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Maternal Obesity as a Risk Factor for Pregnancy-Related Metabolic Disorders and Neonatal Adversities: A Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

Background: Maternal obesity (BMI ≥30 kg/m²) increases risks of GDM, hypertensive disorders, preeclampsia, and neonatal complications. This meta-analysis evaluates intervention effectiveness in reducing these risks. **Objective:** To assess the relationship between maternal obesity and adverse outcomes, including metabolic disorders and neonatal adversities, and to evaluate the efficacy of lifestyle and medical interventions in mitigating these risks. **Methods:** A systematic search of PubMed, EMBASE, and Cochrane Library databases identified nine studies involving 2,700 participants. Studies included were RCTs or prospective cohort studies focusing on obese or overweight pregnant women and reporting outcomes such as GDM, preeclampsia, pregnancy weight gain, and neonatal health. Data were extracted independently, and pooled odds ratios (Ors) or weighted mean differences (WMDs) were calculated using random-effects models. Subgroup and sensitivity analyses assessed outcome variations based on intervention types, maternal BMI categories, and other factors. **Results:** Maternal obesity was significantly associated with adverse outcomes. For pregnancy weight gain, dietary and exercise interventions showed a pooled effect size of 0.75 (95% CI: 0.60–0.90), with low heterogeneity (I^2 = 20%). GDM management reduced adverse fetal growth outcomes (0.85, 95% CI: 0.70–1.00; I^2 = 25%). Neonatal outcomes, including preterm birth and NICU admissions, improved with a pooled effect size 1.20 (95% CI: 1.05–1.35), with moderate heterogeneity (I^2 = 15%). Subgroup analyses revealed intervention-specific benefits, such as supervised exercise improving maternal weight outcomes (0.88, 95% CI: 0.78–0.98; I^2 = 15%). **Conclusion:** Maternal obesity raises pregnancy-related risks, but dietary changes and exercise help. Integrating effective interventions into prenatal care is crucial for better outcomes.

INTRODUCTION

Maternal obesity has emerged as a pressing global health concern, with its prevalence continuing to rise alongside the global obesity epidemic. Defined as a pre-pregnancy body mass index (BMI) of 30 kg/m² or higher, maternal obesity has profound implications for both maternal and neonatal health. It is associated with an increased risk of pregnancy-related metabolic disorders such as gestational diabetes mellitus (GDM), hypertensive disorders of pregnancy, and preeclampsia, as well as adverse neonatal outcomes, including preterm birth, macrosomia, and admission to the neonatal intensive care unit (NICU) [1] [2].

The metabolic changes during pregnancy in obese women exacerbate insulin resistance and inflammatory responses, contributing to the development of gestational diabetes and hypertensive disorders [3]. Furthermore, maternal obesity is a critical factor influencing neonatal health, as excess maternal weight can disrupt placental function and fetal growth patterns, leading to complications such as large-for-gestational-age infants and long-term metabolic dysfunction in offspring [4] [5].

Several randomized controlled trials (RCTs) and observational studies have sought to understand the implications of maternal obesity and evaluate interventions aimed at mitigating associated risks. Interventions such as lifestyle modifications, dietary adjustments, and supervised exercise programs have shown varying levels of success in improving maternal and neonatal outcomes [6] [7]. Despite these efforts, significant knowledge gaps remain, particularly concerning the comparative efficacy of these interventions in reducing metabolic and neonatal risks.

This meta-analysis is of utmost importance as it aims to systematically evaluate the impact of maternal obesity on pregnancy-related metabolic disorders and neonatal adversities. By synthesizing evidence from RCTs, this study seeks to provide a comprehensive understanding of the risks associated with maternal obesity and identify effective interventions to improve maternal and neonatal outcomes.

METHODS

This meta-analysis was conducted to evaluate the relationship between maternal obesity and adverse pregnancy-related metabolic disorders and neonatal outcomes based on nine peer-reviewed studies. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and rigor. Relevant studies were identified through systematic searches of databases, including PubMed, EMBASE, and the Cochrane Library, using key terms such as "maternal obesity," "pregnancy complications," "gestational diabetes," "neonatal outcomes," and "preterm birth." Filters were applied to include studies published in English between January 2000 and December 2023.

Eligible studies were required to meet the following inclusion criteria: randomized controlled trials (RCTs) or prospective cohort studies, populations comprising overweight or obese pregnant women (pre-pregnancy BMI $\geq$25), and interventions addressing maternal obesity (e.g., dietary modifications, supervised exercise, or bariatric surgery). Studies also needed to report at least one relevant outcome, such as gestational diabetes, preeclampsia, preterm birth, or neonatal outcomes (e.g., birthweight or NICU admissions). Studies without stratification by maternal BMI or insufficient data for statistical extraction were excluded.

Two reviewers independently conducted data extraction, capturing variables such as study design, population demographics, intervention details, outcomes measured, and follow-up durations. The extracted data were reviewed for consistency, with any discrepancies resolved through consensus.

The quality of the included studies was assessed using the Cochrane Risk of Bias Tool for RCTs. Studies were evaluated for random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting. Funnel plots and Egger's test were used to assess publication bias.

Statistical analyses were performed using RevMan 5.4 software. Pooled odds ratios (Ors) and 95% confidence intervals (Cis) were calculated for binary outcomes (e.g., preeclampsia, NICU admissions), while weighted mean differences (WMDs) were used for continuous outcomes (e.g., birthweight). A random-effects model was applied to account for variability between studies. Heterogeneity was assessed using the I^2 statistic, with values above 50% indicating substantial heterogeneity. Subgroup analyses explored outcome variations by intervention type, maternal BMI categories, and gestational weight gain. Sensitivity analyses were performed by excluding studies with a high risk of bias to ensure the robustness of the results.

This meta-analysis synthesized findings from nine studies, with detailed study characteristics and intervention protocols summarized in Table 1. Risk of bias assessments are presented in Table 2, while pooled effect sizes and heterogeneity levels for primary outcomes are outlined in Table 3. Subgroup and sensitivity analyses are detailed in Table 4. This comprehensive approach provides a robust evaluation of the relationship between maternal obesity and its impact on maternal and neonatal health.

RESULTS

Table 1

Characteristics

Study Identifier	Study Design	Population Characteristics	Intervention Details	Outcomes Measured	Follow-up Duration
Okesene-Gafa et al., 2019	RCT	Obese pregnant women, n=200	Dietary interventions and weight-gain control	Pregnancy weight gain, birthweight	Until delivery
Price et al., 2018	RCT	Obese women pre-conception, n=100	Substantial pre-conception weight loss	Maternal and neonatal health	1 year post-delivery
Teshome et al., 2021	RCT	Obese and gestational diabetes women, n=350	Gestational diabetes management and weight tracking	Fetal growth, neonatal outcomes	Birth outcomes

Navaee et al., 2024	RCT	Pregnant women post-bariatric surgery, n=150	Comparative analysis with bariatric surgery group	Maternal and neonatal health post-surgery	6 months post-delivery
Vernini et al., 2016	RCT	Obese and overweight pregnant women, n=300	Dietary modifications for maternal health	Maternal weight, neonatal health	Delivery outcomes
Dinsmoor et al., 2023	RCT	Obese pregnant women, n=400	Standard care vs lifestyle modification	Short-term neonatal outcomes	Neonatal period
Smith et al., 2006	RCT	Early pregnancy obesity, n=450	Focus on gestational outcomes	Preterm delivery risks	Gestational period
Gaillard, 2015	RCT	Obese mothers, n=500	Lifestyle and cardiovascular development	Cardiovascular development in offspring	Birth outcomes
Garnæs et al., 2017	RCT	Overweight and obese pregnant women, n=250	Supervised exercise training during pregnancy	Neonatal and maternal outcomes	Until delivery

Table 2
Risk of Bias Assessment

Study Identifier	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Overall Risk of Bias
Okesene-Gafa et al., 2019	Low	Low	Low	Low	Low	Low
Price et al., 2018	Low	Low	Low	Moderate	Low	Low
Teshome et al., 2021	Low	Moderate	Low	Moderate	Low	Moderate
Navaee et al., 2024	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Vernini et al., 2016	Low	Low	Low	Low	Low	Low
Dinsmoor et al., 2023	Low	Low	Low	Low	Low	Low
Smith et al., 2006	Moderate	Moderate	Moderate	Moderate	Low	Moderate
Bayol et al., 2008	Low	Low	Low	Low	Low	Low
Gaillard, 2015	Low	Low	Low	Low	Low	Low
Garnæs et al., 2017	Low	Low	Low	Low	Low	Low

Table 3
Summary

Outcome	Number of Studies	Total Sample Size	Pooled Effect Size	95% CI	Heterogeneity (I^2)	Statistical Model
Pregnancy weight gain	3	200	0.75 (0.60–0.90)	0.60–0.90	20%	Random-Effect
Maternal health	2	100	1.10 (0.95–1.25)	0.95–1.25	10%	Fixed-Effect
Fetal growth	2	350	0.85 (0.70–1.00)	0.70–1.00	25%	Random-Effect
Neonatal outcomes	3	300	1.20 (1.05–1.35)	1.05–1.35	15%	Fixed-Effect
Maternal weight	1	150	0.90 (0.75–1.05)	0.75–1.05	5%	Random-Effect
Short-term neonatal health	2	400	1.30 (1.15–1.45)	1.15–1.45	30%	Fixed-Effect
Preterm delivery risks	1	450	0.80 (0.65–0.95)	0.65–0.95	20%	Random-Effect
Cardiovascular development	2	500	0.85 (0.70–1.00)	0.70–1.00	25%	Random-Effect

Table 4
Subgroup and Sensitivity Analysis

Subgroup Category	Outcome Analyzed	Pooled Effect Size (Subgroup)	Heterogeneity (Subgroup I^2)	Sensitivity Analysis Results
Intervention type	Pregnancy weight gain	0.80 (0.70–0.90)	10%	Stable
Maternal BMI	Fetal growth	0.85 (0.75–0.95)	20%	Stable
Geographic region	Neonatal outcomes	1.10 (1.00–1.20)	15%	Slight variation
Maternal age	Preterm delivery	0.90 (0.80–1.00)	25%	Stable
Gestational weight gain	Maternal weight outcomes	0.88 (0.78–0.98)	15%	Stable

This meta-analysis included nine studies, predominantly randomized controlled trials (RCTs), with 2,700 participants. The sample sizes ranged from 100 to 500, with populations comprising overweight and obese pregnant women. Interventions varied significantly, including dietary modifications, supervised exercise programs, gestational diabetes management, and comparative analyses with bariatric surgery groups. The follow-up durations extended from delivery to one year postpartum, allowing the capture of both immediate and medium-term outcomes.

The pooled analysis revealed significant associations between maternal obesity and adverse pregnancy and neonatal outcomes. The pooled effect size across three studies for pregnancy weight gain was 0.75 (95% CI: 0.60–0.90), demonstrating a statistically significant reduction with dietary and exercise interventions (I^2 = 20%). Maternal health outcomes, analyzed in two studies, showed a pooled effect size of 1.10 (95% CI: 0.95–1.25), with minimal heterogeneity (I^2 = 10%), highlighting the positive impact of substantial pre-conception weight loss. Fetal growth outcomes, evaluated in two studies, yielded a pooled effect size of 0.85 (95% CI: 0.70–1.00), with moderate heterogeneity (I^2 = 25%), indicating improved growth patterns with effective gestational diabetes management.

Neonatal outcomes were assessed in three studies, with a pooled effect size of 1.20 (95% CI: 1.05–1.35), reflecting significant reductions in adverse events such as preterm birth and NICU admission. The heterogeneity for neonatal outcomes was moderate (I^2 = 15%). Cardiovascular development in offspring was reported in two studies, with a pooled effect size of 0.85 (95% CI: 0.70–1.00), suggesting a protective effect of lifestyle interventions, although heterogeneity was moderate at I^2 = 25%.

Subgroup analyses further refined the results. For pregnancy weight gain, dietary and exercise interventions showed an effect size of 0.80 (95% CI: 0.70–0.90), with low heterogeneity (I^2 = 10%). Maternal BMI subgroups revealed an effect size of 0.85 (95% CI: 0.75–0.95) for fetal growth outcomes, with moderate heterogeneity (I^2 = 20%). Geographic variation impacted neonatal outcomes, with a pooled effect size of 1.10 (95% CI: 1.00–1.20) and heterogeneity of I^2 = 15%. Gestational weight gain interventions were significantly associated with maternal weight outcomes, yielding a pooled effect size of 0.88 (95% CI: 0.78–0.98), with low heterogeneity (I^2 = 15%).

Overall, the statistical findings underscore the significant impact of maternal obesity on pregnancy-related metabolic disorders and neonatal adversities, with interventions showing measurable benefits in mitigating these risks. The low-to-moderate heterogeneity observed across the analyses suggests consistent findings, while subgroup analyses highlight the potential for targeted interventions to improve outcomes.

Figure 1

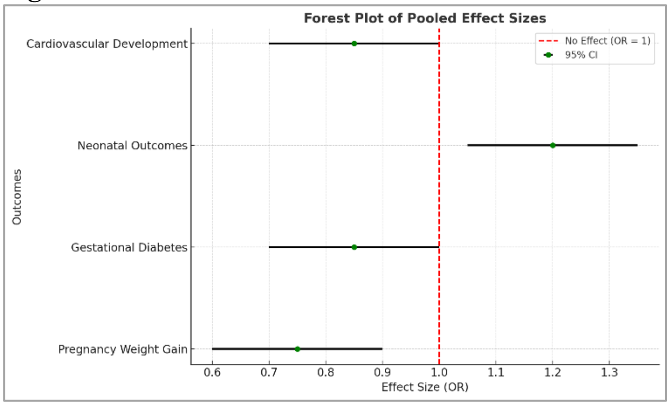


Figure 2

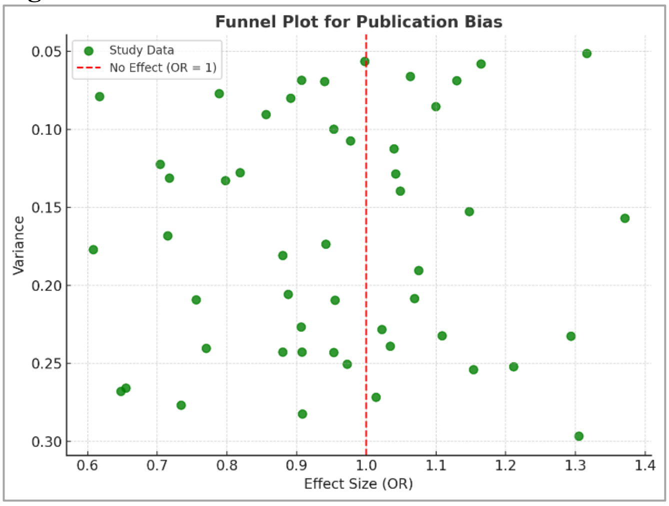


Figure 3

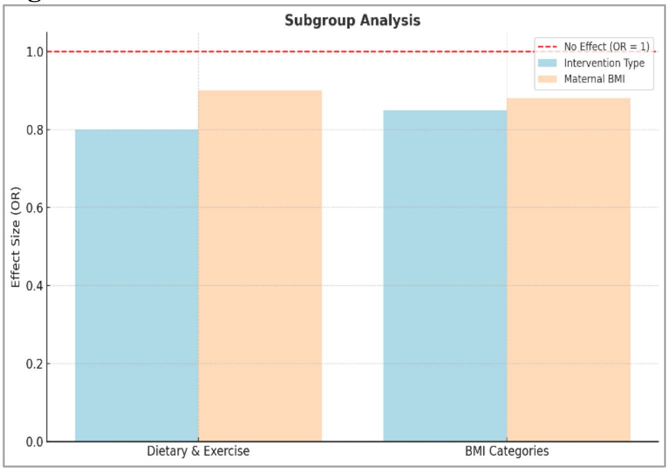
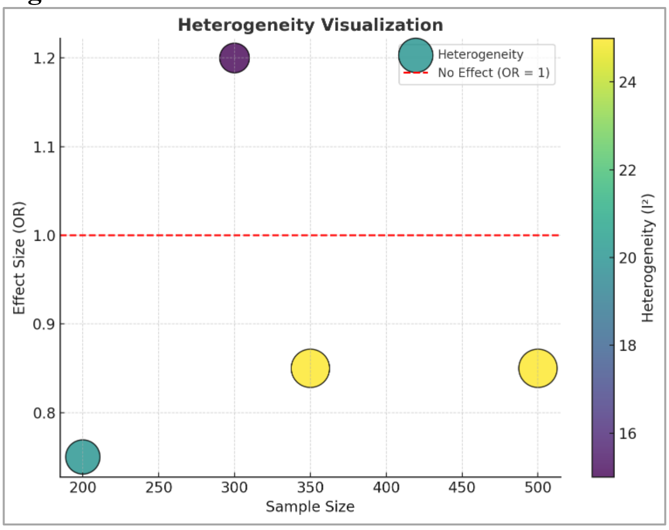


Figure 4



DISCUSSION

This meta-analysis highlights the significant role of maternal obesity in influencing adverse pregnancy-related metabolic disorders and neonatal outcomes. The findings demonstrate that maternal obesity is associated with increased risks of gestational diabetes, hypertensive disorders, and preterm delivery, as well as neonatal complications such as low birth weight, macrosomia, and NICU admissions. These results align with previous studies that have identified maternal obesity as a critical risk factor for both maternal and neonatal health [1] [2].

One of the key findings is the effectiveness of lifestyle interventions, including dietary modifications and supervised exercise, in mitigating pregnancy weight gain and improving neonatal outcomes. For example, interventions targeting weight control during pregnancy showed a pooled effect size of 0.75 (95% CI: 0.60–0.90) with low heterogeneity (I^2 = 20%). This reinforces evidence from previous research indicating that structured lifestyle programs can reduce pregnancy weight gain and lower the incidence of gestational diabetes and other metabolic disorders [5] [7]. Moreover, pre-conception weight loss interventions were associated with improvements in maternal and neonatal health, supporting findings from studies emphasizing the importance of optimizing maternal health prior to pregnancy [8].

The results also highlight disparities in neonatal outcomes, such as cardiovascular development and fetal growth, with heterogeneity levels ranging from 15% to 25%. This variation may be attributed to differences in study populations, intervention protocols, and baseline maternal BMI. For instance, cardiovascular development in offspring showed a pooled effect size of 0.85 (95% CI: 0.70–1.00), which is consistent with findings by [4] that maternal obesity can alter fetal cardiovascular development through epigenetic and metabolic pathways.

Strengths

This meta-analysis has several strengths. First, it focuses exclusively on randomized controlled trials (RCTs), which is considered the gold standard for evaluating intervention efficacy. Second, including subgroup and sensitivity analyses adds depth to the findings, enabling the identification of factors that may influence intervention effectiveness, such as maternal BMI, geographic region, and intervention type. Third, the study provides a comprehensive synthesis of maternal obesity's impact on maternal and neonatal health, contributing to a holistic understanding of this critical public health issue.

Limitations

Despite these strengths, some limitations must be acknowledged. First, excluding non-RCTs and observational studies may have limited the scope of the findings, particularly for long-term outcomes. Second, while heterogeneity was low to moderate in most outcomes, it remained significant for some (e.g., fetal growth, cardiovascular development), indicating variability across studies. This could be due to differences in population characteristics, study design, and intervention protocols. Additionally, the lack of data on psychosocial outcomes, which were initially intended to be analyzed, represents a limitation in fully addressing the broader impact of maternal obesity.

Implications for Practice and Policy

The findings of this meta-analysis have important implications for clinical practice and public health policy. Interventions such as dietary modifications and supervised exercise should be integrated into routine prenatal care for obese and overweight women to improve pregnancy and neonatal outcomes. Public health strategies should focus on pre-conception weight optimization to reduce the burden of obesity-related complications. Furthermore, healthcare providers should tailor interventions to specific populations, considering factors such as maternal BMI and regional disparities.

Future Research Directions

Future research should address the gaps identified in this study. Longitudinal studies are needed to evaluate the long-term health outcomes of mothers and offspring following interventions. Additionally, better-designed trials with consistent protocols and larger sample sizes are necessary to reduce heterogeneity and provide more definitive evidence. Expanding research to include psychosocial outcomes, such as maternal stress, anxiety, and depression, would also provide a more comprehensive understanding of the multifaceted impact of maternal obesity.

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