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Independent risk factors for placental abruption: a systematic review and meta-analysis

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Abstract

Background Placental abruption is one of the most severe complications during pregnancy, and its associated risk factors remain incompletely understood and somewhat controversial.

Methods This study conducted a systematic search of the PubMed, Embase, Cochrane, Web of Science, and Scopus databases to collect literature related to placental abruption, with a cutoff date of July 30, 2024.

Results A total of 54 observational studies were included, covering 7,267,241 pregnant women, with 47,702 cases diagnosed with placental abruption. The study identified three categories of independent risk factors: The first category includes baseline maternal characteristics (18 items), such as maternal age ≥ 35 years, black race, low prepregnancy BMI (< 18.5 kg/m^2), unmarried status, smoking during pregnancy, alcohol consumption, inadequate prenatal care (< 4 visits), marijuana use, multiple pregnancy, parity ≥ 3, anemia (hemoglobin < 11 g/dL), previous placental abruption, previous cesarean section, previous miscarriage, previous stillbirth, cervical incompetence, habitual abortions, and assisted reproductive technology. Among these, previous placental abruption (AOR = 2.72, 95% CI [2.16, 3.42]) was found to be the most significant risk factor. The second category includes pregnancy-related complications (7 items), such as preterm premature rupture of membranes, preeclampsia, small for gestational age, polyhydramnios, antepartum hemorrhage, gestational hypertension, and placenta previa. Of these, placenta previa (AOR = 7.31, 95% CI [4.78, 11.19]) was identified as the most significant risk factor. The third category consists of other independent risk factors (33 items) and protective factors (3 items). However, methodological inconsistencies and publication bias in the current studies may affect the reliability of the meta-analysis results.

Conclusion This study summarizes 58 independent risk factors for placental abruption, covering various aspects such as maternal baseline characteristics and pregnancy complications. For these high-risk populations, it is essential to strengthen the frequency of prenatal check-ups, establish early warning systems, and provide targeted health guidance. Future research should further refine risk factor models and develop more targeted preventive strategies to reduce the incidence of placental abruption and improve maternal and neonatal outcomes.

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Keywords Placental abruption, Independent risk factors, Systematic review, Meta-analysis

Introduction

Placental abruption is a serious complication of pregnancy, with an incidence rate among pregnant women ranging from 0.6 to 1.2% [1]. Despite its relatively low occurrence, it can lead to severe obstetric complications, including postpartum hemorrhage, peripartum hysterectomy, amniotic fluid embolism, severe respiratory distress, disseminated intravascular coagulation, renal failure, and even maternal mortality [2–4]. Furthermore, placental abruption negatively impacts the long-term prognosis for both mothers and newborns, increasing morbidity and mortality rates [5, 6]. The prognosis for patients with placental abruption is closely related to early accurate diagnosis and timely intervention. However, due to its nonspecific symptoms, insidious onset, and rapid progression, the rates of missed and misdiagnosis are high, making diagnosis particularly challenging. Therefore, timely identification of the risk factors for placental abruption is crucial for early diagnosis and treatment.

In recent years, an increasing number of studies have focused on the potential risk factors for placental abruption, including advanced maternal age, chronic hypertension, multiparity, preeclampsia, small-for-gestational-age infants, and previous medical history [7]. However, due to differences in study design, sample sizes, and assessment methods, the conclusions in the existing literature show considerable inconsistency. Some early studies suggested that preeclampsia is not a risk factor for placental abruption [8, 9], while more recent studies indicate that preeclampsia is actually an independent risk factor for placental abruption [10, 11]. Furthermore, women with a history of placental abruption have a significantly increased risk of recurrence [12, 13], but earlier studies failed to sufficiently confirm this, considering such a history not to be an independent risk factor [8]. The inconsistency in these findings often stems from differences in sample selection, data analysis methods, and variable control across studies, leading to a significant misunderstanding and misapplication of risk factors, which causes confusion for clinicians in risk assessment and intervention decision-making. As a result, existing research fails to provide a unified and systematic guideline for the early prevention and management of placental abruption, highlighting the urgent need for further high-quality meta-analyses to synthesize and resolve these contradictions.

Globally, the incidence of placental abruption and its associated complications pose significant challenges to maternal and neonatal health. This issue is especially acute in resource-limited regions, where the lack of effective screening, diagnosis, and treatment methods exacerbates the high incidence and mortality rates of placental abruption, further deepening the global inequities in maternal and child health [14, 15]. Therefore, identifying the independent risk factors for placental abruption not only aids in the early identification of high-risk pregnancies but also contributes to the optimization of prenatal care worldwide, reducing unnecessary maternal and neonatal health losses. This is crucial for reducing maternal mortality, improving neonatal health outcomes, and minimizing the wastage of medical resources. Although previous studies have attempted to summarize the risk factors for placental abruption, most have remained at the descriptive analysis level, without conducting in-depth statistical analysis of the inconsistent findings. Additionally, these studies lack a systematic summary of independent risk factors and fail to assess their clinical guidance value [1]. Therefore, in response to the contradictions and shortcomings in the existing literature, this study aims to comprehensively review and analyze the independent risk factors for placental abruption through systematic review and meta-analysis, clarifying the inconsistencies in current findings. We hope that this research will provide clinicians with more reliable tools for risk factor identification, promote the application of personalized prenatal care, and ultimately contribute to reducing the incidence of placental abruption and improving maternal and neonatal health outcomes globally.

Materials and methods

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (ISMA) guidelines [16] and has been registered in the PROSPERO platform (registration number: CRD42024546514).

Inclusion and exclusion criteria

Inclusion criteria for this study require that at least one risk factor associated with placental abruption be reported. These factors may include, but are not limited to, pregnancy-related hypertension, trauma, smoking, alcohol consumption, maternal age, and parity. Additionally, the reported risk factors must be adjusted for confounding variables, with the adjusted odds ratio (AOR) provided. This requirement ensures that the included studies reflect more reliable and clinically meaningful results, rather than focusing on the impact of a single factor on placental abruption. In multivariable models,

other potential confounders are controlled for, allowing the findings to more accurately identify independent risk factors. Exclusion criteria include review articles, commentaries, conference abstracts, and studies with incomplete data, unextractable data, or those that only perform univariate analysis.

Search strategy

A search strategy combining both subject headings and free-text terms was employed to search the PubMed, Embase, Cochrane, Web of Science, and Scopus databases, with a cutoff date of July 30, 2024. The search terms and strategy were as follows: (placental abruption OR placental abruptions OR placenta abruption OR abruptio placentae) AND (hazard OR risk factors OR risk factor OR related factors OR influence factors OR influencing factors). A detailed search strategy is provided in Supplementary Table 1. Additionally, reference lists of included studies were searched for further relevant literature. To ensure the inclusivity and broad representativeness of the studies, our literature search imposes no language restrictions. If studies in other languages are found to have potential value, we will appropriately handle them through translation resources to ensure their inclusion in the analysis. Furthermore, to mitigate publication bias, we manually searched conference abstracts and clinical trial registries, and consulted gray literature databases such as OpenGrey and the Grey Literature Report. Lastly, we engaged with experts in the field to obtain potentially unpublished research data or studies.

Literature screening and data extraction

Literature screening was conducted strictly according to the predefined inclusion and exclusion criteria. For each eligible study, the following information was extracted: authors, study period, country, study type, sample size, age, data source, and adjusted confounding factors. Two researchers independently performed the literature screening, initially reviewing titles and abstracts for preliminary selection, followed by a thorough reading of the full texts to exclude studies that did not meet the criteria. Ultimately, the two researchers verified the selected studies against each other. In cases of disagreement, discussions were held to reach a consensus; if consensus could not be achieved, a third-party researcher was consulted for final evaluation regarding the inclusion of the study.

Quality assessment of studies

The quality of the included observational studies was assessed using the Newcastle-Ottawa Scale (NOS) [17]. This scale evaluates studies based on three aspects: selection, comparability, and outcome, with a scoring range of 0–9 points. Specific assessment criteria included: selection (representativeness of the study population, adequacy of sample size, confirmation of exposure factors, etc.), comparability (selection of control groups, control of confounding factors, etc.), and outcome (methods of outcome assessment, completeness of follow-up, etc.). Based on the scores, studies were categorized as high quality (7–9 points), moderate quality (4–6 points), or low quality (0–3 points).

Statistical analysis

Statistical analysis was performed using STATA software (version 16.0). Initially, descriptive statistics were conducted on the included studies to understand the study types, sample characteristics, and distribution of risk factors. For the obtained AOR and their 95% confidence intervals (CI), a meta-analysis was conducted using the "metan" command in STATA. In selecting the statistical model, we determined whether to use a fixed-effect model or a random-effects model based on the heterogeneity between studies. The fixed-effect model assumes that the true effect is the same across all studies, making it suitable for situations with low heterogeneity, and providing more precise effect estimates. In contrast, the random-effects model accounts for potential variations in the true effect between studies and is more appropriate for situations with high heterogeneity. During the analysis, we assessed heterogeneity using Cochran' s Q test and the I^2 statistic. If the P-value is greater than 0.05 or the I^2 value is less than 50%, it indicates that heterogeneity is within an acceptable range, and the fixed-effect model was chosen for analysis; otherwise, the random-effects model was applied. To evaluate publication bias, we used funnel plots for visual analysis. The symmetry of the funnel plot typically reflects the completeness of the study results and the potential for publication bias. If the funnel plot shows asymmetry, this may indicate the presence of publication bias. In such cases, we will discuss this issue and consider its potential impact on the study findings. In all statistical analyses, a P-value of less than 0.05 was considered statistically significant.

Results

Overview of included literature

We retrieved a total of 7,066 articles from five databases. After excluding 3,077 duplicate records, we conducted a preliminary screening of the remaining 3,759 articles based on titles and abstracts. Ultimately, we downloaded the full texts of 78 articles for further review, resulting in the inclusion of 54 studies that met the eligibility criteria for subsequent analysis. The literature screening flowchart is illustrated in Fig. 1.

The included 54 studies comprised 20 cross-sectional studies, 32 retrospective cohort studies, and 2 prospective cohort studies, with a total sample size of 7,267,241 individuals, of which 47,702 were pregnant women

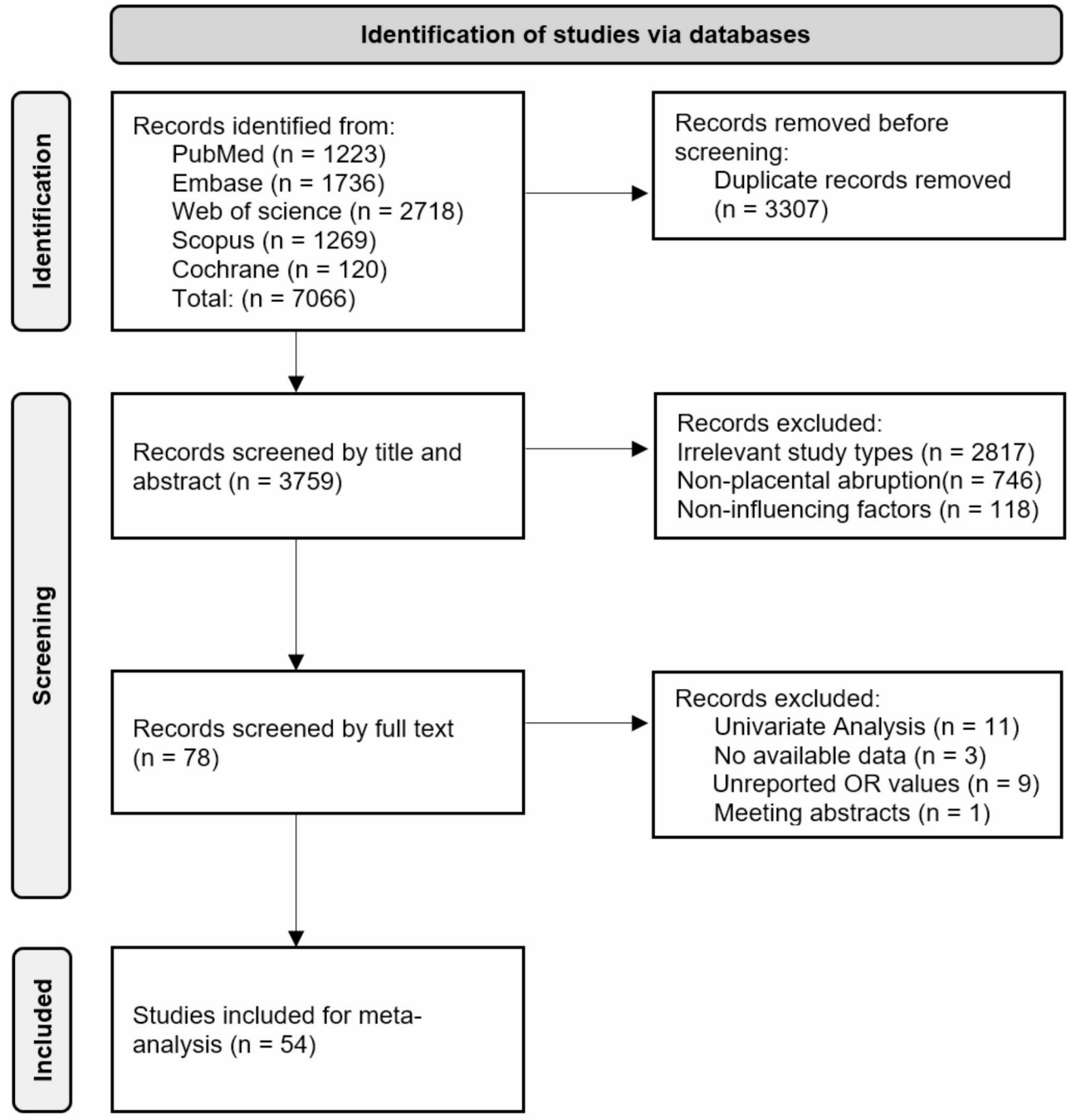

Fig. 1 Literature screening flowchart

diagnosed with placental abruption. The age of the pregnant women ranged from 13 to 53 years; however, 31 studies did not provide age information. Data for 32 studies were sourced from databases, while the remaining 22 studies were conducted in hospitals. All included studies adjusted for confounding factors; however, 11 studies did not explicitly report the specific confounding factors that were adjusted for. Basic information about the included studies is detailed in Supplementary Table 1.

Quality assessment of evidence

Among the 54 included studies, quality assessment scores indicated that 21 studies scored between 4 and 6 points, categorizing them as moderate quality, while 33 studies scored between 7 and 9 points, categorizing them as high quality. The average score on the Newcastle-Ottawa Scale (NOS) was 6.87 ± 1.49 points. Although there was some variability in scores across different domains, most studies performed well in the areas of "participant selection"

and "control of confounding variables". However, several studies received lower scores in the "exposure measurement" domain, suggesting potential methodological biases or inconsistencies in this field. The quality assessment results are presented in Fig. 2. The detailed scores for each study can be found in Supplementary Table 3.

Meta-analysis results

Risk factors associated with maternal baseline characteristics

A total of 21 exposure factors related to maternal baseline characteristics were identified as potential contributors to placental abruption. Given that the I^2 value was less than 50% and the P-value was greater than 0.05, a fixed-effect model was employed for the meta-analysis. The results confirmed 18 factors as independent risk factors for placental abruption, specifically: maternal age ≥ 35 years, black race, low prepregnancy BMI (< 18.5 kg/m^2), unmarried status, smoking during pregnancy, alcohol consumption, inadequate prenatal care (< 4 visits), marijuana use, multiple pregnancies, parity ≥ 3, anemia (hemoglobin < 11 g/dL), previous placental abruption, previous cesarean section, previous miscarriage, previous stillbirth, cervical incompetence, habitual abortions, and assisted reproductive technology. Among these, previous placental abruption (AOR = 2.72, 95% CI [2.16, 3.42]) was identified as the most significant risk factor. Three exposure factors—maternal age < 20 years, loss of employment, and multiparity—did not show a significant association with placental abruption. Detailed results are presented in Fig. 3.

Risk factors associated with maternal pregnancy complications

Eight exposure factors related to maternal pregnancy complications were identified as potential contributors to placental abruption. With an I^2 value of less than 50% and a P-value greater than 0.05, a fixed-effect model was again utilized for the meta-analysis. The results indicated that, except for gestational diabetes, which showed no significant association with placental abruption, the remaining seven pregnancy complications were identified as independent risk factors. These include: preterm premature rupture of membranes, preeclampsia, small for gestational age, polyhydramnios, antepartum hemorrhage, gestational hypertension, and placenta previa. Among these, placenta previa (AOR = 7.31, 95% CI [4.78, 11.19]) was recognized as the most significant risk factor. Detailed results are shown in Fig. 4.

Risk factors not subject to data pooling

A total of 36 factors associated with the occurrence of placental abruption were reported in single studies only, and thus were not included in the meta-analysis. Among these, three were identified as protective factors: folic acid, multivitamins, and the combination of folic acid and multivitamins. The dosage of folic acid was 0.4 mg per day, while the dosage of vitamins was

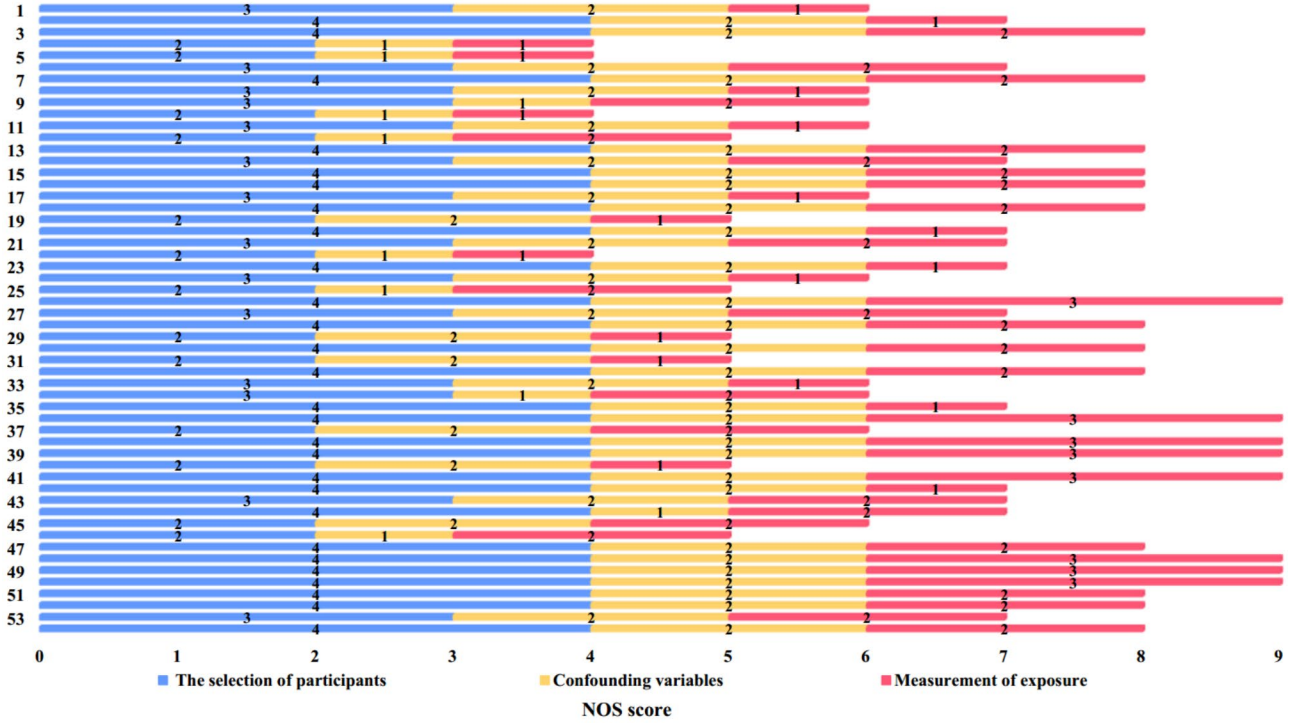

Fig. 2 NOS scores

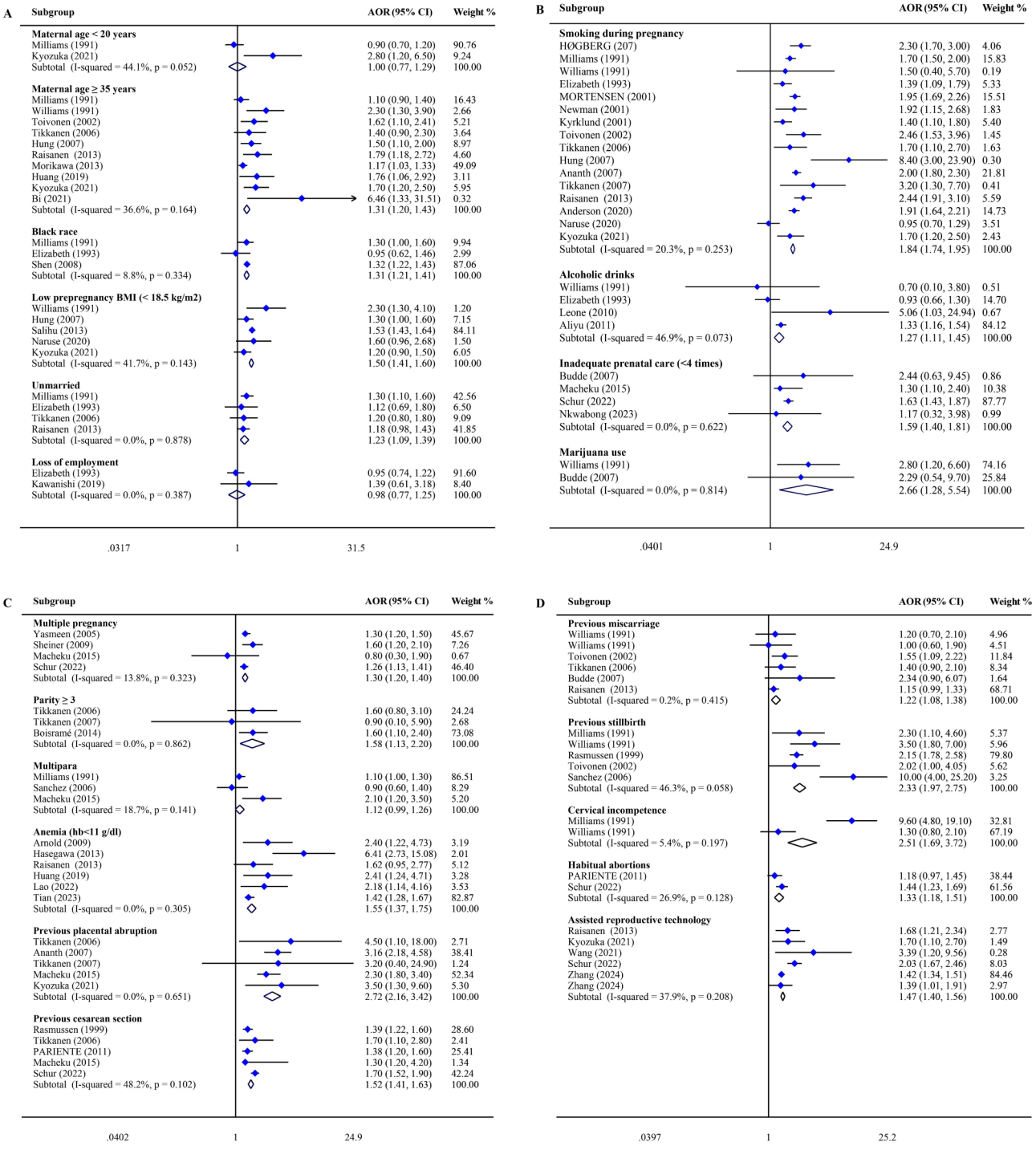

Fig. 3 Risk factors associated with maternal baseline characteristics

not clearly reported. The remaining 33 factors were recognized as independent risk factors for placental abruption, with hyperthyroidism, uterine malformation, and preterm uterine contractions having the highest AOR values, making them the most significant risk factors for placental abruption. Detailed information is provided in Table 1.

Subgroup analysis

We conducted a subgroup analysis of various risk factors based on study type, with the criterion that the number of studies in each subgroup was ≥2 to meet the requirements for meta-analysis. Out of 58 exposure factors, 10 risk factors met this criterion. The results of the subgroup analysis showed that, with the exception of preterm

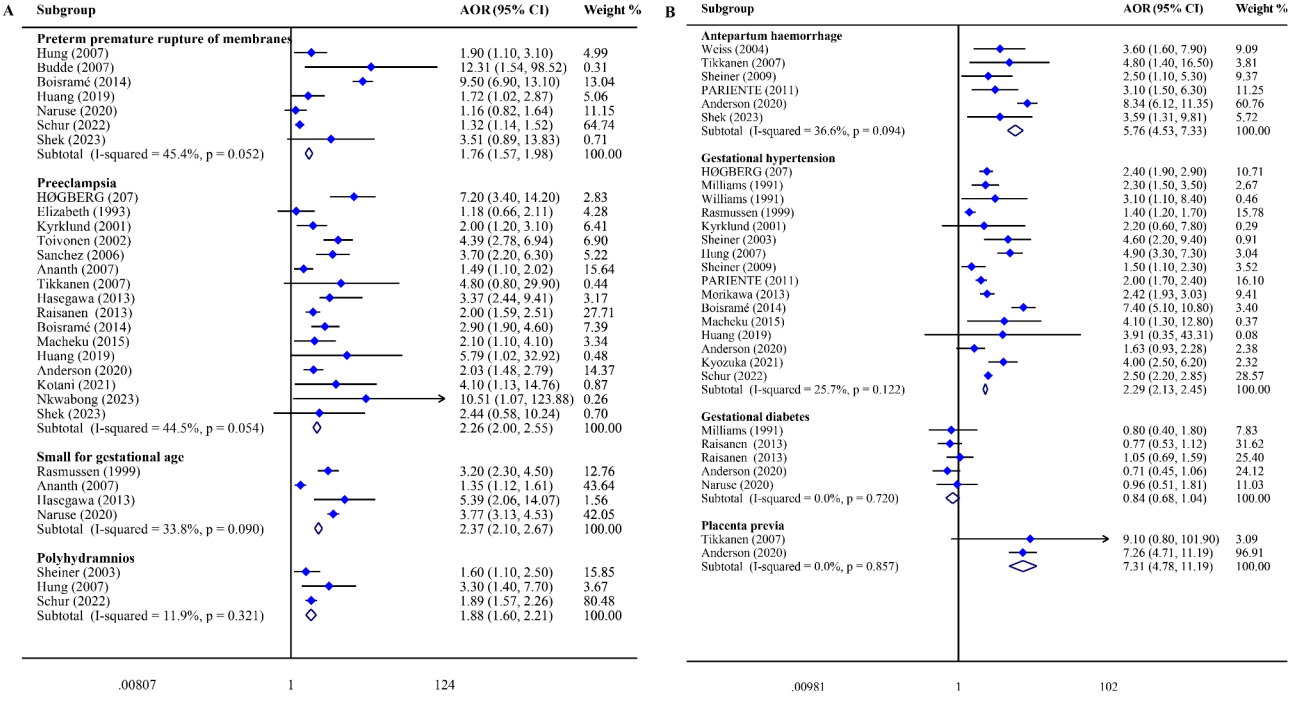

Fig. 4 Risk factors related to pregnancy complications

premature rupture of membranes, the AORs for the other nine risk factors were higher in case-control studies compared to cohort studies. Additionally, heterogeneity between studies was reduced within the subgroups. For further details, see Table 2.

Publication bias

For exposure factors with more than 10 studies, funnel plots were generated to assess publication bias. The results indicated that the funnel plots for maternal age ≥ 35 years, smoking during pregnancy, gestational hypertension, and preeclampsia exhibited asymmetry, suggesting a potential risk of publication bias in the current research. Detailed findings are illustrated in Fig. 5.

Discussion

Placental abruption is a significant contributor to maternal morbidity and perinatal mortality. This study compiles the largest sample size to date, aiming to comprehensively summarize the independent risk factors associated with placental abruption. Currently, several risk factors associated with placental abruption can be categorized as related to the baseline characteristics of the patient. Prevention of placental abruption should focus on managing modifiable behavioral factors, with particular attention to smoking (OR = 1.84, 95% CI: 1.74–1.95) and alcohol use (OR = 1.27, 95% CI: 1.11–1.45), both of which can lead to pathological changes in the placenta. Smoking is associated with elevated plasma homocysteine levels, which in turn can cause endothelial cell damage and local thrombosis [18]. Additionally, the vasoconstrictive effects of nicotine and carbon monoxide, as well as hypoxic conditions, may lead to placental infarction and increased risk of arterial rupture, thereby triggering placental abruption [19–21]. Alcohol, another modifiable risk factor, also significantly increases the incidence of placental abruption. Alcohol easily crosses the placenta and accumulates in the fetus and amniotic fluid, disrupting the hormonal balance between the fetus and the mother. It may also cause constriction of placental and umbilical blood vessels, thereby increasing the risk of placental abruption [22]. Previous studies have shown that the use of illicit drugs, particularly marijuana, significantly increases the risk of placental abruption [23, 24], a finding consistent with our results. Therefore, future efforts should focus on establishing a prenatal risk prevention and control system that includes personalized behavioral interventions for smoking, alcohol abuse, and drug misuse, along with nutritional support and psychological counseling to improve the placental microenvironment. In fact, smoking, alcohol use, and cocaine use are more common among Black women than White women, which may help explain the higher rate of placental abruption observed in Black women in this study [25, 26]. Furthermore, other risk factors such as inadequate prenatal care, low pre-pregnancy body mass index, anemia, and being unmarried can be mitigated through public health interventions such as education and guidance during pregnancy to reduce the risk of placental abruption. For existing risk factors—such as those reported in

Table 1 Risk factors not subject to data pooling

Influencing factor	AOR and its 95% CI		
Hyperthyroidism	8.21	1.76	38.34
Uterine malformation	8.10	1.70	40.00
Preterm uterine contraction	5.96	2.47	14.55
Intimate partner violence during prenatal care	5.17	1.37	19.51
Depressive symptoms	5.01	1.06	23.6
Marginal cord insertion	4.79	1.04	23.38
Maternal serum alpha-fetoprotein greater than 1.5	4.50	1.70	11.90
Fetal growth restriction	4.40	2.62	7.38
Oligohydramnios	4.20	2.70	6.70
Intrauterine growth restriction	4.00	2.30	6.80
> 3 weeks between biparietal diameter and abdominal circumference gestational age	3.92	1.52	9.77
> 7 deliveries	3.60	1.23	10.50
Preterm labor	3.38	1.19	9.64
Schizophrenia	3.17	1.55	6.49
Histologic chorioamnionitis	2.80	1.30	6.10
Complaint of vital exhaustion: 4 time/ Month-Weekly	2.75	1.39	5.48
threatened miscarriage	2.64	1.70	4.09
Velamentous cord insertion	2.53	1.23	5.21
Rate of pregnancy weight gain < 0.15 kg/week	2.50	1.30	4.70
Complaint of vital exhaustion: Ever	2.32	1.42	3.82
Anxiety	2.30	1.23	4.31
> 2 weeks between biparietal diameter and abdominal circumference gestational age	2.29	1.14	4.60
Complaint of vital exhaustion: 1–3 times/Month	2.23	1.30	3.81
sleep time≥9 h	2.18	1.10	4.29
Mid-arm circumference (22–27.9 cm)	2.00	1.20	3.40
Endometriosis	2.00	1.70	2.30
sleep time≤6 h	1.89	1.01	3.56
Entanglement of the umbilical cord with the fetus	1.60	1.20	2.10
Non-vertex presentations	1.50	1.10	2.00
Interpregnancy interval≥4 years	1.50	1.30	1.74
Major congenital anomalies	1.49	1.21	1.84
Primiparity	1.41	1.24	1.60
Interpregnancy interval < 0.5 year	1.27	1.04	1.56
Folic acid	0.81	0.68	0.98
Multivitamins	0.72	0.57	0.91
Folic acid and multivitamins	0.68	0.56	0.83

this study, including Black race, multiple pregnancies, parity ≥ 3, previous placental abruption, prior cesarean section, previous miscarriage, previous stillbirth, cervical incompetence, habitual abortions, and assisted reproductive technology—while they may be difficult to avoid, they should be closely monitored by healthcare providers and patients alike. Increased screening efforts are essential for timely identification and management of potential adverse outcomes. Previous placental abruption may lead to persistent damage to the decidual basalis layer, with the underlying mechanism involving vascular fibrosis mediated by the TGF-β signaling pathway. This process significantly weakens the adhesion between the placenta and the uterine wall. Concurrently, the tendency for thrombosis, such as elevated antiphospholipid antibody levels, may exacerbate the risk of local microthrombosis in the placenta [27]. Therefore, women with a history of placental abruption should remain vigilant regarding the increased risk of placental abruption in future pregnancies.

Identifying and implementing preventive measures for risk factors associated with pregnancy complications is a crucial strategy for avoiding placental abruption. Hypertensive disorders of pregnancy, including gestational hypertension and preeclampsia, have been widely recognized as significant risk factors for placental abruption [11, 28]. Hypertension can lead to arteriosclerosis of small arteries at the site of placental attachment, resulting in ischemia, necrosis, or even rupture and hematoma formation in distal capillaries. These conditions may compress the placenta and lead to its premature detachment [29]. Once placental abruption occurs, it typically presents as widespread and rapidly progressing, making it prone to misdiagnosis. Therefore, for patients with gestational hypertension, symptoms such as bleeding, uterine tenderness, or frequent contractions should raise a high suspicion for the possibility of placental abruption [30]. Premature rupture of membranes is also considered a risk factor for placental abruption, potentially related to intrauterine infection and sudden decreases in uterine

Table 2 Subgroup analysis results based on study type

Outcome	Case control study			Cohort studies		
	Number of studies	I^2	AOR	Number of studies	I^2	AOR
Maternal age ³ 35 years	7	26.90%	1.42(1.22, 1.65)	3	11.80%	1.25(1.12,1.40)
Smoking during pregnancy	7	0.00%	1.90(1.74, 2.08)	9	19.90%	1.80(1.67,1.94)
Previous placental abruption	2	0.00%	4.04(1.27, 12.87)	3	0.00%	2.67(2.11, 3.38)
Previous cesarean section	2	33.10%	1.70(1.53, 1.89)	3	12.80%	1.38(1.25, 1.52)
Assisted reproductive technology	3	1.80%	1.96(1.66, 2.31)	3	35.20%	1.42(1.34, 1.51)
Antepartum haemorrhage	3	33.60%	7.56(5.67, 10.07)	3	0.00%	3.03(1.95, 4.72)
Gestational hypertension	5	7.60%	2.57(2.29, 2.90)	11	19.10%	2.15(1.98, 2.34)
Preterm premature rupture of membranes	4	41.10%	1.37(1.20, 1.57)	3	9.60%	3.23(2.61, 4.00)
Preeclampsia	9	43.70%	2.45(2.09, 2.86)	7	0.00%	2.01(1.67, 2.43)
Small for gestational age	2	27.80%	3.82(3.18, 4.58)	2	17.40%	1.64(1.40, 1.93)

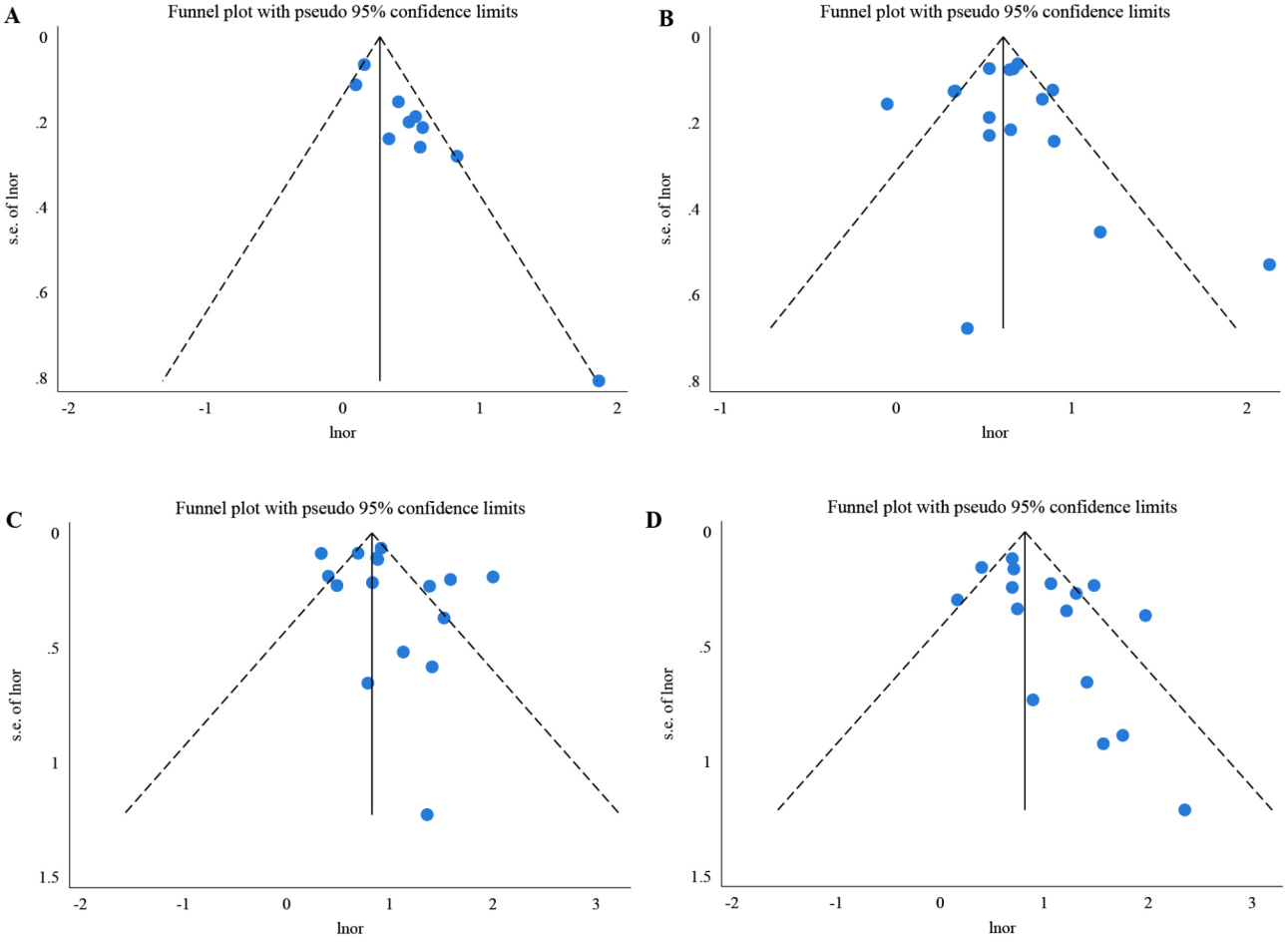

Fig. 5 Funnel Plot (**A**. Maternal Age≥35 Years; **B**. Smoking During Pregnancy; **C**. Gestational Hypertension; **D**. Preeclampsia)

pressure. Premature rupture can lead to a sharp decline in intrauterine pressure, triggering the separation of the decidua from the membranes, activating prostaglandin factors, and resulting in uterine contractions and placental abruption [31]. Additionally, polyhydramnios can increase intrauterine pressure, affecting placental blood flow and further elevating the risk of placental abruption. If a pregnant woman with polyhydramnios experiences membrane rupture, the sudden drop in intrauterine pressure may lead to misalignment and detachment of the uterine wall from the placenta, exacerbating the occurrence of placental abruption [1, 32, 33]. Previous studies have indicated that maternal and fetal circulatory changes due to hypoxia, uteroplacental vascular dysfunction, and placental ischemia are major pathophysiological mechanisms underlying placental abruption [34, 35]. Consequently, placental abruption is viewed as a long-term chronic condition originating in early pregnancy [36]. Based on this understanding, conditions such as small-for-gestational-age infants and preeclampsia can be associated with placental abruption through the pathophysiological mechanisms of ischemia and hypoxia, thereby becoming risk factors [37–39]. Furthermore, antepartum hemorrhage may lead to vascular damage and localized inflammatory responses within the uterus, affecting the attachment and stability of the placenta, thus increasing the risk of detachment. For placenta previa, the associated risk arises from the unique anatomical characteristics of the lower uterine segment. This region has a thinner myometrium and poorly developed spiral arteries, leading to inadequate placental blood supply. Additionally, the abnormally implanted placental villi degrade the extracellular matrix via MMP-9-mediated processes, further compromising the stability of placental attachment [30]. These findings suggest that a dynamic monitoring system should be established for pregnant women with these high-risk factors. This could include a combination of ultrasound-based placental morphological assessment and uterine artery blood flow Doppler studies to enable early risk detection.

In addition to the aforementioned risk factors, this study summarizes 36 independent factors that were reported in only single studies. Among these, three were identified as protective factors: folic acid, multivitamins,

and a combination of folic acid and multivitamins. Folic acid improves placental endothelial function by promoting DNA methylation and reducing homocysteine levels [40], while vitamins, through their antioxidant properties (such as vitamins C and E) and immune modulation (such as vitamin D), can help suppress placental oxidative stress and inflammatory responses [41, 42]. The remaining 33 are independent risk factors. These factors encompass various domains, including psychological and emotional aspects, reproductive history and physiology, pregnancy-related factors, lifestyle and environmental influences, nutrition, and monitoring indicators. For instance, pregnant women with anxiety or schizophrenia exhibit significantly elevated levels of plasma cortisol, corticotropin-releasing hormone, and serotonin. This abnormal increase in hormone levels may lead to inflammatory responses at the maternal-fetal interface, thereby increasing the risk of placental abruption [43]. Additionally, pregnant women with hyperthyroidism often present symptoms such as excessive sweating, heat intolerance, insomnia, and palpitations, which may result in impaired placental function in late pregnancy, subsequently leading to adverse outcomes such as placental abruption [44]. Additionally, uterine malformations can increase the risk of placental abruption by restricting the placental attachment area and disrupting decidual vascular remodeling, leading to inadequate basal plate perfusion and abnormal shear forces [45, 46]. Although uterine malformations have been reported in only a single study, this factor warrants further attention. Although these risk factors have only been reported in individual studies, they still warrant attention. Notably, the cumulative effect of two or more risk factors can significantly elevate the incidence of placental abruption. For example, the combined effects of smoking and hypertension on the risk of placental abruption often exceed the expected risk posed by each individual factor [47]. Therefore, many risk factors may coexist in the same patient, leading to additive effects and potentially more severe consequences.

The subgroup analysis of this study revealed a significant impact of study design on the estimation of risk factors for placental abruption. Among the 10 risk factors that met the subgroup analysis criteria, the AORs in case-control studies were generally higher than those in cohort studies, with the exception of preterm premature rupture of membranes. This discrepancy may be attributed to design biases inherent in the two types of studies: case-control studies, due to their retrospective nature, are more susceptible to recall and selection biases, which may lead to an overestimation of the association between risk factors and outcomes. In contrast, cohort studies, through prospective data collection and more rigorous control of confounding variables, tend to provide more conservative effect estimates [48]. Notably, the reduction in heterogeneity between studies following subgroup analysis suggests that stratification by study type effectively mitigated the variability caused by design differences, thereby enhancing the internal consistency of the results. These findings emphasize the need for cautious interpretation of placental abruption risk factors, considering potential biases related to study design. Additionally, this study found no significant association between certain maternal characteristics (such as young age, unemployment status, parity, and gestational diabetes) and placental abruption. However, this does not imply that these factors are completely unrelated to placental abruption. On the contrary, they should be further examined in future high-quality studies, particularly gestational diabetes.

The strength of this study lies in its inclusion of multifactorial analyses, which aim to minimize the confounding effects and provide a deeper exploration of the independent risk factors for placental abruption. However, there are several limitations in this study that need to be acknowledged. First, among the 51 studies included, 21 were of moderate quality. These studies have certain limitations in design and methodology, which may lead to increased bias and heterogeneity in the results. For example, some studies had shortcomings in exposure measurement and control of confounding variables, which could affect the accurate assessment of independent risk factors for placental abruption. Nevertheless, these studies still provide important clinical insights, suggesting that future research should focus on improving study design quality to enhance the understanding of risk factors for placental abruption. Second, the lack of data on the definition, types, and severity of placental abruption limited further subgroup analyses. Moreover, when attempting subgroup analysis based on geographic region, the limited number of studies related to each risk factor made this analysis unfeasible. However, exploring regional differences in the prevalence of risk factors is crucial for the field, and future research should give this more attention. Third, despite our systematic literature search aimed at including all relevant studies, the asymmetry observed in the funnel plot suggests the potential for publication bias. This bias may arise from the absence of unpublished negative results or studies with small sample sizes, leading to inaccurate estimates of the true effects of certain independent risk factors in the meta-analysis. Therefore, future research should place more emphasis on collecting and analyzing grey literature to comprehensively evaluate the independent risk factors for placental abruption. Finally, the inclusion criteria of this study required that the included studies report AORs for confounding variables. While this decision improved the internal validity of the results, it may have introduced selection bias. Studies that did not report confounder-adjusted AORs were

often from low-resource settings or were observational studies using univariate analyses. The exclusion of these studies may have led to an overestimation of the effect size of certain risk factors and an underestimation of the role of factors unique to resource-limited environments.

Conclusion

Placental abruption is one of the most severe complications during pregnancy, with risk factors spanning multiple domains. This study identified 18 risk factors associated with maternal baseline characteristics, 7 risk factors related to pregnancy complications, and 33 independent risk factors reported in only a single study. Based on these findings, clinical practice should enhance screening and intervention for high-risk pregnant women, particularly through the early identification and management of known risk factors. Future research should focus on exploring the interactions between these risk factors and developing more precise clinical interventions to reduce the incidence of placental abruption. Additionally, research on individualized risk assessment models is recommended to guide more effective prevention and treatment strategies in clinical practice, thereby improving maternal and neonatal health outcomes.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions
ML and RH designed the study framework, managed the research progress, secured funding, and revised the final manuscript. DC drafted the initial manuscript and conducted data analysis and visualization of the. XG and TY performed the literature search and selection. XX and GW carried out data extraction and analysis. HW was responsible for data validation and preservation. All authors reviewed the final version of the manuscript and provided their consent for publication.

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Data availability
All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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