Factors Associated with Inappropriate Gestational Weight Gain

by
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Factors Associated with Inadequate Gestational Weight Gain

Chen-Xi Lin

Abstract

Background: Inadequate gestational weight gain (GWG) has become a prevalent health concern, raising risks for both maternal and neonatal health. Numerous studies have explored various factors associated with GWG across individual, familial, and societal domains, yet the findings remain inconclusive..

Method: This study aimed to investigate the factors associated with GWG, with a particular emphasis on the association between social/institutional, interpersonal/family, and maternal factors and excessive gestational weight gain and the relationship between antenatal depression and GWG. A systematic review and meta-analysis approach was cinducted. The Oregon Pregnancy Risk Assessment Monitoring System (PRAMS) for 2016-2021 was utilized for secondary data analysis.

Results: The results of the meta-analysis showed that antenatal depression was associated with a higher risk of EGWG (pooled OR = 1.13, 95% CI, 1.04–1.22) and IGWG (pooled OR=1.09, 95% CI, 1.02-1.16). The association between antenatal depression and GWG varied at different stages of pregnancy. No association was found between antenatal depression occurring later in pregnancy and insufficient or excessive GWG. The secondary analysis of PRAMS dataset found

no social/institutional and interpersonal/family factors were observed to be associated with EGWG.Having gestational diabetes is associated with a lower risk of EGWG (OR=0.43, 95% CI= 0.22-0.84). No associations were found between any of the depression parameters and GWG, EGWG, or IGWG.

Conclusion: It is important to monitor blood sugar levels and pay close attention to depression, especially when it occurs in the first half of pregnancy. To clarify the association between antenatal depression and GWG, further trimester-specific studies are needed.

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CHAPTER ONE

Introduction

Inadequate gestational weight gain (GWG) has become a prevalent health concern, elevating the risk to both maternal and neonatal health (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, Rode, et al., 2017; Goldstein et al., 2018; Khanolkar et al., 2020). In response, the Institute of Medicine (IOM) updated its weight gain guidelines for expectant mothers in 2009 (IOM, 2010). A recent systematic review and meta-analysis referencing the IOM guidelines found that only 32.8% of mothers adhered to the IOM's 2009 standards. Of note, 27.8% (95% CI; 26.5 - 29.1) exceeded the guideline, while 39.4% (95% CI; 37.1- 41.7) did not achieve them (Martínez-Hortelano et al., 2020).

It has been shown that excessive GWG (EGWG) is associated with a higher risk of fetal macrosomia (Goldstein et al., 2018), large gestational age, gestational hypertension, preeclampsia/eclampsia, cesarean delivery, extended hospital stay (Khanolkar et al., 2020), and postpartum weight retention or obesity after delivery (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, & Rode, 2017). Conversely, insufficient GWG (IGWG) has been associated with an increased risk of small gestational age, developmental delay (Motoki et al., 2022), and preterm birth (Goldstein et al., 2018; Khanolkar et al., 2020).

Numerous studies have delved into the various factors associated with GWG, encompassing

individual, familial, and societal domains, but the findings remain inconclusive (Sámano et al., 2023; Zhou et al., 2022). A notable risk factor for GWG is depression, which has become a significant health concern among pregnant women in the United States, with a 39% increase in diagnoses over the past decade (Tabb et al., 2023). While depression and weight status exhibit a positive correlation in adult populations, and this relationship is particularly pronounced in females as compared to males (Barone & Barra, 2022), the nexus between depression and weight status in pregnant women has yielded mixed results in previous research (Hartley et al., 2015; Kapadia et al., 2015).

Theoretical Framework

The theoretical framework for this dissertation was based on the IOM framework of determinants of GWG that was updated in 2009 to investigate the potential risk and protective factors of inadequate GWG(Figure 1.1). According to the IOM conceptual framework, social/built/nature and life stage environment, and maternal factors are potential determinants of gestational weight gain. Social/built/nature and life stage environment include social/institutional, environmental, neighborhood/community, and interpersonal/family factors (IOM, 2010). Maternal factors include genetic characteristics, developmental programming, epigenetics, sociodemographic, anthropometric, physiological, medical, psychological, and behavioral factors (IOM, 2010) (Figure 1.2).

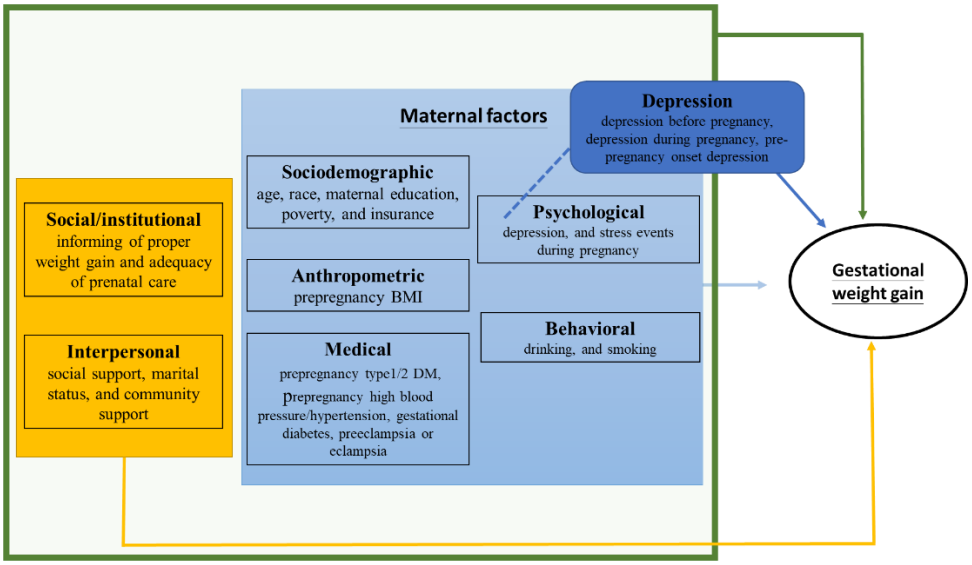

Figure 1.1 A Conceptual Framework of the Study (Adopted from the IOM framework)

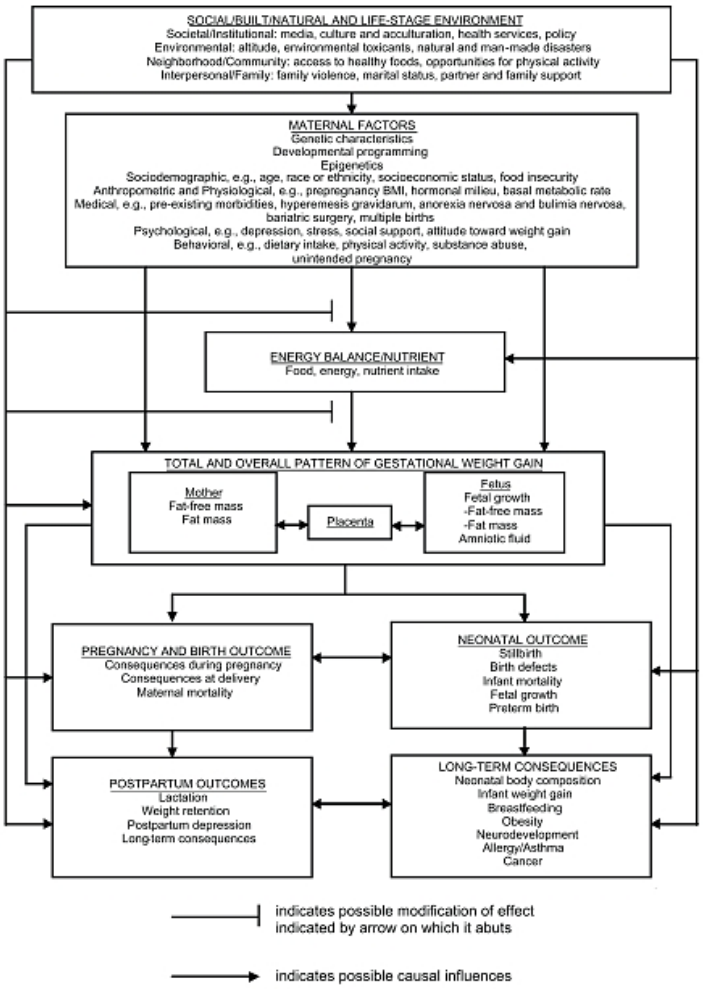

Figure.1.2 The schematic summary of determinants associated with GWG outlined by the IOM

Dissertation Outline

This dissertation comprises three papers, each delving into the factors linked to GWG, with a particular emphasis on the relationship between depression and GWG. Chapter one provides an introduction and theoretical framework, and chapter five synthesizes findings from all three papers and proposes recommendations for future research and practice.

Paper One: The Relationship Between Antenatal Depression and Gestational Weight Gain: A Systematic Review and Meta-analysis.

The purpose of this paper:

1. To investigate the relationship between antenatal depressive symptoms and GWG based on current evidence.
2. To investigate whether the relationship differs with the stage of the pregnancy.

Paper Two: Factors Associated with Excessive Gestational Weight Gain in the United States using Oregon PRAMS: A population-based study.

The purpose of this paper:

1. To investigate the association between social/institutional factors and EGWG based on the Institute of Medicine (IOM) framework.
2. To investigate the association between interpersonal/family factors and EGWG based on the Institute of Medicine (IOM) framework.

3. To investigate the association between maternal factors and EGWG based on the Institute of Medicine (IOM) framework.

Paper Three: Association Between Antenatal Depression and GWG using Oregon PRAMS: A population-based study.

The purpose of this paper:

1. To investigate the association between depression and GWG.
2. To examine whether this association differs between no depression, depression before pregnancy, depression during pregnancy, and prepregnancy onset depression.

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CHAPTER TWO

The Relationship Between Antenatal Depression and Gestational Weight Gain: A Systematic Review and Meta-analysis

Abstract

Purpose: To investigate the relationship between antenatal depressive symptoms and inadequate gestational weight gain (GWG) based on current evidence and whether the relationship differs with the stage of pregnancy.

Methods: A systematic search of PubMed, EMBASE, PsycINFO, Web of Science, and CINAHL databases was conducted, focusing on research published between January 2018 and June 2023. Observational studies assessing the association between antenatal depression and GWG were included. The random-effects model was used to estimate the pooled odds ratio.

Results: Of the 1,797 studies identified, 15 met the inclusion criteria. In the included studies, the prevalence of excessive GWG (EGWG) ranged between 4.9 to 55%, whereas the prevalence of insufficient GWG (IGWG) ranged between 15.3 to 67.2%. Meta-analysis results indicated that antenatal depression was associated with a higher risk of EGWG (pooled OR = 1.13, 95% CI, 1.04–1.22) and IGWG (pooled OR=1.09, 95% CI, 1.02-1.16). Based on three studies that provided analysis needed data, antenatal depression in the first half of pregnancy is associated with IGWG (pooled OR=1.10, 95% CI, 1.02-1.18). No association was found between antenatal

depression occurring later in pregnancy and insufficient or EGWG (pooled OR= 0.88, 95% CI, 0.42-1.33; pooled OR= 0.98, 95% CI, 0.58-1.40).

Conclusions: Overall, antenatal depression appears to be associated with inadequate GWG and may be more prominent earlier in pregnancy. To clarify the association between antenatal depression and GWG, further trimester-specific studies are needed.

Keywords: Gestational weight gain, antenatal depression, maternal weight, pregnant

Statements and Declarations: The authors have no relevant financial or non-financial interests to disclose. No funding was received for conducting this study.

Introduction

Background

During the past three decades, inadequate gestational weight gain (GWG) has become a global issue, with problems of excessive GWG (EGWG) and insufficient GWG (IGWG) reported (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, Rode, et al., 2017; Khanolkar et al., 2020). In 2009, the Institute of Medicine (IOM) updated the weight gain recommendations for pregnant women based on prepregnant body mass index (BMI) (Council, 2010) (Table 2.1). Using the 2009 IOM guidelines, a recent systematic review and meta-analysis reported that only 32.8% of mothers were able to comply with the 2009 IOM guidelines, while the prevalence of GWG above and below the 2009 IOM guidelines was 27.8% (95% CI; 26.5 - 29.1) and 39.4% (95% CI; 37.1- 41.7), respectively (Martínez-Hortelano et al., 2020).

Table 2.1 Institute of Medicine Recommendations for Weight Gain During Pregnancy

Prepregnancy Body Mass Index	Total Weight Gain	Rates of Weight Gain in Second & Third Trimesters
	Range in kg	Mean (range) in kg/week
Underweight ($\leqq$18.5 kg/m^2)	12.5-18	0.51 (0.44–0.58)
Normal weight (18.5–24.9 kg/m^2)	11.5—16	0.42 (0.35–0.50)
Overweight (25.0–29.9 kg/m^2)	7-11.5	0.28 (0.23–0.33)
Obese ($\geqq$30.0 kg/m^2)	5-9	0.22 (0.17–0.27)

Note. Calculation assumes a 0.5-2 kg (1.1-4.4 lbs) weight gain in the first trimester.

Inadequate GWG is associated with adverse maternal and neonatal outcomes (Khanolkar et al., 2020). EGWG is associated with a higher risk of fetal macrosomia (Goldstein et al., 2018), large gestational age, gestational hypertension, preeclampsia/eclampsia, cesarean delivery, extended hospital stay (Khanolkar et al., 2020), and postpartum weight retention or obesity after delivery (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, & Rode, 2017), while IGWG is associated with a higher risk of small for gestational age, developmental delay (Motoki et al., 2022), and preterm birth (Goldstein et al., 2018; Khanolkar et al., 2020).

Several factors have been found to increase the risk for inadequate GWG, including antenatal depression (Zhou et al., 2022). Previous studies examining the association between maternal depression and maternal weight reported inconsistent results. Some of the previously published reviews suggested that depression was not related to GWG (Dachew et al., 2020), while others found that depression was associated with EGWG or high BMI during pregnancy (Faria-Schützer et al., 2017; Hartley et al., 2015), and one suggested the evidence is limited to inconclusive associations between depressive symptoms and maternal weight (Milgrom et al., 2012). The timing of depression has been suggested as one of the possible reasons for the varied relationships between depression and GWG found in previous studies (Badon et al., 2019).

Although the association between depression and maternal GWG is unclear, antenatal depression is a common global health problem with a prevalence rate ranging from 15 to 65%

worldwide (Dadi et al., 2020). Antenatal depression has been reported to be associated with adverse outcomes for both the mother and her child, including intrauterine fetal death (Khanghah et al., 2020), preterm birth (Dadi et al., 2020; Khanghah et al., 2020), low birth weight (Dadi et al., 2020; Khanghah et al., 2020), fetal growth restriction (Khanghah et al., 2020), infant intensive care unit admission (Jacques et al., 2019), preeclampsia (Khanghah et al., 2020), cesarean section (Khanghah et al., 2020), poor prenatal attachment (Smorti et al., 2019), and increased risk of future psychiatric disorders for both mothers and children (Ghaedrahmati et al., 2018; Smith et al., 2019). Understanding the relationship between antenatal depression and GWG can provide greater insight into the impact of depression during pregnancy and lead to interventions to promote healthy weight gain patterns to minimize the risks associated with excessive or inadequate GWG.

Objectives

This systematic review and meta-analysis aimed to investigate (1) the relationship between antenatal depressive symptoms and GWG based on current evidence, and (2) whether the relationship differs with the stage of the pregnancy. The results of this review can serve as a reference for future studies and clinical screening for depression and GWG.

Methods

Protocol and Registration

This systematic review and meta-analysis utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). The study protocol was registered in the International Prospective Register of Systematic Reviews (registration number: CRD42023436865).

Definitions of key terms

For the purposes of this review, some key terms are defined as follows.

Antenatal depression

Antenatal depression was defined as depression or depressive symptoms experienced during pregnancy as measured by screening or diagnostic measures (Dachew et al., 2020). The first half of antenatal depression refers to antenatal depression present up to and including the twentieth week of gestation. The second half antenatal depression refers to antenatal depression present between 21 and the birth of the child.

Gestational weight gain

The definition of GWG was the weight difference women experienced between conception/prepregnant weight and the birth of an infant (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, Rode, et al., 2017). In this review, maternal weight change

measured at any time point during pregnancy is considered gestational weight.

Eligibility criteria

Studies were eligible for inclusion in this systematic review if they (1) examined the associations between gestational weight gain and antenatal depression, (2) used a quantitative research design, (3) recruited people capable of pregnancy, (4) were written in English, and (5) were published between January 2018 to June 2023. Studies were excluded if the sample was limited to those with specific diseases (e.g., diabetes, gestational diabetes, and polycystic ovary syndrome) or specific prepregnancy weight status (e.g., recruited obese or underweight participants only). Grey literature, non-peer reviews journal articles, unpublished theses, conference abstracts, letters to editors, review articles, and commentary articles were excluded.

Search Strategy

A systematic search of PubMed, EMBASE, PsycINFO, Web of Science, and CINAHL databases was conducted with assistance from a librarian. Medical Subject Heading (MeSH) and keyword searches were used to extract relevant articles based on inclusion and exclusion criteria. The search was performed using the following relevant search terms (1) depress OR depression, (2) gestational weight OR weight gain OR weight change, and (3) pregna* OR maternal OR maternity OR prenatal OR antenatal OR antepartum. Detailed search strategies for each database are presented in Table 2.2. A hand search was conducted of the references in the reference lists of

the included studies.

Table 2.2 Search Terms and Strategies

Database	Search Strategies	Results
CINAHL	limit to peer review/scholarly articles (pregna* OR maternal OR maternity OR prenatal OR antenatal OR antepartum) AND (depression OR depressive) AND (“gestational weight” OR “weight gain” OR “weight change”)	178
EMBASE	limit to articles/articles in press ('pregnancy'/exp OR 'pregnancy' OR pregnan* OR 'maternal' OR 'maternal'/exp OR maternal OR 'maternity' OR 'maternity'/exp OR maternity OR 'prenatal' OR 'prenatal'/exp OR prenatal OR antenatal OR antepartum) AND ('depression' OR 'depression'/exp OR depression OR depressive) AND ('gestational weight gain'/exp OR 'gestational weight gain' OR 'gestational weight' OR 'weight gain'/exp OR 'weight gain' OR 'weight change' OR 'body weight change')	512
PsycINFO	limit to peer review (pregna* OR maternal OR maternity OR prenatal OR antenatal OR antepartum) AND (depression OR depressive) AND (“gestational weight” OR “weight gain” OR “weight change”)	206
PubMed	("Pregnancy"[MeSH] OR pregna* OR maternal OR maternity OR prenatal OR antenatal OR antepartum) AND ("Depression"[Mesh] OR depression OR depressive OR "Depressive Disorder"[Mesh]) AND ("Gestational Weight Gain"[Mesh] OR “gestational weight” OR “weight gain” OR "Weight Gain"[Mesh] OR “weight change”)	342
Web of Science	(pregna* OR maternal OR maternity OR prenatal OR antenatal OR antepartum) AND (depression OR depressive) AND (“gestational weight” OR “weight gain” OR “weight change”)	559

Study Selection

The eligibility assessment was performed by two authors independently (J.C and C.L.), and disagreements were resolved through discussion. The relevant results were compiled in Endnote (version 20, Philadelphia) to exclude duplicate research articles. Studies were then screened by title and abstract and those that met the inclusion criteria were subjected to full-text review using eligibility with exclusion criteria based on participants and outcome measurements.

Data Extraction

Data were extracted from eligible studies to obtain the following information: (1) study characteristics, including the year of publication, location of study, sample size, age of participants, ethnicity, prevalence of EGWG and IGWG, and summary of results; and (2) measurement characteristics, including study design, tools used to measure depressive symptoms and associated cutoff scores, the timing of depression assessments, measured GWG period, and whether the IOM recommendation was used to categorize GWG.

Quality Assessment

The quality of the included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tool (Barker et al., 2023) for cross-sectional studies and cohort studies. The JBI critical appraisal tool included eight items and eleven items in the checklist for cross-sectional study and cohort study, respectively, and a summary rating of poor, fair, or good quality is derived. Since no validated study provides a cut-off score for JBI tool ratings of poor, fair, or good quality, one-third of the maximum total score was chosen as an arbitrary cut-off for each category for this review. For cohort studies, the cut-off points were three and seven, and for cross-sectional studies, the cut-off points were three and six.

Data analysis

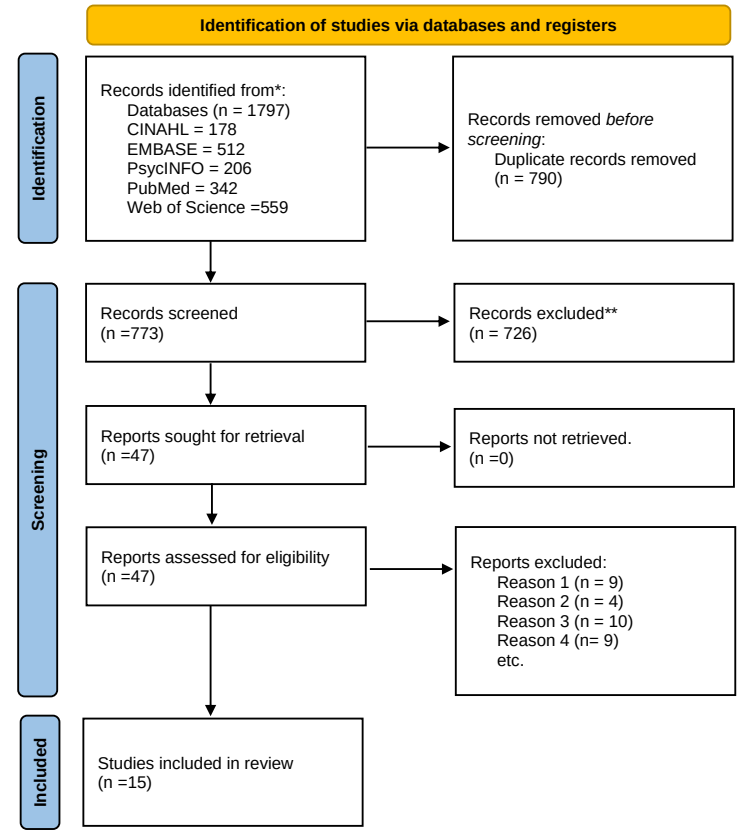
In the meta-analysis, the odds ratios (ORs) value was used to calculate the combined effect

size and its 95% CI (Chang & Hoaglin, 2017). The heterogeneity among the studies was evaluated using the heterogeneity chi-squared, I-square, and Tau-squared. The random effect model was adopted as it provided a more conservative result than a fixed model (Borenstein et al., 2010). Sensitivity analysis was performed by excluding studies one by one to detect whether any study accounted for a large proportion of heterogeneity. Evidence of publication bias was assessed using funnel plots, Begg's, and Egger's tests. Subgroup analyses were performed across key study characteristics, including study design, antenatal depression measurement, and GWG tracking period. All statistical analyses were performed using STATA (version 18, College Station, Texas). Statistical significance was defined as two-sided $P < 0.05$.

Result

Study selection

The study selection process is shown in Figure 2.1. The database search returned 1,797 records. After removing the duplicates, 773 articles were screened for eligibility. A total of 726 studies were excluded based on title and abstract, and 32 were excluded based on full-text screening. There were 15 studies that met the systematic review inclusion criteria, and 10 studies that provided data on the association between antenatal depression and different GWG categories and could be included in the meta-analysis. A hand search of the references found no further studies.



Reason 1: Don't have data of GWG.

Reason 2: Don't have data of antenatal depression.

Reason 3: Don't have results of the association between antenatal depression and GWG.

Reason 4: Focus on specific participant only

Figure 2.1 Study selection process

Study characteristics

The basic information for each included study is shown in Table 2.3. This review included studies from the Americas (n = 5), Asia (n = 4), Europe (n = 5), and Africa (n = 1).

In total, 105,399 participants were included, all of whom identified as women, with sample

sizes varying from 70 (Hecht et al., 2020) to 87,600 (Badon et al., 2019). In the included studies, the prevalence of EGWG ranged between 4.9 and 55%, whereas the prevalence of IGWG ranged between 15.3 to 67.2%.

Table 2.3 Study Characteristics

Authors, publication year	Study location	Sample size	Age of participants (SD/%)	Ethnicity	Prevalence of IGWG	Prevalence of NGWG	Summary of results
Asefa et al., 2021	Sub-Saharan Africa	359	25.3 (3.9)		67.2	27.9	Perinatal depression was not associated with inadequate GWG, but associated with EGWG
Babacan GÜMÜŞ et al., 2021	Turkey	713	28.1 (5.25)		-	-	Having excessive - weight gain is associated with higher depression.
Badon et al., 2019	US	87,600	30.2 (5.4)	Non-Hispanic white (41) Non-Hispanic black (6) Hispanic (25) Asian/Pacific Islander (24) Native American/multiracial (4) Other/unknown (1)	24%	21%	Early-onset prenatal depression was associated with greater GWG and greater risk of EGWG Prepregnancy onset depression increased the risk of both IGWG and EGWG

Authors, publication year	Study location	Sample size	Age of participants (SD/%)	Ethnicity	Prevalence of IGWG	Prevalence of NGWG	Summary of results
Braig et al., 2020	Germany	970	≥ 36 70.3%		22.7	38.9	No association between depressive symptoms and GWG.
Chagarlamudi et al., 2018	US	410	approximately 27	Black (50.7) White (34) Hispanic or other (15)	29.5	25.9	Prenatal depression was not associated with exceeding or falling recommended GWG compared with meeting recommendations.
Choi et al., 2022	Korea	4,195	33.3 (3.8)		32	45	Women with EGWG had an increased risk of antenatal depression symptoms.
Dekel et al., 2019	Finland	824	-		-	-	More depression symptoms in the first trimester were associated with higher maternal relative weight gain.
Dolatian et al., 2020	Iran	734	28.73 (4.41)	Kurdish (81.6) Lor (10.5) Lak (5.3) Others (2.6)	28.7	49.6	Prenatal depression had an indirect effect on GWG.

Authors, publication year	Study location	Sample size	Age of participants (SD/%)	Ethnicity	Prevalence of IGWG	Prevalence of NGWG	Summary of results
Eichler et al., 2019	Germany	463	29.77 (4.18)		33.2	22.3	Weight gain in the second trimester did not predict prenatal depressive symptoms in the second or third trimester.
Farias et al., 2021	Brazil	206	< 30 (67.6%)		19.7	27.7	Women with prenatal depression in the first trimester had lower total GWG compared to women without prenatal depression in the first trimester. Women with persistent depressive symptoms had a higher risk of insufficient GWG compared to women without persistent depression.

Authors, publication year	Study location	Sample size	Age of participants (SD/%)	Ethnicity	Prevalence of IGWG	Prevalence of NGWG	Summary of results
Garay et al., 2021	UK	275	34.0 (7.0)	Caucasian (92.4) Other (7.6)	15.3	28.7	Prenatal depression was associated with increased odds of EGWG compared to normal GWG.
Gomes et al., 2023	Brazil	297	25.9 (5.9)	White (54.2) Others (45.9)	18.5	27.3	The presence of depressive symptoms significantly increased the chance of IGWG
Hecht et al., 2020	US	70	33.12 (4.13)	Caucasian (81.4) African American (5.7) Asian (5.7) Hispanic/Latino (4.3) Native American/ Alaskan (2.9)	-	-	Prenatal depression was a significant contributor to EGWG.
Vehmeijer et al., 2020	Netherlands	3,393	31.0 (4.7)	Dutch-European (72.1) Surinamese (5.9) Turkish (5.2) Moroccan (3.2) Cape Verdian (2.1) Dutch Antilles(2.1) Others (9.4)	20.1	34.9	Depression was not associated with weight gain in the second half of pregnancy and the risk of inadequate/EGWG.

Authors, publication year	Study location	Sample size	Age of participants (SD/%)	Ethnicity	Prevalence of IGWG	Prevalence of NGWG	Summary of results
Zhou et al., 2023	China	4,890	30.59 (3.57)	Han (98.1) Non-Han (1.9)	20.4	42.1	Depression scores did not differ significantly among the GWG subgroup. There was no significant association between depression scores and GWG.

Abbreviation: BMI, body mass index; GWG, gestational weight gain; IOM, the Institute of Medicine

A summary of the characteristics of the included studies is shown in Table 2.4. Of the 15 studies, most were cohort studies (n=12); 9 used a prospective design, and 3 used a retrospective design. Three included studies were cross-sectional studies (Babacan GÜMÜŞ et al., 2021; Gomes et al., 2023; Hecht et al., 2020). Most of the studies used the Edinburgh Postnatal Depression Scale (EPDS) (n = 8) for assessing maternal antenatal depressive symptoms and the 2009 IOM recommendation for classifying GWG (n=11). Only five studies calculated GWG from maternal weight changes over a period greater than eight months (Braig et al., 2020; Chagarlamudi et al., 2018; Choi et al., 2022; Farias et al., 2021; Garay et al., 2021).

Four studies examined antenatal depression at different stages of pregnancy (Badon et al., 2019; Dekel et al., 2019; Eichler et al., 2019; Farias et al., 2021), and only two studies reported

GWG data at different stages of pregnancy (Braig et al., 2020; Farias et al., 2021). The most common confounders adjusted for in the analyses across all included studies were level of education (n=8) and maternal age (n=7).

Table 2.4 Study Design and Measurement of Depression and Gestational Weight Gain

Authors, publication year	Study design	Depression			Gestational weight gain	
		Measurement	Cut-off score	Timing	Weight gain period	Measurement
Asefa et al., 2021	Prospective cohort	EPDS	Unclear	Unclear	Between 16weeks and 36 weeks	Categorized based on IOM recommendations
Babacan GÜMÜŞ et al., 2021	Cross-sectional	BSI (Depression subscales)	Continue	From the first to the third trimester	Unclear	Unclear
Badon et al., 2019	Prospective cohort	1.Depressive symptoms* 2.PHQ-9	5, 10, and 15	1.6 months before pregnancy 2.Within the first 20 weeks of pregnancy	Between the weight at depression screening time and the last prenatal weight before delivery.	1.GWG rate (lb/week) 2.Categorized based on IOM recommendations
Braig et al., 2020	Retrospective cohort	HADS (depression domain)	Tert 1, Tert 2, and Tert 3	Unclear	The difference between the monthly GWGs and GWG in 1st month	Obstetrician-documented weight measured nearest to the end of each gestational month till month 9

Authors, publication year	Study design	Depression			Gestational weight gain	
		Measurement	Cut-off score	Timing	Weight gain period	Measurement
Chagarlamudi et al., 2018	Retrospective cohort	EPDS	≥10	First prenatal care visit	Between prepregnancy weight and weight at 36 weeks.	Categorized based on IOM recommendations
Choi et al., 2022	Prospective cohort	EPDS	≥10	1.Before 12 weeks 2.24 weeks 3.36-40 weeks	1.Before 12 weeks 2.24 weeks 3.36-40 weeks 4.End of pregnancy 5.	Categorized based on IOM recommendations
Dekel et al., 2019	Prospective cohort	EPDS	≥10	1.6-12 weeks 2.28-43 weeks	-	1.Total GWG (kg) 2.Maternal relative weight gain (in %)
Dolatian et al., 2020	Prospective cohort	DASS-21	Continue	24–28 gestational weeks	-	Total GWG
Eichler et al., 2019	Prospective cohort	PHQ-9	≥10	1.23-28 week 2.33-38 weeks	Between weight at the beginning of pregnancy and objectively measured weight.	1.Weight gain during pregnancy (kg) 2.GWG of 2nd trimester categorized based on IOM recommendation.
Farias et al., 2021	Prospective cohort	EPDS	≥ 11	1.5–13 weeks 2.20–26 weeks 3.30–36 weeks	Between prepregnancy weight and the weight in each visit.	1.Cumulative GWG in each visit 2.Total GWG categorized based on IOM recommendations

Authors, publication year	Study design	Depression			Gestational weight gain	
		Measurement	Cut-off score	Timing	Weight gain period	Measurement
Garay et al., 2021	Retrospective cohort	EPDS	≥ 13	37 weeks or above	Between prepregnancy weight and weight at delivery.	Total GWG categorized based on IOM recommendations.
Gomes et al., 2023	Cross-sectional	EPDS	≥ 13	unclear	beginning of the second and end of the third gestational trimester.	Average weekly weight gain is categorized based on the IOM recommendations.
Gomes et al., 2023	Cross-sectional	EPDS	≥ 13	unclear	beginning of the second and end of the third gestational trimester.	Average weekly weight gain is categorized based on the IOM recommendations.
Hecht et al., 2020	Cross-sectional	EPDS	Continue	8–41 weeks	Between prepregnancy weight and the weight at the time of data collection.	Weight at data collected categorized based on the IOM recommendations

Authors, publication year	Study design	Depression			Gestational weight gain	
		Measurement	Cut-off score	Timing	Weight gain period	Measurement
Vehmeijer et al., 2020	Prospective cohort	BSI (depression subscales)	Continue	20 weeks	1.Maximum weight in the 2nd half of pregnancy 2.Between prepregnancy weight and maximum weight in pregnancy	1.Weight gain in the second half of pregnancy. 2.Total GWG categorized based on the IOM recommendations
Zhou et al., 2023	Prospective cohort	CESD	16	Unclear	Difference between pre-pregnancy weight and weight during pregnancy	Total GWG categorized based on the IOM recommendations

Abbreviation: EPDS, The Edinburgh Postnatal Depression Scale; BSI, The Brief Symptom Inventory questionnaire; PHQ, Patient Health Questionnaire; HADS, Hospital Anxiety and Depression Scale; DASS-21, DASS-21 standard questionnaire of stress, anxiety, and depression; CESD, Centers for Epidemiologic Study-Depression.

* Depressive symptoms were defined by DSM-V diagnosis codes and usage of antidepressant medication

Risk of bias of included studies

All but one of the studies were rated as good quality using the JBI quality assessment scale for cohort and cross-sectional studies. One study (Babacan GÜMÜŞ et al., 2021) was rated as fair quality. Detailed quality assessment results are presented in Table 2.5.

Table 2.5 Quality Assessment Results Using the JBI Quality Assessment Scale (Barker et al., 2023)

Cohort studies													
Authors, publication year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total score**	**Quality**
Asefa et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Badon et al., 2019	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	9	Good
Braig et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11	Good
Chagarlamudi et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Choi et al., 2022	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Dekel et al., 2019	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	10	Good
Dolatian et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	U	N	Y	9	Good
Eichler et al., 2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11	Good
Farias et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Garay et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Vehmeijer et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	10	Good
Zhou et al., 2023	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	10	Good
Cross-sectional studies													
Authors, publication year	1	2	3	4	5	6	7	8	Total score	Quality			
Babacan GÜMÜŞ et al., 2021	Y	Y	Y	Y	N	N	U	Y	5	Fair			
Gomes et al., 2023	Y	Y	Y	Y	Y	Y	Y	Y	8	Good			
Hecht et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	8	Good			

Abbreviation: Y, yes; N, No; U, unclear; NA, not applicable

The relationship between antenatal depression and GWG throughout pregnancy

Inconsistent results regarding the association between antenatal depression and GWG were found among the 15 studies. Five studies found no significant association between antenatal depression and GWG (Braig et al., 2020; Chagarlamudi et al., 2018; Eichler et al., 2019; Vehmeijer et al., 2020; Zhou et al., 2023). Six studies reported that antenatal depression was associated with EGWG (Asefa et al., 2021; Babacan GÜMÜŞ et al., 2021; Badon et al., 2019; Choi et al., 2022; Garay et al., 2021; Hecht et al., 2020), and one study reported that depression was associated with higher GWG (Dekel et al., 2019). Conversely, three studies reported that antenatal depression was associated with IGWG (Dolatian et al., 2020; Farias et al., 2021; Gomes et al., 2023), and one of the three studies found that the relationship was significant only when antenatal depression occurred during all three trimesters (Farias et al., 2021).

All of the five studies that found no significant association between antenatal depression and GWG were cohort studies design (Braig et al., 2020; Chagarlamudi et al., 2018; Eichler et al., 2019; Vehmeijer et al., 2020; Zhou et al., 2023), whereas all cross-sectional studies reported significant findings. However, the findings were inconsistent, with two reporting that antenatal depression was associated with EGWG (Babacan GÜMÜŞ et al., 2021; Hecht et al., 2020) and one study reporting antenatal depression was associated with IGWG (Gomes et al., 2023). Study findings did not qualitatively appear to vary based on publication year, study location,

depression, or GWG measurements.

Antenatal depression and EGWG: meta-analysis findings

Ten studies included in the meta-analysis investigated the relationship between antenatal depression and EGWG. The meta-analysis results showed that women with antenatal depression had a significantly higher odds ratio of EGWG (pooled OR = 1.13, 95% CI, 1.04–1.22) compared with women without antenatal depression (Figure 2.2). The between-study heterogeneity was low (Heterogeneity chi-squared = 14.81, I-square = 39.2%, Tau-squared = 0.006). The results of leave-one-out sensitivity analysis with pooled estimates varied between 1.12 (95% CI, 0.98–1.26) and 1.14 (95% CI, 1.04–1.25). The funnel plot displayed minor asymmetry (Figure 2.3), and Begg's and Egger's tests did not indicate publication bias (P=0.531 and P=0.396, respectively). No statistically significant subgroup differences were found when studies were grouped based on study design (Q<0.01, P=0.987), whether they used EPDS to assess depression or another scale (Q=0.01, P=0.928), whether GWG was tracked over eight months or less (Q=0.49, P=0.486), or whether the prevalence of EGWG was higher or lower than 50% (Q=0.02, P=0.888).

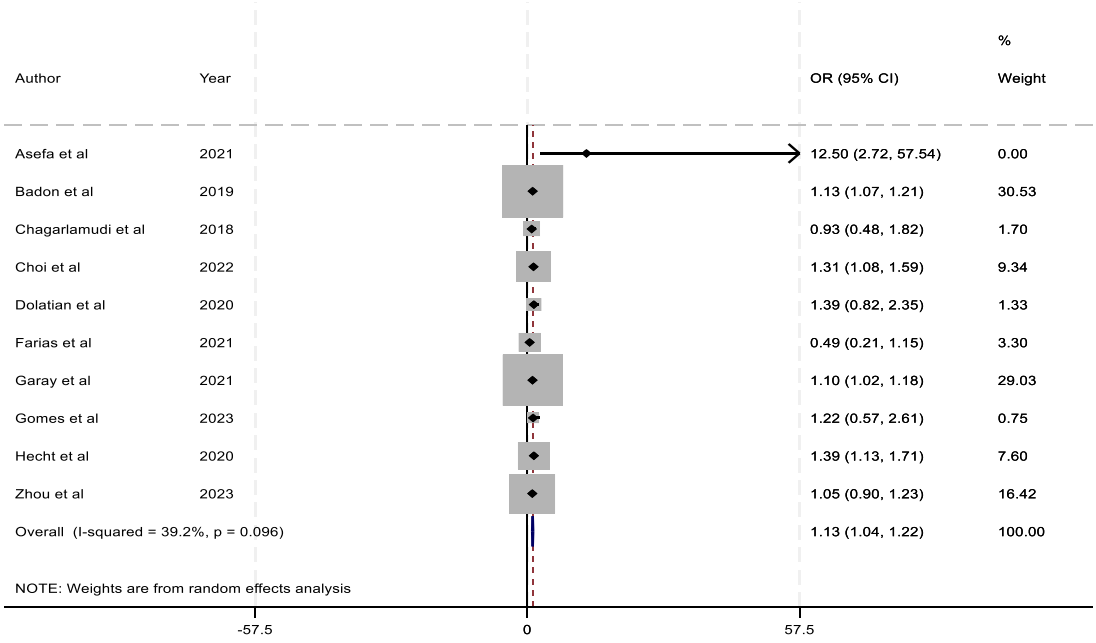


Figure 2.2 Forest plot of antenatal depression and EGWG

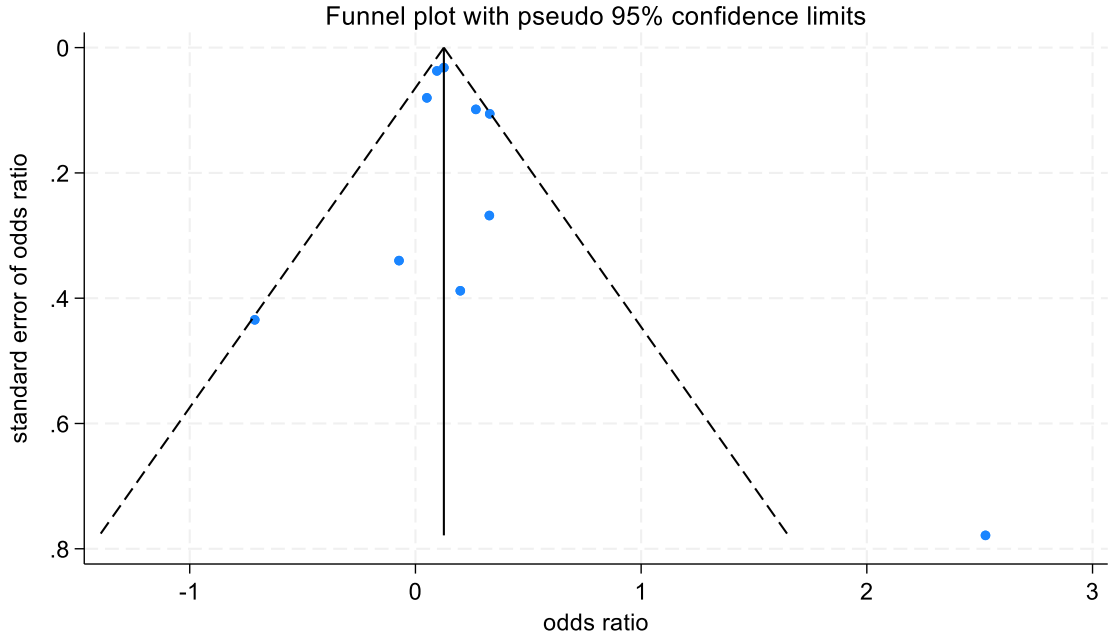


Figure 2.3 Funnel plot of antenatal depression and EGWG

Antenatal depression and IGWG: meta-analysis findings

Eight studies were included in the meta-analysis to investigate the relationship between antenatal depression and IGWG. Meta-analysis results indicated that women with antenatal depression were significantly more likely to have IGWG (pooled OR=1.09, 95% CI, 1.02-1.16) compared with those without antenatal depression (Figure 2.4). The between-study heterogeneity was low (Heterogeneity chi-squared = 5.38, P=0.614, I-square = 0.0%, Tau-squared <0.0001). The results of leave-one-out sensitivity analysis with pooled estimates varied between 1.08 (95% CI, 0.94–1.2) and 1.11 (95% CI, 1.04–1.19). The funnel plot displayed minor asymmetry (Figure 2.5), and Begg's and Egger's tests did not indicate publication bias (P=0.322 and P=0.133, respectively). No statistically significant subgroup differences were found based on study designs, the use of EPDS or another scale to assess depression (Q=1.11, P=0.293), whether GWG was tracked over eight months or less (Q=1.24, P=0.265), or whether the prevalence of EGWG was higher or lower than 50% (Q=0.16, P=0.689).

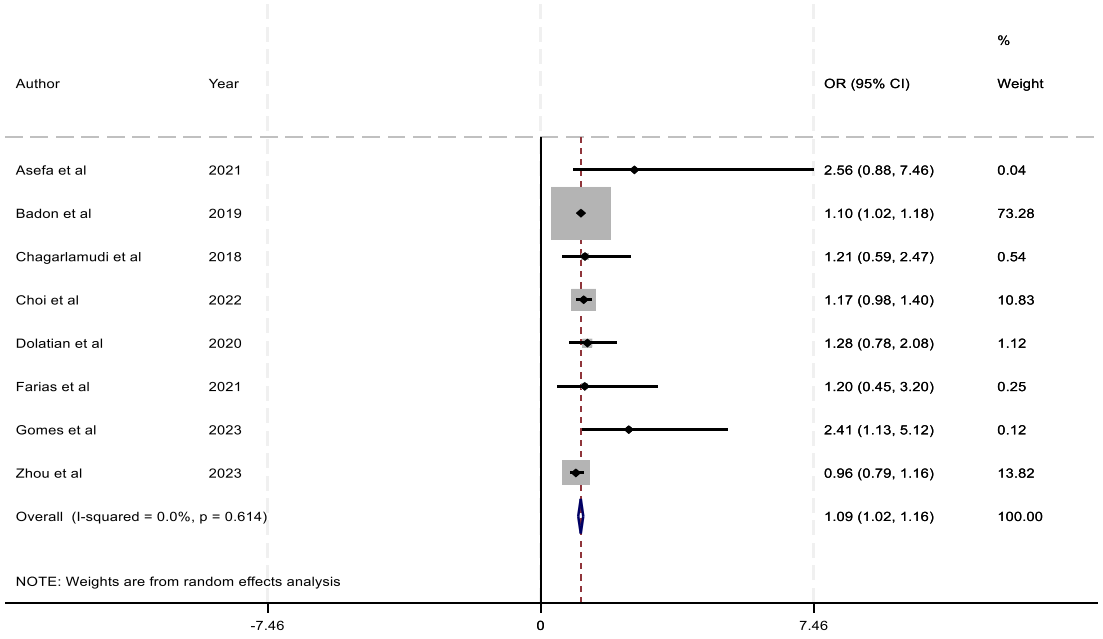


Figure 2.4 Forest plot of antenatal depression and IGWG

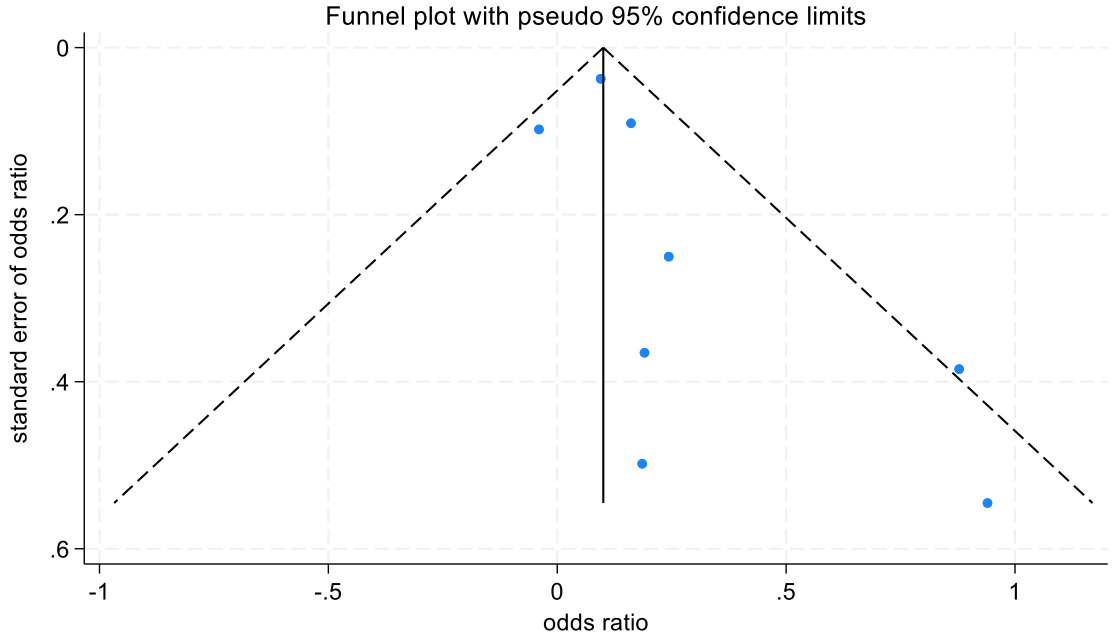


Figure 2.5 Funnel plot of antenatal depression and IGWG

The relationship between antenatal depression and GWG at different stages of pregnancy

Three studies included an assessment of antenatal depression at more than one-time point during pregnancy (Badon et al., 2019; Dekel et al., 2019; Eichler et al., 2019). One study investigated GWG more than once during pregnancy (Braig et al., 2020), and one study investigated both antenatal depression and GWG in each trimester (Farias et al., 2021). Among the studies investigating antenatal depression more than once during pregnancy, two out of three measured antenatal depression in the first trimester, and these studies found that antenatal depression was associated with EGWG or higher total GWG compared with women without antenatal depression in the first trimester (Badon et al., 2019; Dekel et al., 2019). One study suggested that antenatal depression was not associated with GWG during the second trimester (Eichler et al., 2019). However, the study that investigated both antenatal depression and GWG in each trimester found that antenatal depression during all three trimesters was associated with a lower mean of total GWG compared to women without depression during each trimester and that persistent depression was associated with IGWG (Farias et al., 2021). One study tracked GWG monthly and divided the participants into three groups based on the severity of depression symptoms and reported that participants in the middle depression group had the highest GWG compared with those in the lowest and highest depression groups (Braig et al., 2020). The recent

findings regarding the association between antenatal depression and GWG in different trimesters are inconsistent but reveal the possibility that the association may vary between trimesters or stages of pregnancy. Explicit depression and GWG timing are necessary for relevant research.

Antenatal depression and GWG at different stages of pregnancy: meta-analysis findings

A total of five studies were included in the meta-analyses to investigate the relationship between antenatal depression and IGWG at different stages of pregnancy. Because some studies examined the relationship between antenatal depression and GWG before and after 20 weeks gestation, while others did not, four separate meta-analyses were conducted, each comprising of two to three studies.

The results revealed that women with antenatal depression in the first half of pregnancy had higher odds of IGWG than women without antenatal depression in the first half of pregnancy (pooled OR=1.10, 95% CI, 1.02-1.18), but antenatal depression in the first half of pregnancy did not increase the odds of EGWG (pooled OR= 0.88, 95% CI, 0.42-1.33) (Figure 2.6 and 2.7).

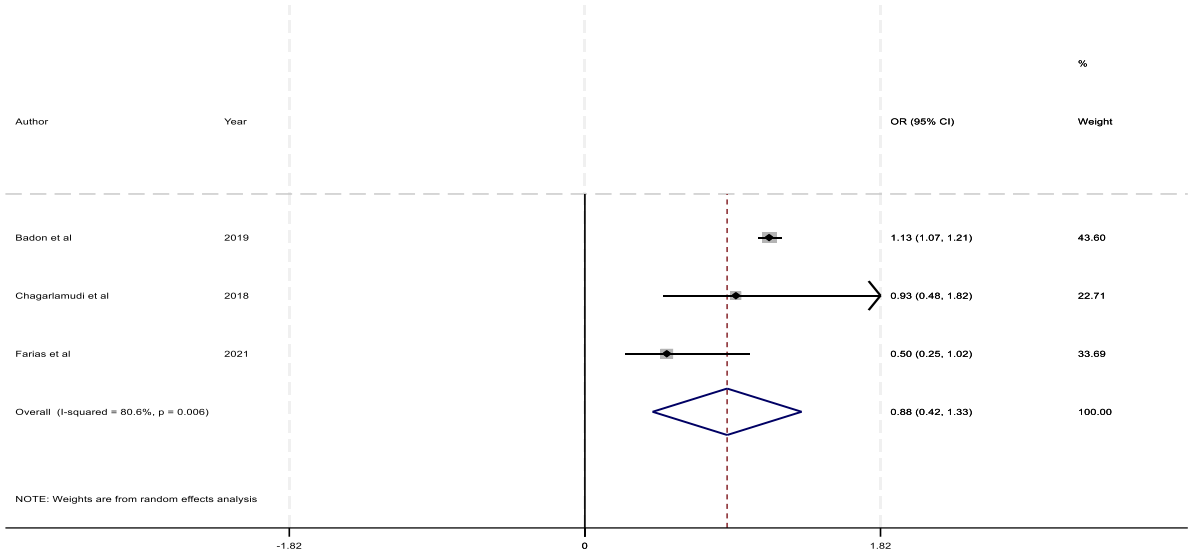


Figure 2.6 Forest plot of antenatal depression in the first half of pregnancy and EGWG

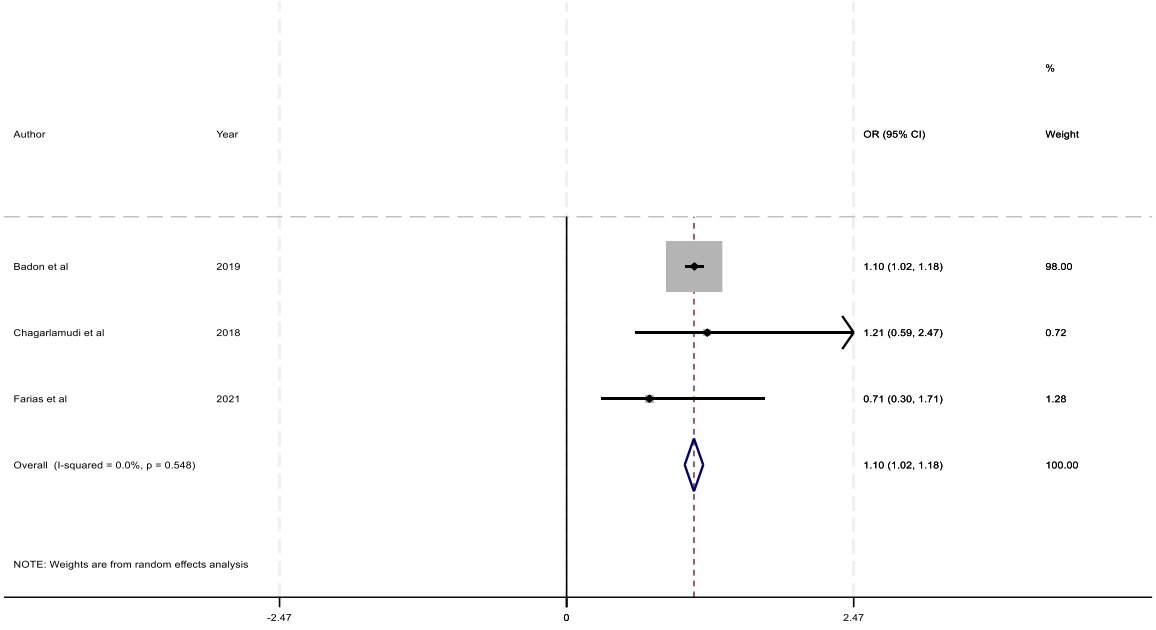


Figure 2.7 Forest plot of antenatal depression in the first half of pregnancy and IGWG

There was no significant association between antenatal depression in the second half of pregnancy and EGWG or insufficient (pooled OR= 0.98, 95% CI, 0.58-1.40; pooled OR= 1.05, 95% CI, 0.52-1.58) (Figure 2.8 and Figure 2.9).

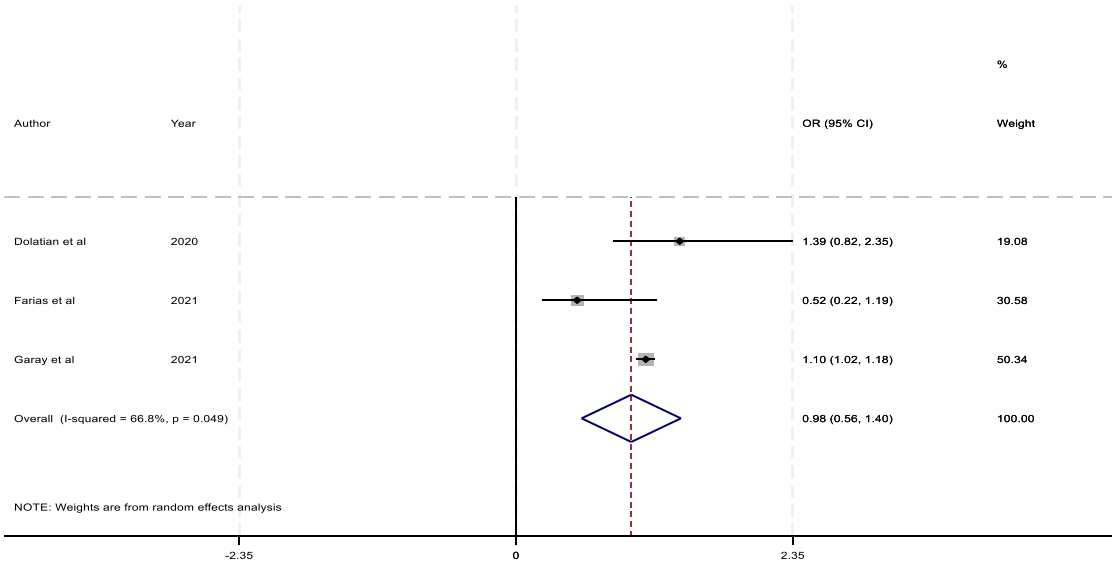


Figure 2.8 Forest plot of antenatal depression in the second half of pregnancy and EGWG

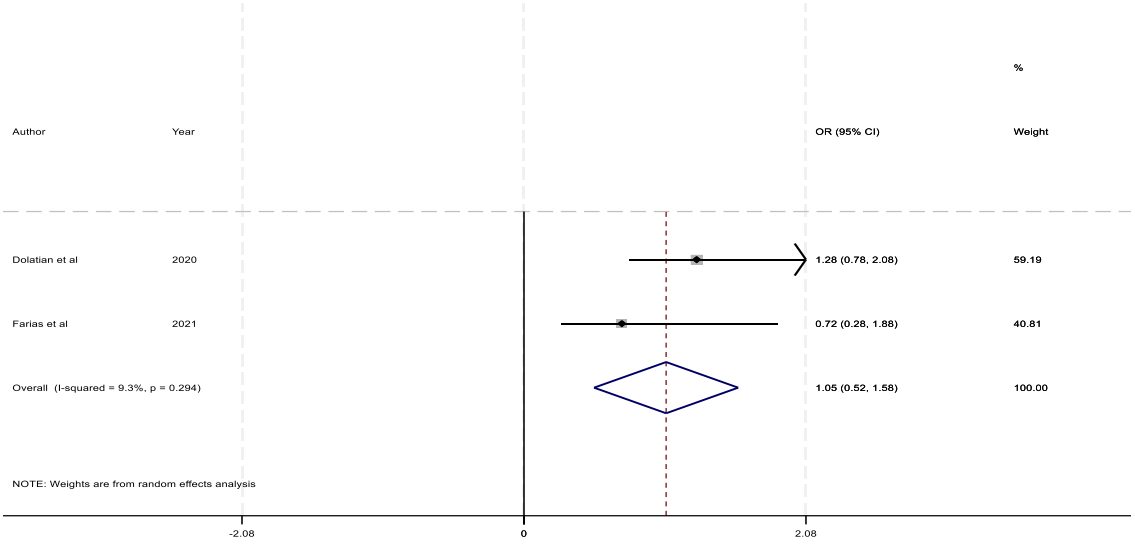


Figure 2.9 Forest plot of antenatal depression in the second half of pregnancy and IGWG

A high level of between-study heterogeneity was observed in the analysis of the association between antenatal depression in the first half of pregnancy and EGWG (Heterogeneity chi-squared = 10.32, P = 0.006, I-square = 80.6%, Tau-squared =0.1243), while a borderline between-study heterogeneity was observed in the analysis of the association between antenatal depression in the second half of pregnancy and EGWG (Heterogeneity chi-squared = 6.02, P=0.049, I-square = 66.8%, Tau-squared =0.0898). The results of leave-one-out sensitivity analysis with pooled estimates varied between 0.62 (95% CI, 0.24–1.00) and 1.13 (95% CI, 1.06–1.20) in the analysis of the antenatal depression and EGWG. The results of leave-one-out sensitivity analysis with pooled estimates varied between 0.62 (95% CI, 0.24–1.00) and 1.13 (95% CI, 1.06–1.20) in the analysis of antenatal depression in the first half of pregnancy and EGWG; between 0.86 (95% CI, 0.30–1.42) and 1.11 (95% CI, 1.02–1.18) in the analysis of antenatal depression in the second half of pregnancy and EGWG.

In the analysis of antenatal depression in the first and second half of pregnancy and IGWG, the heterogeneity between studies was low (Heterogeneity chi-squared = 5.38, P=0.614, I-square = 0.0%, Tau-squared <0.0001; Heterogeneity chi-squared = 1.2, P=0.548, I-square = 0.0%, Tau-squared <0.0001, respectively). The results of leave-one-out sensitivity analysis with pooled estimates varied between 0.89 (95% CI, 0.32–1.46) and 1.11 (95% CI, 1.02–1.18) in the analysis of antenatal depression in the first half of pregnancy and IGWG, and between 0.72 (95% CI,

0.28–1.88) and 1.28 (95% CI, 0.78–2.08) in the analysis of antenatal depression in the second half of pregnancy and IGWG.

Discussion

This is one of the first systematic reviews and meta-analyses to investigate the relationship between antenatal depression and GWG and whether the relationship differs with the stage of the pregnancy. This systematic review and meta-analysis revealed that women with antenatal depression have a higher risk of both EGWG and IGWG. Based on a limited number of studies for subgroup analysis, antenatal depression in the first half of pregnancy was found to be associated with IGWG, but not with EGWG. Conversely, there was no significant association between antenatal depression in the second half of pregnancy and either insufficient or EGWG.

Our results suggested that overall antenatal depression is associated with a greater risk of excessive and IGWG. The findings of this systematic review and meta-analysis differ from a previous systematic review and meta-analysis conducted by Dachew et al. (2020) that found no significant association between GWG and depression. However, similar to our study, a recent systematic review and meta-analysis carried out with postpartum women have found an association between postpartum depression and both excessive and inadequate GWG (Qiu et al., 2022). Differences in results may be attributed to variations in study design and timing of antenatal depression. We noticed that all cross-sectional studies reported significant findings,

whereas all of the studies that found no significant association between antenatal depression and GWG used a cohort study design. In addition, our findings suggest that the association between depression and GWG may differ between the first and second half of pregnancy. It is essential to specify the timing and duration of antenatal depression and GWG measurements in future studies of the association between antenatal depression and GWG. If these studies confirm the association varies over the course of pregnancy, that may have implications for the prevention and treatment of inadequate weight gain.

Different depression subtypes may be one of the reasons for the findings that antenatal depression is associated with an increased risk of excessive or IGWG. At the beginning of the 1900s, weight loss was considered a typical clinical feature of depression, and dominant hyperphagia, weight gain, and oversleeping were later described as atypical depression symptoms (Caroleo et al., 2019). Recently, subtypes of depression have been found to exhibit different hypothalamic-pituitary-adrenal axis activity (Juruena et al., 2018), levels of regulating appetite hormones (Caroleo et al., 2019), and patterns of neural circuit activity under the influence of food stimuli (Simmons et al., 2016). As depression symptoms include both weight loss and weight gain, this could explain the findings of antenatal depression associated with increased risk for excessive and IGWG.

Weight change during pregnancy is more complicated than in the general population, as it

includes consideration of the changing weight of both the pregnant woman and fetus. According to previous studies, maternal depression is associated with fetal growth and fetal weight, which is included in the GWG measure (Ecklund-Flores et al., 2017). Some studies suggest maternal depression may cause fetal growth restriction (Lewis et al., 2016), while other studies suggest that maternal depression may cause hemodynamic changes and increase fetal weight (Ecklund-Flores et al., 2017). Future studies should include measures of the effects of different subtypes of depression on GWG and measurement of fetal weight gain.

Our systematic review and meta-analysis included studies conducted in both high- and low-income countries across Africa, North and South America, Asia, and Europe. The rates of excessive and IGWG varied between studies. Although we did not find significant evidence of a subgroup difference based on whether the prevalence of EGWG was higher or lower than 50%, we cannot entirely disregard the potential effects of peer influences and cultural values on the association between antenatal depression and GWG. For example, some countries provide national guidelines for GWG and routinely repeated weighing during prenatal care, whereas others do not (Kominiarek & Peaceman, 2017). In some ethnic groups, higher GWG values are viewed as healthy, whereas in others, lower GWG values are viewed as healthy (Denize et al., 2018).

Some limitations need to be considered when interpreting the results of this meta-analysis.

First, it is important to note that significant heterogeneity was detected across studies in the analysis of antenatal depression in the first half of pregnancy and EGWG. In addition, the associations observed in our meta-analysis for the first and second half of pregnancy may be influenced by the small number of studies available for analysis within each subgroup. Due to only a limited number of studies providing trimester-specific information, the ability to assess the association between antenatal depression and GWG within each trimester was constrained. Last but not least, our inclusion criteria were limited to articles published in the English language, which may introduce language bias and potentially exclude relevant studies published in other languages.

In summary, antenatal depression appears to be associated with inadequate GWG and may be more prominent earlier in pregnancy. In studies investigating the association between antenatal depression and GWG, it is important to report the timing and duration of the depression. Further trimester-specific studies are needed to clarify the relationship between antenatal depression and GWG.

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CHAPTER THREE

Factors Associated with Excessive Gestational Weight Gain in the United States using Oregon PRAMS: A population-based study

Abstract

Background

Excessive gestational weight gain (EGWG) has become a common health concern and is associated with a series of negative maternal health conditions. Research findings regarding factors associated with EGWG are quite inconsistent. The aim of this study is to investigate the social/institutional, interpersonal/family, and maternal factors associated with EGWG based on the Institute of Medicine (IOM) framework.

Methods

The study utilized data from the Oregon Pregnancy Risk Assessment Monitoring System (PRAMS) for 2016-2021. The Oregon PRAMS sample was a representative sample of live births randomly selected from the birth certificate file each month. EGWG was defined based on the 2009 IOM recommendation. Descriptive analysis and multivariable logistic models were performed to investigate the association between each social/institutional, interpersonal/family factors, maternal factors, and EGWG.

Results

After excluding women with insufficient GWG (IGWG), 57.27% of the remaining 7,690 participants had EGWG. No social/institutional and interpersonal/family factors were observed to be associated with EGWG. In the final model, having gestational diabetes is associated with a lower risk of EGWG (OR=0.43, 95% CI= 0.22-0.84).

Conclusion

Results from this study emphasize the importance of monitoring gestational diabetes and GWG. The results of this study can be used to complement previous evidence regarding the domains of factors associated with EGWG.

Keywords: Gestational weight gain, excessive gestational weight gain, maternal weight

Background

Excessive gestational weight gain (EGWG) has become a common health concern in the United States, with a prevalence of over 40% in the past few decades (Dalfra et al., 2022; Hirko et al., 2020; Hutchins et al., 2022). EGWG increases the risk of fetal macrosomia, gestational diabetes mellitus (Lautredou et al., 2022), preeclampsia, placental abruption (Li et al., 2022), cesarean delivery, hospitalization during pregnancy (Goławski et al., 2023), and negatively impacts long-term maternal cardiovascular health (Hutchins et al., 2022).

To reduce the rate and negative impacts of EGWG among mothers and infants, the Institute of Medicine (IOM) updated the guideline of gestational weight gain (GWG) in 2009 (IOM, 2010). According to the updated guideline, underweight women who have a pre-pregnancy body mass index (BMI) of 18.5 kg or less are recommended to gain between 12.5 to 18 kg during pregnancy, normal weight women with a BMI of 18.5 to 24.9 kg to gain 11.5 to 16 kg, overweight women with a BMI of 25 to 29.9 kg gain 7 to 11.5 kg, and obese woman with a BMI of 30 or greater to gain 5 to 9 kg (IOM, 2010). In addition to the GWG recommendation, the guidelines consist of a framework of determinants of GWG that integrated from several conceptual models, including obesogenic environment that triad ecological, health field and epidemiological perspective, and life-course theory. The IOM framework categorizes these factors as social/institutional, environmental, neighborhood/community, interpersonal/family,

and maternal factors (IOM, 2010).

Numerous studies have examined potential social/institutional, interpersonal/family, and maternal factors influencing GWG since the IOM issued a revised framework, but the research findings are quite inconsistent (Zhou et al., 2022). For example, health services are one of the important parts of social/institutional factors, but the effect of prenatal care on GWG is inconclusive (Whitaker et al., 2021). Studies have suggested that prenatal care is associated with compliance with IOM guidelines (Deputy et al., 2018), while others have found discordant advice from healthcare providers to be associated with EGWG (Herring et al., 2012), and some have found no association at all (Emery et al., 2018a; Vinturache et al., 2019). In terms of interpersonal/family factors, intimate partners and family members are the closest people to pregnant women, but there have been contradictory results regarding the relationship between excessive gestation weight gain and marital status (Bogaerts et al., 2012; Pawlak et al., 2015). More evidence is needed regarding the relationship between social/institutional, interpersonal/family, and EGWG.

Pre-pregnancy BMI is one of the most frequently studied determinants of GWG (Zhou et al., 2022). The majority of studies report that being overweight or obesity obese prior to pregnancy is a risk factor for EGWG (Aji et al., 2022; Restall et al., 2014); however, some studies do not support this conclusion (Itani et al., 2020; Rodrigues et al., 2010). In Rodrigues'

study, prepregnancy overweight was associated with insufficient GWG (IGWG). Itani et al. (2020) found no difference between various prepregnancy BMIs and GWG categories. Various research designs, such as different timing of GWG measurement, classification criteria for BMI, and confounding factors, may contribute to inconsistent results.

To better understand the factors associated with EGWG, this study aims to investigate the social/institutional, interpersonal/family, and maternal factors associated with EGWG based on the Institute of Medicine (IOM) framework. Having an integrated understanding of social/institutional, interpersonal/family, and maternal factors allows healthcare providers with a reference to adopt family-centered approaches in addressing EGWG and improving overall maternal and child health.

Methods

Study design

This study utilized a longitudinal design with data from the Oregon Pregnancy Risk Assessment Monitoring System (PRAMS) from 2016 to 2021. The Centers for Disease Control and Prevention (CDC) Division of Reproductive Health conducted PRAMS to monitor maternal health behaviors, access to care, and experiences before, during, and immediately following pregnancy to decrease maternal and infant mortality (Shulman et al., 2018). Each participating state carried out PRAMS data collection following a standard protocol (Shulman et al., 2018). To

collect data for PRAMS, a tailored design method developed by Dillman and colleagues was used to send an introductory letter, conduct a survey in either English or Spanish, and contact those who have not replied by telephone (Dillman et al., 2014; Shulman et al., 2018). PRAMS questionnaire contains over 80 questions and is revised every few years. The annual datasets contain variables across five sets: birth certificate, operational, weight, questionnaire, and analytical variables for researchers (Shulman et al., 2018)

The Oregon PRAMS sample was oversampled in terms of race/ethnicity and selected randomly from mothers residing in Oregon who had recently given birth within the preceding 2-4 months. Mothers giving birth outside Oregon or with a multi-birth greater than three gestations, stillbirths, fetal deaths, or induced abortions were excluded. The detailed data collection methodology can be found on the CDC website (CDC, 2023). The inclusion criteria of this study are similar to the Oregon PRAMS, but for the purpose of the research, women with multiple births or inadequate GWG were excluded from the analysis. This study was deemed exempt from review by the University of California San Francisco institutional review board as the data were deidentified.

Measures

Dependent Variable

The dependent variable of this study is EGWG, which was extracted from birth certificate

variables and classified according to the 2009 IOM recommendation, which is introduced in the introduction section. Accordingly, we calculated the prepregnancy BMI using the answers to the questions "How tall are you without shoes?" and "Just before you got pregnant, how much did you weigh?" then classified GWG, assessed from PRAMS birth certificates, based on the IOM's recommendations.

Independent variables

The social/institutional, interpersonal/family, and maternal factors were analyzed as the dependent variables.

Social/institutional factors

This study's social/institutional factors include informing patients of adequate weight gain and prenatal care adequacy.

Informing patients of adequate weight gain from healthcare providers was assessed based on the question, "During any of your prenatal care visits, did a doctor, nurse, or other healthcare worker ask you any of the things listed below?" Answer "Yes" to "If I knew how much weight I should gain during pregnancy" indicates being informed about adequate weight gain. The prenatal care adequacy was assessed based on the Kotelchuck Indexes. The Kotelchuck Indexes evaluate the number of antenatal visits performed and the number of expected visits according to antenatal care start and pregnancy duration and are categorized into four groups: inadequate,

intermediate, adequate, and adequate plus (Kotelchuck, 1994). The Kotelchuck Indexes are one of the most widely used indicators in antenatal care worldwide and have been adopted in related studies (Morón-Duarte et al., 2019).

Interpersonal/family factors

Social support was assessed by counting the number of help types the mother had when she needed them. The higher the number, the better the reported social support. Community support was assessed based on a five-item list of what neighbors sometimes do for each other. The response options included never, almost never, sometimes, fairly often, and very often. In this study, the research team determined poor community support as all five items answered never or almost never. Data on marital status was obtained from the birth certificate and was classified as married or other in the database.

Maternal factors

The maternal factors in this study included five subgroups: sociodemographic, anthropometric, medical, psychological, and behavioral factors. Sociodemographic factors included maternal age, race, ethnicity, education, Federal poverty level, and insurance for prenatal care. Maternal age, maternal race, maternal education, and Federal poverty level were queried from the database. Insurance for prenatal care was derived from questionnaire variables and collapsed into a bivariate variable as having or not having insurance for prenatal care.

Anthropometric factors included pre-pregnancy BMI, which was extracted based on the following formulas: weight (kg) / [height (m)]2. According to the CDC, BMI < 18.5 kg/m2 is considered underweight, 18.5 kg/m2 ≤ BMI < 24.9 kg/m2 is considered normal weight, 25.0 kg/m2 ≤ BMI < 29.9 kg/m2 is considered overweight, and BMI ≥ 30.0 kg/m2 is considered obese.

Medical factors included a self-report of prepregnancy type 1 or 2 diabetes, prepregnancy high blood pressure or hypertension, gestational diabetes, and preeclampsia/eclampsia. Psychological factors included experiencing depression and stressful events during pregnancy. Stressful events were assessed based on the number of stressful events the mother experienced (such as a close family member being very sick and going to the hospital). Behavioral factors included pre-pregnancy heavy drinking and smoking. Prepregnancy heavy drinking was defined as consuming more than eight drinks per week in this study since the same classification was adopted by the PRAMS research team (OHA, 2023). Smoking during pregnancy was classified as never smoking, quitting while pregnant, continuing to smoke during pregnancy, and starting to smoke during pregnancy.

Analysis

Data analytic strategies include the use of descriptive analysis and multivariable logistic regression. Differences in maternal characteristics by GWG categories were assessed using the

chi-square test for categorical data or the t-test for continuous data with a Bonferroni corrected (for 19 variables) significance level of 0.026. Separate multivariable logistic regression analyses were performed to determine odds ratios (ORs) and 95% confidence intervals (CIs) between each independent variable group/risk factor and EGWG. To investigate the relationship between social/institutional/interpersonal/family factors and EGWG, multivariate regression models were performed to determine ORs and 95% CIs between social/institutional factors, interpersonal/family, and both social/institutional factors and interpersonal/family factors and EGWG, respectively. To investigate the relationship between maternal factors and EGWG, multivariate regression models were performed to determine ORs and 95% CIs between sociodemographic, anthropometric, medical, psychological, behavioral, and EGWG, respectively. To investigate the relationship between social/institutional/interpersonal/family as well as maternal factors and EGWG, based on the results in previous models. Model 1 consists of social/institutional and interpersonal/family factors that are significant in previous models. Model 2 consists of maternal factors that are significant in previous models.

Statistical analyses were performed with STATA SE v18.0 (Stata Corp LP, College Station, TX). For all statistical analyses, the survey weights provided by the PRAMS were applied to account for the complex survey design.

Results

A total of 11,592 mothers completed the Oregon PRAMS survey between the 2016 and 2021 period. A total of 1,166 mothers were excluded from this study due to multiple births, and 152 mothers were excluded due to lack of GWG data. The rate of adequate GWG was 32%, while the rate of IGWG was 26.6%, and the rate of EGWG was 41.4%. After excluding the 2,736 mothers with IGWG, 7,690 mothers remained for the final analysis. This led to the rate of adequate GWG increasing to 43.6% and the rate of EGWG rising to 56.4% among the remaining participants.For the remaining participants, the mean age was 29.3 (standard deviation =5.49).. Most participants were married (66.5%) and had some colleague or higher education (67.8%). Maternal characteristics across GWG categories are presented in Table 3.1. There were differences in marital status, Federal poverty level, and stressful events between those with adequate GWG and EGWG. The portion of married women in the adequate GWG group is lower than women in the EGWG group (47.3% vs. 52.7%, $p=0.004$). People in the EGWG group experienced more stressful events during pregnancy and were more likely to be obese than those in the normal GWG group ($p<0.001$).

Table 3.1 Maternal characteristics across GWG categories

Variables (n/%)	Adequate GWG (n=3286)	EGWG (n=4252)	Total (N=7538)	P-value
Prenatal care adequacy				0.183
Inadequate	328 (48.4%)	458 (51.6%)	786 (100.00%)	
Intermediate	459 (33.2%)	590 (66.8%)	1049 (100.00%)	
Adequate	1584 (45.9%)	1981 (54.1%)	3565 (100.00%)	
Adequate plus	903 (38.4%)	1193 (61.7%)	2096 (100.00%)	
Informing of proper weight gain				0.109
No	1296 (38.0%)	1700 (62.0%)	2996 (100.0%)	
Yes	1854 (45.5%)	2347 (54.5%)	4201 (100.0%)	
Social support[a]	4.3 (± 1.4)	4.4 (± 1.3)	4.3 (± 1.4)	0.148
Community support				0.238
Poor	1108 (38.6%)	1628 (61.4%)	2736 (100.0%)	
Adequate	2178 (44.3%)	2624 (55.7%)	4802 (100.0%)	
Marital status				0.004
Married	2179 (47.3%)	2421 (52.7%)	4600 (100.0%)	
Other	1106 (32.9%)	1831 (67.1%)	2937 (100.0%)	
Maternal age				0.752
<20	98 (40.5%)	202 (59.5%)	300 (100.0%)	
20-29	3066 (42.3%)	3900 (57.7%)	6966 (100.0%)	
≥ 30	122 (52.2%)	150 (47.8%)	272 (100.0%)	
Maternal race				0.015
White	1307 (41.9%)	1651 (58.1%)	2958 (100.0%)	
African American	289 (48.2%)	376 (51.8%)	665 (100.0%)	
AI/AN	124 (33.9%)	272 (66.1%)	396 (100.0%)	
Asian	621 (59.1%)	461 (40.9%)	1082 (100.0%)	
Pacific Islander	164 (29.9%)	299 (70.1%)	463 (100.0%)	
Multiple races	599 (35.0%)	1001 (65.0%)	1600 (100.0%)	
Other/Blank	182 (43.3%)	192 (56.7%)	374 (100.0%)	
Maternal ethnicity				
Not Hispanic	2387 (41.4%)	3164 (58.6%)	5551 (100.0%)	0.115
Hispanic	899 (48.0%)	1088 (52.0%)	1987 (100.0%)	
Maternal education				0.227
Less than high school	426 (31.2%)	577 (68.8%)	1003 (100.0%)	
Highschool or GED	678 (41.3%)	994 (58.7%)	1672 (100.0%)	
College or higher	2172 (44.6%)	2670 (55.4%)	4842 (100.0%)	
Federal poverty level				0.014
At or below 100%	693 (37.1%)	1051 (62.9%)	1744 (100.0%)	
100.1% - 200%	639 (40.4%)	919 (59.6%)	1558 (100.0%)	
200.1% - 400%	698 (35.6%)	919 (64.4%)	1617 (100.0%)	
More than 400%	915 (53.8%)	893 (46.2%)	1808 (100.0%)	
Insurance for prenatal care				0.213
Have insurance	3196 (42.3%)	4118 (57.7%)	7314 (100.0%)	
Have no insurance	25 (68.0%)	40 (32.0%)	65 (100.0%)	

Variables (n/%)	Adequate GWG (n=3286)	EGWG (n=4252)	Total (N=7538)	P-value
Prepregnancy BMI				<0.001
Underweight	245 (72.8%)	107 (27.2%)	352 (100.0%)	
Normal	1560 (47.6%)	1536 (52.4%)	3096 (100.0%)	
Overweight	747 (46.3%)	803 (53.7%)	1550 (100.0%)	
Obese	734 (27.5%)	1806 (72.5%)	2540 (100.0%)	
Prepregnancy type 1 or 2 diabetes				0.171
No	3154 (42.8%)	4076 (57.2%)	7230 (100.0%)	
Yes	98 (27.3%)	140 (72.4%)	238 (100.0%)	
Prepregnancy high blood pressure or hypertension				0.109
No	3146 (43.1%)	4021 (56.9%)	7167 (100.0%)	
Yes	112 (23.3%)	201 (76.7%)	313 (100.0%)	
Gestational diabetes				0.064
No	2839 (41.1%)	3735 (58.9%)	6574 (100.0%)	
Yes	404 (55.5%)	451 (44.5%)	855 (100.0%)	
Preeclampsia/eclampsia				0.052
No	2877 (44.0%)	3452 (56.0%)	6329 (100.0%)	
Yes	351 (30.6%)	732 (69.4%)	1083 (100.0%)	
Depression during pregnancy				0.252
No	2797 (43.3%)	3467 (55.3%)	6264 (100.0%)	
Yes	426 (35.0%)	706 (62.4%)	1132 (100.0%)	
Stressful events[a]	15.5 (± 2.4)	15.8 (± 2.7)	15.6 (± 2.6)	<0.001
Prepregnancy heavy drinking				0.774
No	2001 (41.4%)	2783 (58.6%)	4784 (100.0%)	
Yes	102 (37.9.%)	148 (62.1%)	250 (100.0%)	
Smoking during pregnancy				0.090
Never smoke	2829 (45.5%)	3355 (54.5%)	6184 (100.0%)	
Quitting	206 (29.3%)	431 (70.7%)	637 (100.0%)	
Continuing	151 (30.3%)	266 (69.7%)	417 (100.0%)	
Starting to smoke	1 (14.3%)	6 (85.7%)	7 (100.0%)	

Abbreviation: P-value, designed-based p-value by t-test for continuous variables and Chi2 test for binary/categorical variables. [a]Mean (± standard deviation); AI/AN, American Indian and Alaska Native.

Table 3.2 presents the results of the multiple logistic regression models examining the association between social/institutional/interpersonal/family factors and EGWG. There is a higher risk of EGWG among individuals who are not married compared with those who are married in the model in the social/institutional and interpersonal/family domains (OR= 1.75,

95% CI:1.14-2.67).

Table 3.2 Multivariable logistic regression models examining the relationship between social/institutional and interpersonal/family and EGWG using Oregon PRAMS 2016-2021

	(1) EGWG	(2) EGWG	(3) EGWG
Social/institutional factors			
Prenatal care adequacy			
Inadequate	1.00		1.00
	[1.00,1.00]		[1.00,1.00]
Intermediate	1.80		1.66
	[0.75,4.30]		[0.71,3.77]
Adequate	1.10		1.05
	[0.56,2.18]		[0.55,2.01]
Adequate plus	1.51		1.34
	[0.73,3.09]		[0.67,2.69]
Informing of proper weight gain			
No	1.00		1.00
	[1.00,1.00]		[1.00,1.00]
Yes	0.71		0.70
	[0.48,1.04]		[0.47,1.03]
Interpersonal/family factors			
Social support		1.09	1.10
		[0.96,1.24]	[0.96,1.25]
Community support			
Poor		1.00	1.00
		[1.00,1.00]	[1.00,1.00]
Adequate		0.82	0.82
		[0.55,1.25]	[0.53,1.25]
Marital status			
Married		1.00	1.00
		[1.00,1.00]	[1.00,1.00]
Other		1.78**	1.75*
		[1.18,2.71]	[1.14,2.67]

Odds ratio; 95% confidence intervals in brackets.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.3 presents the results of multiple logistic regression models examining the association between maternal factors and EGWG. Individuals with incomes exceeding 400% of

the federal poverty level are associated with a lower risk of EGWG compared to those at or lower than 100% of the federal poverty level (OR= 0.32, 95% CI:0.14-0.75 in the model 6). Regarding medical factors, having gestational diabetes is associated with lower EGWG risk (OR= 0.36, 95% CI: 0.13-1.00 in the model 6), whereas having preeclampsia or eclampsia is associated with a higher risk of EGWG (OR= 2.36, 95% CI:1.00-5.59 in the model 6). No anthropometric, psychological, and behavioral variables in the maternal factors were identified to be associated with EGWG.

Table 3.3 Multivariable logistic regression models examining the relationship between maternal factors and EGWG using Oregon PRAMS 2016-2021

	(1)	(2)	(3)	(4)	(5)	(6)
	EGWG	EGWG	EGWG	EGWG	EGWG	EGWG
Sociodemographic						
Maternal age						
<20	0.79					1.92
	[0.24,2.66]					[0.38,9.65]
20-29	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
>=30	0.81					0.41
	[0.27,2.43]					[0.06,2.60]
Maternal race						
White	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
African American	0.55*					0.53
	[0.30,0.99]					[0.21,1.33]
AI/AN	1.24					1.21
	[0.61,2.52]					[0.45,3.24]
Asian	0.50**					0.76
	[0.34,0.75]					[0.44,1.33]
Pacific Islander	1.04					1.06
	[0.58,1.86]					[0.37,3.02]

	(1)	(2)	(3)	(4)	(5)	(6)
	EGWG	EGWG	EGWG	EGWG	EGWG	EGWG
Multiple races	1.22					1.23
	[0.83,2.70]					[0.75,2.02]
Other	1.28					2.15
	[0.61,2.70]					[0.60,7.74]
Maternal ethnicity (Hispanic vs non-Hispanic)						
Not Hispanic	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
Hispanic	0.53**					0.57
	[0.34,0.81]					[0.31,1.04]
Maternal education						
Less than high school	2.79**					2.57
	[1.42,5.48]					[0.92,7.16]
Highschool / GED	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
College or higher	1.19					1.50
	[0.67,2.12]					[0.68,3.30]
Federal poverty level						
At or below 100%	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
100.1% - 200%	0.91					0.64
	[0.49,1.67]					[0.26,1.56]
200.1% - 400%	1.08					0.78
	[0.57,2.02]					[0.33,1.83]
More than 400%	0.49*					0.32**
	[0.27,0.91]					[0.14,0.75]
Insurance for prenatal care						
Have insurance	1.00					1.00
	[1.00,1.00]					[1.00,1.00]
Have no insurance	0.27					0.31
	[0.04,1.73]					[0.04,2.62]
Anthropometric						
Prepregnancy BMI						
Underweight		0.34*				0.31
		[0.12,0.97]				[0.08,1.26]
Normal		1.00				1.00
		[1.00,1.00]				[1.00,1.00]
Overweight		1.05				0.78
		[0.65,1.70]				[0.41,1.47]
Obese		2.40***				1.78
		[1.51,3.82]				[0.89,3.55]

	(1)	(2)	(3)	(4)	(5)	(6)
	EGWG	EGWG	EGWG	EGWG	EGWG	EGWG
Medical						
Prepregnancy type 1 or 2 diabetes						
No			1.00			1.00
			[1.00,1.00]			[1.00,1.00]
Yes			1.59			1.49
			[0.39,6.51]			[0.27,8.14]
Prepregnancy high blood pressure or hypertension						
No			1.00			1.00
			[1.00,1.00]			[1.00,1.00]
Yes			1.44			1.00
			[0.36,5.84]			[0.19,5.26]
Gestational diabetes						
No			1.00			1.00
			[1.00,1.00]			[1.00,1.00]
Yes			0.47*			0.36*
			[0.25,0.88]			[0.13,1.00]
Preeclampsia/eclampsia						
No			1.00			1.00
			[1.00,1.00]			[1.00,1.00]
Yes			2.04*			2.36*
			[1.06,3.91]			[1.00,5.59]
Psychological						
Depression during pregnancy						
No				1.00		1.00
				[1.00,1.00]		[1.00,1.00]
Yes				1.32		1.25
				[0.72,2.43]		[0.58,2.73]
Stressful event				1.04		0.98
				[0.95,1.13]		[0.85,1.14]
Behavioral						
Prepregnancy heavy drinking						
No						1.00
						[1.00,1.00]
Yes						1.66
						[0.45,6.08]
Smoking during pregnancy						
Never					1.00	1.00
					[1.00,1.00]	[1.00,1.00]
Quitting					1.66	1.50
					[0.81,3.40]	[0.66,3.41]
Continuing					1.67	1.06
					[0.49,5.68]	[0.26,4.32]

Abbreviation: AI/AN American Indian and Alaska Native.
Odds ratio; 95% confidence intervals in brackets.
* p < 0.05, ** p < 0.01, *** p < 0.001

Table 3.4 presents the resulting multiple logistic regression models based on the significant factors identified in previous analyses. Regarding social/institutional/interpersonal/family factors, marital status is the only factor in the final model. When including maternal factors (such as including Federal poverty level, gestational diabetes, and preeclampsia/eclampsia) in the final model, having gestational diabetes is associated with a lower risk of EGWG (OR=0.36, 95% CI: 0.17-0.77).

Table 3.4 Multivariable logistic regression models examining the relationship between potential social/institutional and maternal factors and EGWG using Oregon PRAMS 2016-2021

	(1) EGWG	(2) EGWG
Interpersonal/family factors		
Marital status		
Married	1.00	1.00
	[1.00,1.00]	[1.00,1.00]
Other	1.83**	1.52
	[1.21,2.76]	[0.93,2.50]
Maternal factors		
Federal poverty level		
At or below 100%		1.00
		[1.00,1.00]
100.1% - 200%		0.95
		[0.51,1.77]
200.1% - 400%		1.36
		[0.72,2.54]
More than 400%		0.70
		[0.38,1.29]

Gestational diabetes	
No	1.00 [1.00,1.00]
Yes	0.36* [0.17,0.77]
Preeclampsia/eclampsia	
No	1.00 [1.00,1.00]
Yes	1.55 [0.78,3.11]

Odds ratio; 95% confidence intervals in brackets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discussion

This study examines social/institutional, interpersonal/family, and maternal factors associated with EGWG according to the IOM framework. The prevalence of EGWG is high (41.4%). We found that having gestational diabetes is associated with a lower risk of EGWG. The present study did not observe associations between social/institutional factors and EGWG. Not being married is associated with a higher risk of EGWG in the first model, yet it was not a significant factor in the final model.

The observed prevalence of EGWG is 41.4 % before excluding mothers with IGWG. This is lower than the 51% prevalence reported in a prior systematic review and meta-analysis for the United States by Goldstein et al. (2018), and the 50.6% prevalence found in the Oregon PRAMS data from 2012 to 2013, as noted by Deputy et al. (2015). The observed prevalence of EGWG is 41.4% before excluding mothers with IGWG, which is lower than the 51% prevalence reported

in a prior systematic review and meta-analysis for the United States by Goldstein et al. (2018), and the 50.6% prevalence found in the Oregon PRAMS data from 2012 to 2013, as noted by Deputy et al. (2015). Although the prevalence of EGWG we observed is relatively lower compared to previous data, an overall prevalence rate of over 40% for EGWG is still quite high. Given the negative impact of EGWG on maternal and infant health, understanding the causes of EGWG and proposing appropriate prevention strategies is imperative.Having gestational diabetes is associated with a decreased risk for EGWG, and these findings are consistent with previous evidence that gestational diabetes is associated with lower total GWG (Fritsche et al., 2022; Saito et al., 2022). A plausible explanation for this finding is that women with gestational diabetes might be asked to monitor their glucose levels and adhere to healthy lifestyles and slow weight gain as ways to manage their gestational diabetes (Karavasileiadou et al., 2022). Therefore, it is likely that they will decrease weight gain in an effort to manage gestational diabetes. However, due to the design of this study, the causal relationship between gestational diabetes and EGWG cannot be established. There is a need for additional research to clarify whether GWG is affected by blood sugar during pregnancy, or if there is a bidirectional or opposite relationship.

We found no associations between social/institutional factors and EGWG. The results of prenatal care adequacy and informing of adequate weight gain are not associated with EGWG,

which is in accordance with previous studies (Emery et al., 2018b; Vinturache et al., 2019). Vinturache and colleagues found no differences between the groups regarding antenatal advice received and encounters with healthcare providers when stratified by the GWG. Emery and colleagues found that the amount of gestational weight women reported being advised to gain from their healthcare providers was not associated with actual GWG. One of the reasons could be a lack of specific, targeted information based on weight gain, or the information is not delivered in a culturally appropriate and understandable fashion (Vinturache et al., 2019). Moreover, some studies suggest that healthcare providers do not provide appropriate information or feel confident in providing advice regarding adequate weight gain (Callaghan et al., 2020; Willcox et al., 2012). However, it is unclear whether the mothers lack the motivation to meet the GWG suggested by healthcare providers or encounter challenges while attempting to do so. Research in the future should examine the mothers' attitudes, actions, and GWG trajectory following the receipt of GWG recommendations from healthcare providers and the level of confidence from healthcare providers in giving appropriate advice on pregnancy weight gain.

In the present study, no interpersonal/family factor was associated with EGWG. The result is consistent with previous studies suggesting that marital status is not associated with the risk of EGWG (Fraga & Theme Filha, 2014) but inconsistent with other studies suggesting unmarried is associated with a higher risk of EGWG (Bogaerts et al., 2012; Sangi-Haghpeykar et al., 2014).

The inconsistency in results might arise from different levels of pressure or stigmas that unmarried mothers face across different cultures or regions. It is interesting to note that the effect of the marital status and Federal poverty level on EGWG no longer remained significant in the final model, including both interpersonal/family factors and maternal factors. It may be worthwhile to investigate the interaction between marriage and poverty levels in relation to EGWG.

A major strength of this study was the use of a randomly selected, race representative multiyear dataset that was compiled and weighted according to CDC and state protocols. In addition, the pre-selected variables are based on the IOM framework, which is well known, based on theories, and has been tailored to meet the needs of understanding GWG contributing factors. However, there are some limitations that should be considered when interpreting the findings. First, the majority of data comes from the self-reported answers during the early postpartum period to the questionnaire, which leads to potential recall biases. Second, the datasets could not cover a comprehensive domain of potential contributing factors that affect GWG, such as diet or exercise were not included. Further studies investigating the impact of maternal behaviors and living environments on GWG are necessary.

Conclusion

The results emphasize the need for close observation of gestational diabetes and changes in

GWG throughout pregnancy. Additional research exploring interactions between factors, such as marital status and poverty levels, is needed.

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CHAPTER FOUR

Associations Between Antenatal Depression and Gestational Weight Gain using Oregon PRAMS: A Population-Based Study

Abstract

Background

Both depression and inadequate gestational weight gain (GWG) are serious global health issues, but the association between antenatal depression and GWG remains inconclusive. This study aimed to investigate (1) the association between antenatal depression and total GWG and (2) the association between antenatal depression and both excessive GWG (EGWG) and insufficient GWG (IGWG).

Methods

The study utilized data from the Oregon Pregnancy Risk Assessment Monitoring System (PRAMS) for 2016-2021. The Oregon PRAMS sample is a representative sample of live births randomly selected from the birth certificate. Antenatal depression was obtained from self-reported answers and categorized as depression before pregnancy, depression during pregnancy, prepregnancy onset depression, and no depression. Total GWG was measured as overall GWG during pregnancy. IGWG and EGWG were defined based on the 2009 United States Institute of Medicine (IOM) recommendations. Weighted multivariable linear and logistic regression

analyses were conducted to explore the associations between antenatal depression and GWG.

Results

Among 10,426 participants, when weighted, 17.4% experienced depression either before or during pregnancy, or both. About 22.7% had IGWG, and over 44.7% had EGWG. No associations were found between any of the depression parameters and GWG, EGWG, or IGWG.

Conclusion

This study highlights the importance of routine follow-up of antenatal depression and GWG throughout pregnancy. Future studies that monitor changes in depression and GWG throughout the different phases of pregnancy while considering perceptions of body image and weight stigma are essential to clarify the association between antenatal depression during pregnancy and GWG.

Keywords: Gestational weight gain, antenatal depression, maternal weight

Introduction

Inadequate gestational weight gain (GWG), or the amount of weight gain during pregnancy, is a global issue that has been linked to adverse maternal and neonatal health outcomes (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, Rode, et al., 2017; Khanolkar et al., 2020). Based on a recent systematic review and meta-analysis, it was observed that approximately 27.8% of mothers experienced excessive GWG (EGWG), whereas 39.4% had insufficient GWG (IGWG) (Martínez-Hortelano et al., 2020). It has been shown that EGWG is associated with a higher risk of fetal macrosomia (Goldstein et al., 2018), large gestational age, gestational hypertension, preeclampsia/eclampsia, cesarean delivery, extended hospital stay (Khanolkar et al., 2020), and postpartum weight retention or obesity after delivery (Goldstein, Abell, Ranasinha, Misso, Boyle, Black, Li, Hu, Corrado, & Rode, 2017). Conversely, IGWG has been associated with an increased risk of small gestational age, developmental delay (Motoki et al., 2022), and preterm birth (Goldstein et al., 2018; Khanolkar et al., 2020).

Weight gain during pregnancy is determined by many factors (IOM, 2010). One of the potentially important risk factors related to inadequate GWG is depression (Zhou et al., 2023). Antenatal depression is a pervasive global health issue, with the prevalence rates estimated to be 7-20% worldwide. (Biaggi et al., 2016; Yin, Sun, Jiang, Xu, Gan, Zhang, Qiu, Yang, Shi, Chang, et al., 2021). Diverse mechanisms have been proposed to elucidate the connection between

depression, in general, and weight fluctuations, including disturbance of appetite regulation, changes in metabolic, hormonal, and immunological parameters, and behavioral changes such as reduced physical activity or emotional eating (Konttinen, 2020; Patsalos et al., 2021). Although previous studies have shown that depression is associated with weight change outside of pregnancy, the relationship between depression and weight gain during pregnancy remains inconclusive (Badon et al., 2019; Jung et al., 2017). Some evidence suggests that depression during pregnancy is unrelated to GWG (Eichler et al., 2019; Vehmeijer et al., 2020). Meanwhile, other studies indicate that depression during pregnancy is associated with high GWG (Dolatian et al., 2020; Garay et al., 2021), and still others suggest that depression during pregnancy is associated with low GWG (Farias et al., 2021; Shieh & Wu, 2014). One of the potential reasons for the inconsistent findings could be the timing of depression occurrence, as some study results suggest that the relationship between depression and GWG may vary based on the timing of depression onset (Badon et al., 2019).

Thus, the findings regarding the impact of depression onset and duration (prepregnancy, pregnancy, or both) on GWG remain inconclusive. Additionally, because depression has been found to be associated with weight change, both increase, and decrease, it is crucial to determine whether antenatal depression will lead to too much or too little GWG. To fill the research gaps, this study aimed (1) to investigate the association between antenatal depression and total GWG

during pregnancy and (2) to examine whether the associations between antenatal depression and GWG differ by insufficient IGWG and EGWG.

Material and methods

Study design

This study is based on a secondary analysis of data from the Oregon Pregnancy Risk Assessment Monitoring System (PRAMS) for the period 2016-2021. PRAMS is an ongoing population-based survey conducted by the Centers for Disease Control and Prevention's (CDC's) Division of Reproductive Health to decrease maternal and infant morbidity and mortality by monitoring maternal health behaviors, access to care, and experiences before, during, and shortly after pregnancy in the United States (Shulman et al., 2018). The PRAMS data collection mode is primarily based on a tailored design method developed by Dillman and colleagues, which involves sending an introductory letter, conducting a survey in either English or Spanish, and contacting those who had not sent back the mail by telephone to complete the survey (Dillman et al., 2014; Shulman et al., 2018). Five sets of variables—birth certificate, operational, weight, questionnaire, and analytic variables—are included in the PRAMS analytic research file.

Participants

The Oregon PRAMS sample is a representative sample of live births that was randomly selected from the birth certificate file. The Oregon PRAMS employed an oversampling technique

for racial and ethnic minorities to enhance insights into the maternal-infant health dynamics of lesser-represented groups. The inclusion criteria for the Oregon PRAMS were (1) mothers who were Oregon residents and (2) had recently delivered a live-born infant during the preceding 2-4 months. Exclusion criteria were (1) mothers who gave birth outside of Oregon and (2) mothers with a multi-birth greater than three gestations, stillbirths, fetal deaths, or induced abortions. This study excluded women with twin or multiple births.

There were 11,592 women in the Oregon PRAMS 2016-2021 sample. Of these, after 1,166 participants were excluded from the study due to having multiple births, 10,426 remained. Of these, we excluded 152 participants who did not have information on GWG and 287 who did not have complete data on antenatal depression. 9,987 mothers were included in our study.

Measures

Exposures

Antenatal depression variables were derived from two questions: "During the 3 months before you got pregnant with your new baby, did you have any of the following health conditions?" and "During your most recent pregnancy, did you have any of the following health conditions?" Several health conditions, including ‘depression,’ were listed as a response, thus, a checked box indicated ‘depression’ and an unchecked box indicated ‘no depression’ for both questions.

1. Depression before pregnancy

Depression before pregnancy was defined as a checked box for depression during the 3 months before pregnancy and *not* during the most recent pregnancy.

2. Depression during pregnancy

Depression during pregnancy was defined as a checked box for depression during the most recent pregnancy and *not* during the 3 months before pregnancy.

3. Prepregnancy onset depression

Prepregnancy onset depression was defined as a checked box for depression for *both* during the 3 months before pregnancy and during the most recent pregnancy.

Outcome

The outcomes of this study were total GWG, EGWG, and insufficient IGWG. Total GWG was recorded in the birth certificate. The GWG categories (EGWG and IGWG) were derived from questions regarding prepregnancy BMI and total GWG and then classified according to the 2009 IOM recommendations. Prepregnancy BMI was extracted based on the answers to the questions "How tall are you without shoes?" and "Just before you got pregnant with your new baby, how much did you weigh?" then calculated based on the formula: weight (kg) / [height (m)]^2. After calculating prepregnancy BMI, total GWG was used to classify GWG categories. The IOM recommends that women with a prepregnancy BMI $\leq$ 18.5 kg/m^2 gain 12.5 to 18 kg,

women with a prepregnancy BMI of 18.6 to 24.9 kg/m^2 gain 11.5 to 16 kg, women with a prepregnancy BMI of 25.0 to 29.9 kg/m^2 gain 7 to 11.5 kg; and women with a prepregnancy BMI of 30.0 kg/m^2 gain 5–9 kg. Women who gained weight above the recommendation were classified as having EGWG, and those who gained weight below the recommendation were classified as having IGWG.

Confounding factors

The following demographics were included as confounders in the analysis: prepregnancy BMI, maternal age, maternal ethnicity, marital status, maternal education, Federal Poverty Level, prenatal care adequacy, social support, and community support.

1. Prepregnancy BMI

Prepregnancy BMI was calculated as mentioned above.

2. Maternal age

Maternal age was extracted from the PRAMS dataset and categorized into three groups: below 20, 20 to 34, and 35 or above. This categorization was chosen because those under 20 are often considered teenage pregnancies, and a maternal age of 35 or above is deemed advanced maternal age (Dalton-O'reilly et al., 2023; Panda et al., 2023).

3. Maternal race

Maternal race was derived from the Oregon birth certificate records. Maternal race was

categorized as White, Black, American Indian and Alaska Native, Asian, Pacific Islander, multiple races, and other.

4. Maternal ethnicity

Maternal ethnicity was sourced from the Oregon birth certificate records and categorized as Hispanic and Non-Hispanic.

5. Marital status

Marital status was obtained from the Oregon birth certificate records and was categorized as married and other.

6. Maternal education

Maternal education was derived from the Oregon birth certificate record and categorized as less than high school, high school or GED, and some college or higher degree. This categorization was chosen in consideration of the compulsory education system in the United States (U.S.), which generally ensures free education up to the high school level.

7. Federal Poverty Level

Federal Poverty Level was calculated by the Oregon PRAMS based on the amount of annualized income earned by a household and documented as lower than 100%, 100.1% to 200%, 200.1% to 400%, and more than 400%.

8. Prenatal care adequacy

Prenatal care adequacy was assessed based on the Kotelchuck Indexes, which measure the number of antenatal visits performed and the number of expected visits according to antenatal care start and pregnancy duration (Kotelchuck, 1994). Kotelchuck Indexes are classified as inadequate, intermediate, adequate, and adequate plus and have been adopted in studies relating to GWG (Hecht et al., 2022).

9. Social support

Social support from the PRAMS dataset was assessed based on the answer to the question "Would you have the kinds of help listed below if you needed them?" Five sub-questions were included, and types of help included help with money, illness, etc. ‘Yes’ responses were added up, where a higher number indicated better social support.

10. Community support

Community support from the PRAMs dataset was assessed based on the answer to the question "Below is a list of items neighbors sometimes do for each other. How often do your neighbors-" The list comprised of five items, with response options ranging from 'never' to 'very often.' The list includes actions such as doing favors for each other, asking each other for advice about personal things, etc. Community support was considered 'poor' if all five items received responses of 'never' or 'almost never'.

Statistical analysis

Participant characteristics were examined with descriptive analyses, including the frequency and weighted percentages if categorical or weighted mean and weighted standard deviation if continuous. Differences in maternal characteristics by no depression, depression before pregnancy, depression during pregnancy, and prepregnancy onset depression were assessed using the chi-square test for categorical data or the t-test for continuous data.

Weighted multivariable linear regression models to examine the associations between antenatal depression and total GWG were employed, where beta coefficients (β) and 95% confidence intervals (CIs) were reported. Model 1 adjusted for prepregnancy BMI, maternal age, maternal race, and marital status. Model 2 additionally adjusted for maternal education, Federal Poverty Level, and prenatal care adequacy. Model 3 additionally adjusted for social support and community support. Separate weighted multivariable logistic regression models were performed to examine the associations between antenatal depression and EGWG and IGWG, where odds ratios (ORs) and 95% CIs were reported. Similar to the linear regression analyses, Model 1 adjusted for prepregnancy BMI, maternal age, maternal race, and marital status. Model 2 additionally adjusted for maternal education, Federal Poverty Level, and prenatal care adequacy. Model 3 additionally adjusted for social support and community support. All statistical analyses

were performed with STATA SE v18.0 (Stata Corp LP, College Station, TX) with a significance value set at $p < 0.05$.

Results

Of the remaining 9,987 participants between 14 to 52 years of age, the majority was aged 20 to 34 years (78.1% after weighted). The characteristics of the mothers by antenatal depression category and weighted prevalence are presented in Table 4.1. About 17.4% of participants experienced depression either before or during pregnancy, or both, where 3.9% of participants experienced prepregnancy depression, 5.2% of participants experienced depression during pregnancy, and 8.3% of participants experienced prepregnancy onset depression. Most participants had insufficient or EGWG (22.7% and 44.7%), but the difference was not significant by antenatal depression (p=0.143). There were significant differences in maternal race, marital status, and social support between different antenatal depression categories. Those identifying with multiple races had the highest rates of antenatal depression, with the highest rates of depression in the depression before pregnancy (8.2%) and prepregnancy onset depression (12.6%) groups. Similarly, unmarried mothers (other) had higher rates of depression, especially those who experienced prepregnancy onset depression (13.5%). Those who experienced depression during pregnancy had the lowest social support (mean = 3.9).

Table 4.1 Maternal characteristics across antenatal depression using Oregon PRAMS 2016-2021

	No depression (n=7533)	Before pregnancy (n=466)	During pregnancy (n=504)	Prepregnancy onset (n=973)	Total (N=9496)	P-value
Characteristics	n (weighted%)	n (weighted%)	n (weighted%)	n (weighted%)	n (weighted%)	
GWG						0.144
Adequate	2644 (86.1%)	134 (2.8%)	156 (6.3%)	267 (4.8%)	3201 (100.0%)	
Insufficient	2104 (83.1%)	113 (2.5%)	145 (3.4%)	281 (11.1%)	2643 (100.0%)	
Excessive	3206 (79.7%)	238 (5.4%)	239 (5.4%)	460 (9.6%)	4143 (100.0%)	
Prepregnancy BMI						0.642
Underweight	523 (80.3%)	15 (1.1%)	34 (6.7%)	41 (12.0%)	613 (100.0%)	
Normal	3276 (86.3%)	169 (3.1%)	174 (4.5%)	373 (6.2%)	3992 (100.0%)	
Overweight	1882 (79.4%)	117 (4.4%)	145 (6.3%)	205 (9.9%)	2349 (100.0%)	
Obese	2273 (79.4%)	184 (5.3%)	187 (5.3%)	389 (10.0%)	3033 (100.0%)	
Maternal age						0.314
<20	257 (79.0%)	30 (11.7%)	25 (0.5%)	71 (8.9%)	383 (100.0%)	
20-34	5951 (83.0%)	372 (3.4%)	398 (4.9%)	783 (8.7%)	7504 (100.0%)	
>=35	1746 (81.3%)	83 (4.5%)	117 (7.4%)	154 (6.8%)	2100 (100.0%)	
Maternal race						0.002
White	3099 (81.9%)	199 (3.9%)	192 (5.3%)	390 (9.0%)	3880 (100.0%)	
African American	761 (87.1%)	33 (4.6%)	63 (5.2%)	97 (3.1%)	954 (100.0%)	
AI/AN	369 (81.0%)	25 (4.8%)	31 (4.8%)	80 (9.5%)	505 (100.0%)	
Asian	1403 (94.0%)	37 (2.8%)	55 (2.6%)	38 (0.6%)	1533 (100.0%)	
Pacific Islander	497 (88.0%)	20 (3.5%)	36 (3.0%)	34 (5.6%)	587 (100.0%)	
Multiple races	1384 (73.3%)	150 (8.2%)	128 (5.9%)	342 (12.6%)	2004 (100.0%)	
Other	441 (88.8%)	21 (1.5%)	35 (6.8%)	27 (3.0%)	524 (100.0%)	
Maternal						0.426

ethnicity						
Not Hispanic	5710 (81.9%)	355 (4.2%)	376 (5.1%)	743 (8.8%)	7184 (100.0%)	
Hispanic	2244 (85.2%)	130 (2.6%)	164 (5.7%)	265 (6.5%)	2803 (100.0%)	
Marital status						0.002
Married	5211 (86.8%)	244 (3.1%)	276 (4.3%)	395 (5.8%)	6126 (100.0%)	
Other	2739 (73.9%)	241 (5.5%)	263 (7.1%)	613 (13.5%)	3856 (100.0%)	
Maternal education						0.531
Less than high school	1035 (82.4%)	79 (4.7%)	88 (4.3%)	173 (12.6%)	1375 (100.0%)	
Highschool or GED	1658 (77.9%)	126 (3.6%)	149 (5.6%)	306 (13.7%)	2239 (100.0%)	
Some college / higher degree	5226 (84.1%)	278 (3.9%)	300 (5.3%)	528 (8.3%)	6332 (100.0%)	
Federal Poverty Level						0.054
≤100%	1685 (74.9%)	144 (4.1%)	173 (7.3%)	395 (13.7%)	2397 (100.0%)	
100.1% - 200%	1617 (80.5%)	107 (3.4%)	115 (5.2%)	240 (11.0%)	2079 (100.0%)	
200.1% - 400%	1744 (83.4%)	103 (5.4%)	111 (5.5%)	160 (5.8%)	2118 (100.0%)	
≥ 400%	2086 (89.8%)	83 (3.8%)	76 (3.4%)	112 (3.0%)	2357 (100.0%)	
Prenatal care adequacy						0.668
Inadequate	862 (78.6%)	48 (1.0%)	83 (6.0%)	125 (14.4%)	1118 (100.0%)	
Intermediate	1110 (83.8%)	58 (4.4%)	60 (6.2%)	107 (5.6%)	1335 (100.0%)	
Adequate	3771 (84.5%)	214 (3.9%)	227 (4.7%)	430 (6.9%)	4642 (100.0%)	
Adequate plus	2170 (79.6%)	161 (4.4%)	168 (5.7%)	343 (10.2%)	2842 (100.0%)	
Social support[a]	4.3 (± 1.4)	4.4 (± 1.4)	3.9 (± 1.6)	4.1 (± 1.2)	4.3 (± 1.4)	0.006
Community support						0.143
Poor	2822 (83.5%)	187 (3.9%)	208 (7.2%)	422 (5.3%)	3639 (100.0%)	
Adequate	5132 (82.1%)	298 (3.9%)	332 (4.3%)	586 (9.8%)	6348 (100.0%)	

Abbreviation: P-value, p-value by t-test for continuous variables and Chi^2 test for categorical variables; AI/AN, American Indian and Alaska Native.

[a]Weighted mean and weighted standard deviation

Table 4.2 presents the results of multivariable linear regression models examining the weighted associations between antenatal depression and GWG. No associations between depression and GWG were observed in all three models.

Table 4.2 Weighted multivariable linear regression models examining the relationship between antenatal depression and total GWG using Oregon PRAMS 2016-2021

	GWG		
Depression	Model 1[a] β [95% CI]	Model 2[b] β [95% CI]	Model 3[c] β [95% CI]
No depression before or during pregnancy	Ref	Ref	Ref
Depression before pregnancy	4.11 [-2.01,10.22]	3.70 [-2.56,9.95]	3.70 [-2.52,9.93]
Depression during pregnancy	4.13 [-1.17,9.44]	4.94 [-0.44,10.32]	5.09 [-0.19,10.37]
Prepregnancy onset depression	0.38 [-4.72,5.49]	2.58 [-2.37,7.53]	2.70 [-2.21,7.60]

Abbreviation: CI, confidence interval.

[a] Adjusted for prepregnancy BMI, age, maternal race, maternal ethnicity, and marital status.

[b] Additionally adjusted for maternal education, Federal Poverty Level, and prenatal care adequacy.

[c] Additionally adjusted for social support and community support.

Table 4.3 presents the results of multivariable logistic regression models examining the weighted associations between antenatal depression and EGWG. All three models found no association between depression before pregnancy, depression during pregnancy, or prepregnancy onset depression and EGWG.

Table 4.3 Weighted multivariable logistic regression models examining the relationship between antenatal depression and EGWG using Oregon PRAMS 2016-2021

	GWG		
Depression	Model 1[a] OR [95% CI]	Model 2[b] OR [95% CI]	Model 3[c] OR [95% CI]
No depression before or during pregnancy	Ref	Ref	Ref
Depression before pregnancy	1.75 [0.70,4.39]	1.68 [0.64,4.35]	1.67 [0.63,4.38]
Depression during pregnancy	0.85 [0.38,1.91]	0.78 [0.34,1.79]	0.78 [0.34,1.79]
Prepregnancy onset depression	2.07 [0.81,5.27]	2.17 [0.81,5.82]	2.24 [0.83,6.06]

Abbreviation: OR, odds ratio; CI, confidence interval.

[a] Adjusted for prepregnancy BMI, age, maternal race, maternal ethnicity, and marital status.

[b] Additionally adjusted for maternal education, Federal Poverty Level, and prenatal care adequacy.

[c] Additionally adjusted for social support and community support.

Table 4.4 presents the results of the weighted multivariable logistic regression models examining the associations between antenatal depression and IGWG. All three models found no association between depression before pregnancy, depression during pregnancy, or prepregnancy onset depression and IGWG.

Table 4.4 Weighted multivariable logistic regression models examining the relationship between antenatal depression and IGWG using Oregon PRAMS 2016-2021

	GWG		
Depression	Model 1[a] OR [95% CI]	Model 2[b] OR [95% CI]	Model 3[c] OR [95% CI]
No depression before or during pregnancy	Ref	Ref	Ref
Depression before pregnancy	0.83 [0.24,2.83]	0.95 [0.25,3.54]	0.94 [0.25,3.59]
Depression during pregnancy	0.54 [0.21,1.39]	0.37 [0.13,1.00]	0.37 [0.13,1.00]
Prepregnancy onset depression	2.33 [0.91,6.01]	1.34 [0.49,3.66]	1.37 [0.51,3.69]

Abbreviation: OR, odds ratio; CI, confidence interval.

[a] Adjusted for prepregnancy BMI, age, maternal race, maternal ethnicity, and marital status.

[b] Additionally adjusted for maternal education, Federal Poverty Level, and prenatal care adequacy.

[c] Additionally adjusted for social support and community support.

Discussion

To the best of our knowledge, this study is the first to examine antenatal depression using Oregon PRAMS at different time points during the antenatal period and to investigate the differences between depression onset and duration with GWG, considering both total GWG

during pregnancy and by categories, excessive or insufficient GWG based on pre-pregnancy BMI. Our study, which utilized a state-representative sample from the Oregon PRAMS 2015-2021, found that 17.4% reported overall antenatal depression with most participants reporting prepregnancy onset depression (8.3%). Additionally, the majority of participants gained either too little or too much weight (67.4%). Unmarried women had higher rates of depression before pregnancy, depression during pregnancy, and prepregnancy onset depression than married women. Our study found no associations between antenatal depression and inadequate, excessive, and total GWG, which are consistent with findings from a recent systematic review and meta-analysis (Dachew et al., 2020).

The overall prevalence of antenatal depression in our study falls between the pooled estimated prevalence of overall antenatal depression at 20.7% and the pooled prevalence of major depression at 15.0% reported by a recent systematic review and meta-analysis (Yin, Sun, Jiang, Xu, Gan, Zhang, Qiu, Yang, Shi, & Chang, 2021). Our findings that more unmarried women and those with less social support experienced antenatal depression align with the risk factors identified in the systematic review and meta-analysis (Yin, Sun, Jiang, Xu, Gan, Zhang, Qiu, Yang, Shi, & Chang, 2021). We observed that more participants who self-identified with multiple races reported antenatal depression. However, limited research has been conducted on how individuals identifying as multiple races influence antenatal depression (Mukherjee et al.,

2016), thus further studies investigating antenatal depression among this group is necessary.

Pregnancy is a period during a woman's life where the correlation between depression and weight gain may differ from that of women in the general adult population. Studies have shown a bidirectional relationship between weight gain and depression in the adult population (Zhang, 2021). Furthermore, depression has been linked to weight changes, both increased and decreased (Brailean et al., 2020). According to Jeffrey and colleagues' theoretical model, experiencing weight stigma or weight-based social identity threat may negatively affect psychological health and physical health, leading to depression, anxiety, physiological stress, undermining self-regulation and executive functioning that all contribute to further weight gain (Hunger et al., 2015). However, weight gain is expected during pregnancy (Grenier et al., 2021; Vanstone et al., 2017), and GWG can be seen as an indicator of a healthy and growing baby (Groth & Kearney, 2009). This perception may offer pregnant women a unique perspective to counter stigma and social identity threats, potentially preventing depression associated with weight change. Future studies should include perceptions of body image and weight stigma when studying the relationship between antenatal depression and GWG.

Furthermore, contrary to our findings of no associations between onset and duration of depression and our three outcomes, Badon et al. (2019) reported that women with prepregnancy onset depression (6 months prior to pregnancy) had a higher risk for both IGWG and EGWG.

They also found that early pregnancy onset depression (first 20 weeks of pregnancy) was associated with a higher weekly GWG and a greater risk of EGWG, compared to those without depression in prepregnancy or early pregnancy. The potential reason for our different findings could be due to two differences in how depression was measured and defined. First, our study employed self-reported dichotomous measures of depression while Badon et al. utilized both clinical diagnosed International Classification of Diseases, 9th Revision and 10th Revision (ICD-9 and ICD-10) depression codes to assess for prepregnancy onset depression and the self-reported Patient Health Questionnaire-9 (PHQ-9) to assess for early pregnancy depression. Second, the timing and duration of antenatal depression was measured differently, where our depression categories spanned from 3 months prior to pregnancy and during the entire duration of pregnancy as compared to 6 months prior to and the first 20 weeks of pregnancy in Badon et al.'s study.

Clinician diagnosis is the gold standard for depression measurements followed by validated screening tools such as the PHQ-9 questionnaire. However, clinician diagnosis may not be feasible for large population-based studies. Additionally, pregnancy cannot be predicted and can often be unplanned, leading to challenges to data collection during antenatal depression. Routine evaluation before and during pregnancy can be particularly difficult in large population-based studies due to need for routine follow-up. Additionally, Badon et al. employed different methods

to evaluate depression at various times, which may introduce measure and information bias. In this context, the method we adopted in our study provides a consistent basis for comparison across different periods of antenatal depression. Given the inconsistency in findings, further studies defining the onset and the duration of antenatal depression and examining these association with GWG are essential.

Second, similar to our study findings, previous studies have also reported that depression during pregnancy is not associated with total GWG, IGWG, or EGWG (Chagarlamudi et al., 2018; Ertel et al., 2017; Hartley et al., 2016; Vehmeijer et al., 2020) as well as a recent systematic review and meta-analysis (Dachew et al., 2020). However, some studies reported significant relationships between depression during pregnancy and higher GWG (Dekel et al., 2019; Dolatian et al., 2020; Matthews et al., 2018) while others suggested that depression during pregnancy was associated with lower GWG (Farias et al., 2021; Shieh & Wu, 2014). The inconsistent findings could be attributed to the different confounders included in each of the studies. For example, Shieh and Wu (2014) reported the correlation between depression and GWG without adjusting for confounding factors while in our fully adjusted model, we adjusted for factors including several maternal and sociodemographic factors, inadequate prenatal care, social support, and community support during pregnancy. Additionally, the specific timing at which depression is assessed during pregnancy may also influence the outcomes, as previously

described. For example, while Matthews et al. reported a positive relationship between depression and total GWG in the first and second trimester, they found no association in the third trimester. Therefore, it is crucial for future research to routinely screen for depression and track GWG across all pregnancy stages to provide a clearer understanding of the relationship between depression during pregnancy and GWG.

One of the strengths of this study lies in the use of a multi-year dataset drawn from a randomly selected representative population, employing a methodology consistent with CDC and Oregon state protocols. Another strength is our consistent measurement of antenatal depression before and during pregnancy, providing a uniform metric for comparison. Furthermore, our total GWG outcome is sourced directly from birth certificates, eliminating the risks of recall biases. Nonetheless, our study has limitations. First, our measure of antenatal depression is based on self-reported responses obtained during the early postpartum period, introducing potential biases related to self-reporting and recall. Since antenatal depression was dichotomized, we could not measure symptom severity. The sensitivity and specificity of the questions on antenatal depression are unknown. Second, the datasets used in this study do not encompass all possible domains or factors that might influence depression and GWG, such as specific details about depression medication and treatment regimens. Third, although the Oregon PRAMS has been prepared in line with protocols set by the CDC, variations between states, such as demographic

characteristics or differences in prenatal care, may limit the generalizability of our findings to other states in the U.S.

Conclusion

Our findings suggest that the rates of antenatal depression during pregnancy as well as excessive and IGWG are fairly high although depression was not associated with GWG. Thus, clinicians should track depression for women of childbearing age and GWG throughout pregnancy. Further studies that routinely measure antenatal depression and GWG across the different stages of pregnancy are needed. Considerations in body image and weight perception should be considered to provide a more comprehensive understanding of the relationship between antenatal depression during pregnancy and GWG.

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CHAPTER FIVE

Conclusion, Implications, and Future Research Recommendations

Purpose of the Dissertation

This study aimed to investigate the factors associated with GWG, with a particular emphasis on the association between social/institutional, interpersonal/family, and maternal factors and excessive gestational weight gain and the relationship between antenatal depression and GWG.

Summary of the Findings

Inconsistent results were observed between the systematic review and meta-analysis and the secondary analysis of the Oregon PRAMS database. The results of the meta-analysis showed that antenatal depression was associated with a higher risk of EGWG and IGWG. The association between antenatal depression and GWG varied at different stages of pregnancy. Based on the limited number of studies that provided analysis needed data, antenatal depression in the first half of pregnancy is associated with IGWG. No association was found between antenatal depression occurring later in pregnancy and insufficient or excessive GWG.

The secondary analysis of the Oregon PRAMs data examined the relationship between social/institutional, interpersonal/family, and maternal factors and EGWG based on the IOM framework. No social/institutional and interpersonal/family factors were observed to be associated with EGWG. Interestingly, having gestational diabetes is associated with a lower risk of EGWG. Results from this study emphasize the importance of monitoring gestational diabetes and GWG. The results of this study can be used to complement previous evidence regarding the

domains of factors associated with EGWG.

The second part of the secondary analysis of the Oregon PRAMs data examined the relationship between antenatal depression and gestational weight gain. The total percentage of participants who reported experiencing depression either before, during pregnancy, or both amounted to 17.4%, with 3.9% experiencing depression before pregnancy, 5.2% during pregnancy, and an additional 8.3% also reporting depression during pregnancy. No associations between depression before pregnancy, depression during pregnancy, or pregnancy-onset depression and GWG, EGWG, or IGWG were observed.

The potential reason for the inconsistent results might be the variation in study designs of the studies included in the systematic review and meta-analysis and the secondary analysis of the Oregon PRAMS dataset in this study. The timing of antenatal depression assessment, the methods used to assess antenatal depression, differences between cross-sectional and longitudinal study designs, the confounding factors considered and adjusted for, and the cultural values of the regions where the studies were conducted may all contribute to the inconsistent findings.

In summary, our findings indicate the importance of focusing on maternal factors when addressing inadequate GWG. It is important to monitor blood sugar levels and pay close attention to depression, especially when it occurs in the first half of pregnancy. No direct

association between depression and GWG was observed, but the high prevalence of antenatal depression and inadequate GWG highlights the need to monitor depression in women of childbearing age and to assist mothers in achieving adequate GWG during pregnancy..

Significance and Implications

The results of this study can provide information for targeting populations at risk of inadequate GWG in clinical care and contribute evidence to guide the development of future policies or interventions aimed at preventing inadequate GWG.

In clinical care, mothers who suffer from depression before 20 weeks of gestation need to be evaluated carefully and may need further actions to prevent inadequate GWG and relevant negative impacts (Khanolkar et al., 2020). The presence of gestational diabetes as a protective factor of EGWG highlights the importance of regular screenings and tracking of pregnancies throughout pregnancy.

In terms of policies and interventions to prevent inadequate GWG, it's crucial to implement strategies that have a profound and immediate impact on expectant mothers. As for the timing of these interventions, focusing on those that significantly influence mothers early in their pregnancy appears more beneficial than those applied before or later in the gestational period.

Limitations

This study presents certain limitations. In relation to the meta-analysis, one should be

cautious when interpreting the results due to the observed heterogeneity and the limited number of studies available for subgroup analysis. As for the secondary analysis of the Oregon PRAMS dataset, potential recall or self-report biases might affect the accuracy of the data. Additionally, the method for assessing depression in the database was based on mothers' self-reported responses to a few simple checkbox questions. Further studies adopting perinatal depression diagnostic criteria or robust and valid depression assessment measures are needed."Third, the results might have limited generalizability outside of the Oregon state population. Last but not least, the datasets could not cover a comprehensive domain of potential contributing factors that affect GWG, such as maternal attitude toward GWG, diet, or exercise. Considering the potential impact of maternal attitudes and behaviors on GWG would be necessary when interpreting the findings.

Recommendations for Future Research

For future studies, research on factors influencing GWG may need to consider whether the impact of these factors differs when they occur in early versus later stages of pregnancy. Further studies investigating the impact of maternal attitudes and behaviors on GWG are necessary. To better understand the relationship between antenatal depression and GWG, further studies that are specific to each trimester and that adopt robust depression assessment measures are needed.

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