-birth outcome of assisted reproductive technology in mainland China. *Fertil Sterility*. 2014;101(2):385–391. doi:10.1016/j.fertnstert.2013.10.017
85. Lei LL, Lan YL, Wang SY, Feng W, Zhai ZJ. Perinatal complications and live-birth outcomes following assisted reproductive technology: a retrospective cohort study. *Chinese Med J*. 2019;132(20):2408–2416. doi:10.1097/CM9.0000000000000484

86. He ML, Sun WCF XX, Sui YL, Sui Y. Analysis of the risk of complications during pregnancy in pregnant women with assisted reproductive technology: a retrospective study using registry linkage from 2013 to 2018 in Shanghai, China. *BMC Pregnancy Childbirth*. 2022;22(1):526. doi:10.1186/s12884-022-04846-1
87. Lu HM, Ge ZP, Sun LZ. Relationship of red blood cells parameters and gestational diabetes mellitus in early non anemia pregnant women. *Acta Univ Med Nanjing*. 2013;33(09):1247–1250.
88. Min L, Wang X, Yao Q. Predictive values of first trimester red blood cell parameters on gestational diabetes mellitus in non-anemic pregnant women. *Chin J Obstet Gynecol Pediatr*. 2017;13(06):669–673.
89. Wang C, Lin L, Su R, et al. Hemoglobin levels during the first trimester of pregnancy are associated with the risk of gestational diabetes mellitus, pre-eclampsia and preterm birth in Chinese women: a retrospective study. *BMC Pregnancy Childbirth*. 2018;18(1):263. doi:10.1186/s12884-018-1800-7
90. Jiao MY, Xu XR, Zhang R, et al. Association between red blood cell parameters during early pregnancy and risk of gestational diabetes: a retrospective cohort study. *Chin J Public Health*. 2020;36(4):555–559.
91. Shen Y. *Iron Supplement And Hemoglobin Concentration During Pregnancy Were Associated With An Increased Risk Of Gestational Diabetes Mellitus* [Master]. Zhejiang University; 2020.
92. Yan MX, Zhao DD, Wan HL, et al. Relationship between hemoglobin level in early pregnancy and gestational diabetes mellitus: a birth cohort study. *Chin J Dis Control Prev*. 2023;27(1):60–64.
93. Zhang YQ, Lan X, Cai CJ, et al. Associations between maternal lipid profiles and pregnancy complications: a prospective population-based study. *Am J Perinatol*. 2021;38(8):834–840. doi:10.1055/s-0039-3402724
94. 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
95. Lean SC, Derricott H, Jones RL, Heazell AEP. Advanced maternal age and adverse pregnancy outcomes: a systematic review and meta-analysis. *PLoS One*. 2017;12(10):e0186287. doi:10.1371/journal.pone.0186287
96. Azeez TA, Abo-Briggs T, Adeyanju AS. A systematic review and meta-analysis of the prevalence and determinants of gestational diabetes mellitus in Nigeria. *Indian J Endocrinol Metab*. 2021;25(3):182–190. doi:10.4103/ijem.ijem_301_21
97. Karaçam Z, Çelik D. The prevalence and risk factors of gestational diabetes mellitus in Turkey: a systematic review and meta-analysis. *J Matern Fetal Neonatal Med*. 2021;34(8):1331–1341. doi:10.1080/14767058.2019.1635109
98. Zhang Y, Xiao CM, Zhang Y, et al. Factors associated with gestational diabetes mellitus: a meta-analysis. *J Diabetes Res*. 2021;2021:6692695. doi:10.1155/2021/6692695
99. Al-Rifai RH, Abdo NM, Paulo MS, Saha S, Ahmed LA. Prevalence of gestational diabetes mellitus in the Middle East and North Africa, 2000-2019: a systematic review, meta-analysis, and meta-regression. *Front Endocrinol*. 2021;12:668447. doi:10.3389/fendo.2021.668447
100. Paulo MS, Abdo NM, Bettencourt-Silva R, Al-Rifai RH. Gestational diabetes mellitus in Europe: a systematic review and meta-analysis of prevalence studies. *Front Endocrinol*. 2021;12:691033. doi:10.3389/fendo.2021.691033
101. Najafi F, Hasani J, Izadi N, et al. The effect of prepregnancy body mass index on the risk of gestational diabetes mellitus: a systematic review and dose-response meta-analysis. *Obesity Rev*. 2019;20(3):472–486. doi:10.1111/obr.12803
102. Habibi N, Mousa A, Tay CT, et al. Maternal metabolic factors and the association with gestational diabetes: a systematic review and meta-analysis. *Diabet/Metab Res Rev*. 2022;38(5):e3532. doi:10.1002/dmrr.3532
103. 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
104. Natamba BK, Namara AA, Nyirenda MJ. Burden, risk factors and maternal and offspring outcomes of gestational diabetes mellitus (GDM) in sub-Saharan Africa (SSA): a systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2019;19(1):450. doi:10.1186/s12884-019-2593-z
105. Moosazadeh M, Asemi Z, Lankarani KB, et al. Family history of diabetes and the risk of gestational diabetes mellitus in Iran: a systematic review and meta-analysis. *Diabetes Metab Syndr*. 2017;11(Suppl 1):S99–s104. doi:10.1016/j.dsx.2016.12.016
106. Fernández-Cao JC, Aranda N, Ribot B, Tous M, Arija V. Elevated iron status and risk of gestational diabetes mellitus: a systematic review and meta-analysis. *Maternal and Child Nutrition*. 2017;13(4). doi:10.1111/mcn.12400
107. Kataria Y, Wu Y, Horskjær PH, Mandrup-Poulsen T, Ellervik C. Iron status and gestational diabetes-a meta-analysis. *Nutrients*. 2018;10(5):621. doi:10.3390/nu10050621
108. Pandey S, Shetty A, Hamilton M, Bhattacharya S, Maheshwari A. Obstetric and perinatal outcomes in singleton pregnancies resulting from IVF/ICSI: a systematic review and meta-analysis. *Human Reprod Update*. 2012;18(5):485–503. doi:10.1093/humupd/dms018
109. Bouthoorn SH, Silva LM, Murray SE, et al. Low-educated women have an increased risk of gestational diabetes mellitus: the generation R study. *Acta diabetologica*. 2015;52(3):445–452. doi:10.1007/s00592-014-0668-x
110. Bo S, Menato G, Bardelli C, et al. Low socioeconomic status as a risk factor for gestational diabetes. *Diabetes Metabolism*. 2002;28(2):139–140.

Diabetes, Metabolic Syndrome and Obesity

Dovepress
Taylor & Francis Group

Publish your work in this journal

Diabetes, Metabolic Syndrome and Obesity is an international, peer-reviewed open-access journal committed to the rapid publication of the latest laboratory and clinical findings in the fields of diabetes, metabolic syndrome and obesity research. Original research, review, case reports, hypothesis formation, expert opinion and commentaries are all considered for publication. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit http://www.dovepress.com/testimonials.php to read real quotes from published authors.

Submit your manuscript here: https://www.dovepress.com/diabetes-metabolic-syndrome-and-obesity-journal