

The Effect of Lower Carbohydrate and Lower Glycemic Index Diets in Maternal and Neonatal Outcomes among Pregnant Women: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Greg J. Marchand, MD, FACS, FACOG^{1*}, Daniela Gonzalez Herrera, BS¹, Mckenna Robinson, BS¹, Emily Kline, BS¹, Sarah Mera, BS¹, Michelle Koshaba, BS¹, Nidhi Pulicherla, BA¹, Brooklynn O'Connell BS¹, Fatma Ibrahim, MD², Katelyn Sainz, MD³

Abstract

Objective: To evaluate the effects of low-carbohydrate (low-CHO), low-glycemic-index (low-GI), and low-glycemic-load (low-GL) diets on maternal and neonatal outcomes in pregnant women.

Methods: Systematic review and meta-analysis of randomized controlled trials (RCTs). Six databases were searched from inception to 1 January 2024. Included RCTs compared low-CHO with higher-CHO diets or low-GI/GL with higher-GI/GL diets in pregnancy, using authors' definitions. Risk of bias was assessed with Cochrane RoB 2 tool; analyses were performed in Review Manager 5.3.5.

Results: Twenty-four RCTs (n=3795 women) were included: 5 examined low-CHO diets and 19 examined low-GI or low-GL diets. Low-CHO diets showed no significant benefits for maternal or neonatal outcomes. Low-GI/GL diets significantly reduced postprandial glucose (SMD -0.40, 95% CI -0.53 to -0.28), gestational weight gain (SMD -0.14, 95% CI -0.21 to -0.07), excess weight gain (RR 0.79, 95% CI 0.68–0.90), large-for-gestational-age infants (RR 0.70, 95% CI 0.50–0.98), and preterm delivery (RR 0.55, 95% CI 0.40–0.77). They also improved lipid profiles (higher HDL, lower total cholesterol and triglycerides). No significant effects were seen on fasting glucose, HbA1c, insulin requirement, LDL, gestational age at delivery, cesarean section rate, small-for-gestational-age infants, birth weight, or newborn length.

Conclusion: In pregnancy, low-GI or low-GL diets are associated with modest improvements in maternal glycemia, weight gain, lipid profile, and selected neonatal outcomes (fewer LGA infants and preterm births). Evidence for low-CHO diets remains limited, with no clear benefits demonstrated in the small number of available RCTs.

Affiliation:

¹Marchand Institute for Minimally Invasive Surgery, Mesa, Arizona, USA

²Fayoum University, Faculty of Medicine, Fayoum, Egypt

³Dartmouth Health Children's, Department of Neonatology, Lebanon, NH, USA

*Corresponding author:

Greg J. Marchand, MD, FACS, FACOG, Marchand Institute for Minimally Invasive Surgery, Mesa, Arizona, USA.

Citation: Greg J. Marchand, Daniela Gonzalez Herrera, Mckenna Robinson, Emily Kline, Sarah Mera, Michelle Koshaba, Nidhi Pulicherla, Brooklynn O'Connell, Fatma Ibrahim, Katelyn Sainz. The Effect of Lower Carbohydrate and Lower Glycemic Index Diets in Maternal and Neonatal Outcomes among Pregnant Women: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Journal of Pediatrics, Perinatology and Child Health*. 10 (2026): 19-39.

Received: January 31, 2026

Accepted: February 11, 2026

Published: February 23, 2026

Keywords: Low Carbohydrate; Low Carb Diet; Pregnancy

Abbreviations: CI: Confidence interval; GDM: Gestational diabetes mellitus; HAPO: Hyperglycemia and Adverse Pregnancy Outcome; HbA1c: Glycated hemoglobin; HDL: High-density lipoprotein; I²: Heterogeneity statistic; LDL: Low-density lipoprotein; MD: Mean difference; PICOS: Population, Intervention, Comparison, Outcomes, Study design; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT: Randomized controlled trial; RoB: Risk of bias; RR: Risk ratio; SMD: Standardized mean difference

Introduction

Pregnancy is characterized by maternal physiological metabolic changes, resulting in increased nutritional requirements and altered carbohydrate metabolism

to facilitate maternal metabolism and allow fetal growth [1]. Glucose is an essential source of energy for the growth of both the placenta and fetus [2]. Gestational diabetes (GDM) affects approximately 10% of pregnancies, involving insulin resistance developing during pregnancy, and increases risks of preeclampsia, cesarean delivery, and neonatal hypoglycemia [2,3]. Pregestational diabetes, present before pregnancy, has distinct risks including congenital anomalies due to early hyperglycemia and higher rates of stillbirth [4]. However, pregnancy seems to be naturally associated with decreased insulin sensitivity, and approximately 10% of pregnancies are further complicated by gestational or pregestational diabetes [2,3]. This in turn increases the risk of both maternal and fetal complications, especially in overweight or obese women. As a result, many feel that the pregnancy state itself could be considered a metabolic test that may predict the development of metabolic syndrome in women later in life [1,3,5]. Longitudinal studies (e.g., HAPO Follow-up) show GDM increases metabolic syndrome risk by 3-4 fold postpartum [6].

Nutrition during pregnancy affects many maternal and fetal outcomes, especially glucose levels [7]. Lifestyle and diet modifications have been tested in many studies to attempt to both optimize maternal glucose levels and to treat pathological states, such as diabetes [8,9]. The average required daily amount or quantity of carbohydrates for pregnant women is controversial. The Academy of Nutrition and Dietetics suggests that a diet should contain at least 175 grams per day to provide sufficient macronutrients [10]. On the other hand, the American Endocrine Society suggests that about 33% to 45% of total calories should consist of carbohydrates [8,9], which is approximately 200 to 300 grams daily for most diets [10]. While multiple studies have been performed to look at the effects of low carbohydrate and lower glycemic index diets on blood sugar levels, there is no consensus on a direct effect of either of these modalities in the pregnant or non-pregnant state [11-13]. Low carbohydrate diets are typically defined as less than 40% of energy or less than 130 grams per day, low glycemic index diets as less than 55, and low glycemic load diets as less than 120 per day, as per study definitions [14].

Table 1: Summary of the analyzed maternal and neonatal outcomes in both low carbohydrate diet and low glycemic diet analyses.

Outcome name	Number of studies	MD / SMD / RR	95% CI	P. value	Model	Heterogeneity
Maternal outcomes in low carbohydrates group						
Fasting blood glucose change	3	MD = 1.64	(-1.29, 4.57)	0.27	Fixed effect model	(I ² = 0%, P = 0.92)
Insulin therapy	4	RR = 1.03	(0.8, 1.33)	0.81	Fixed effect model	(I ² = 0%, P = 0.94)
Cesarean section	5	RR = 0.93	(0.68, 1.27)	0.64	Fixed effect model	(I ² = 29%, P = 0.23)
Gestational age at delivery	5	MD = 0.09	(-0.22, 0.4)	0.58	Fixed effect model	(I ² = 0%, P = 0.1)
Gestational weight gain	5	MD = -0.62	(-1.28, 0.04)	0.07	Fixed effect model	(I ² = 49%, P = 0.12)
Neonatal outcomes in low carbohydrates group						
Birth length	2	MD = -1.04	(-2.14, 0.06)	0.06	Fixed effect model	(I ² = 0%, P = 0.66)
Birth weight	2	MD = -24.82	(-153.34, 104.00)	0.71	Fixed effect model	(I ² = 0%, P = 0.057)
Large for gestational age	3	RR = 0.71	(0.29, 1.72)	0.44	Fixed effect model	(I ² = 0%, P = 0.50)
Macrosomia	3	RR = 0.53	(0.2, 1.44)	0.21	Fixed effect model	(I ² = 0%, P = 0.21)
Small for gestational age	3	RR = 0.96	(0.49, 1.85)	0.89	Fixed effect model	(I ² = 0%, P = 0.38)
Maternal outcomes in low glycemic group						
Fasting blood glucose change	7	SMD = -0.15	(-0.39, 0.09)	0.21	Random effect model	(I ² = 68%, P = 0.005)
Two hour postprandial level change	7	SMD = -0.4	(-0.53, -0.28)	<0.00001	Fixed effect model	(I ² = 32%, P = 0.19)
HbA1c change	6	MD = 0.03	(-0.02, 0.08)	0.2	Fixed effect model	(I ² = 0%, P = 0.78)
Insulin therapy	6	RR = 0.94	(0.78, 1.14)	0.52	Fixed effect model	(I ² = 0%, P = 0.49)
Excess weight gain - After Sensitivity Analysis [†]	7	RR = 0.73	(0.60, 0.91)	0.004	Random effect model	(I ² = 46%, P = 0.09)
	6	RR = 0.79	(0.68, 0.90)	0.0006		(I ² = 0%, P = 0.49)
Gestational weight gain	14	SMD = -0.14	(-0.21, -0.07)	0.0002	Fixed effect model	(I ² = 28%, P = 0.16)
HDL level change	4	MD = 0.08	(0.05, 0.12)	<0.00001	Fixed effect model	(I ² = 3%, P = 0.38)
Cholesterol level change	4	MD = -0.11	(-0.15, -0.07)	<0.00001	Fixed effect model	(I ² = 19%, P = 0.3)
LDL level change	4	MD = 0.02	(-0.01, 0.05)	0.19	Fixed effect model	(I ² = 19%, P = 0.3)
Triglycerides level change	4	MD = -0.15	(-0.21, -0.10)	<0.00001	Fixed effect model	(I ² = 0%, P = 0.69)

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Gestational age at delivery	11	MD = 0.1	(-0.14, 0.33)	0.43	Random effect model	(I2 = 68%, P = 0.0005)
- After Sensitivity Analysis†	10	MD = -0.03	(-0.18, 0.12)	0.67		(I2 = 31%, P = 0.16)
Cesarean section	8	RR = 0.80	(0.64, 1)	0.05	Fixed effect model	(I2 = 28%, P = 0.21)
Neonatal outcomes in low glyceimic group						
Small for gestational age	9	RR = 1	(0.69, 1.45)	0.99	Fixed effect model	(I2 = 0%, P = 0.85)
Large for gestational age	9	RR = 0.70	(0.50, 0.98)	0.04	Fixed effect model	(I2 = 35%, P = 0.14)
Birth weight	14	MD = -0.01	(-0.12, 0.09)	0.8	Random effect model	(I2 = 85%, P < 0.00001)
- After Sensitivity Analysis†	13	MD = 0.02	(-0.03, 0.07)	0.43		(I2 = 28%, P = 0.17)
Newborn length	7	MD = -0.02	(-0.45, 0.40)	0.92	Random effect model	(I2 = 61%, P = 0.02)
- After Sensitivity Analysis†	6	MD = 0.12	(-0.24, 0.48)	0.51		(I2 = 42%, P = 0.12)
Preterm	10	RR = 0.55	(0.4, 0.77)	0.0004	Fixed effect model	(I2 = 34%, P = 0.14)
Macrosomia	14	RR = 0.89	(0.79, 1.02)	0.08	Fixed effect model	(I2 = 18%, P = 0.25)

†: Data after sensitivity analysis, excluding Walsh et al. 2012

The glyceimic index quantifies the incremental area under the glucose curve after consuming 50 grams of available carbohydrate relative to a reference food [14]. In a low carbohydrate diet, the quantity of carbohydrates, regardless of type, is strictly decreased. In a diet with a lower glyceimic index or lower glyceimic load, carbohydrates are not necessarily reduced in quantity but are chosen based on their lower impact on blood glucose levels [15]. Differences in the glyceimic index of carbohydrates can affect glucose levels and in turn affect maternal and neonatal outcomes [12,16,17].

Previous meta-analyses, such as Zhang et al. [18], Liu et al. [19], and Deng et al. [20], have examined low glyceimic index diets in pregnancy, often focusing on high-risk groups and showing benefits in macrosomia and weight gain [18-20]. Our review innovates by separately analyzing low carbohydrate diets (5 RCTs), incorporating 24 RCTs total (updated to January 2024), and assessing a broader population including non-GDM women. Primary outcomes of this study include maternal glucose levels and weight gain, as well as neonatal birth weight and macrosomia. Secondary outcomes encompass cesarean delivery rates, preterm delivery, and lipid profiles, as detailed in Table 1.

Methods

We reported our systematic review and meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [21].

Literature Search We conducted our search through six databases (PubMed, Medline, Cochrane Library, Web of Science, Scopus, and ClinicalTrials.gov) for all relevant studies until January 2024 using this search strategy: (((low glyceimic load) OR (low glyceimic index) OR (low energy diet) OR (low-calorie diet) OR (low-carb diet) OR (keto diet) OR (low carbohydrate diet) OR (low carb diet) OR (carbohydrate-restricted diet)) AND ((Pregnancy) OR (Pregnant))). The search utilized MeSH terms (e.g.,

Pregnancy, Diet, Carbohydrate-Restricted) and filters for RCTs and human studies.

Eligibility Criteria Using the PICOS framework, we defined the study parameters as follows:

- **Population:** pregnant women;
- **Intervention:** low carbohydrate diets or low glyceimic index/load diets (as defined by study authors);
- **Comparison:** higher carbohydrate diets or higher glyceimic index diets;
- **Outcomes:** maternal (e.g., glucose levels, weight gain, cesarean rates) and neonatal (e.g., birth weight, macrosomia, preterm delivery) outcomes;
- **Study Design:** randomized controlled trials.

No strict cut-offs were used; we accepted author definitions to reflect clinical variability. To capture real-world variability in dietary advice, we included diverse dietary interventions as defined by study authors. Cross-over trials were excluded due to potential carry-over effects in dietary interventions during pregnancy. Outcomes were specified in advance as detailed in Table 1.

Study Selection The results of database searches were exported to EndNote X8.0.1 [22] and then to Excel software to start screening. At first, two authors independently screened the titles and abstracts of the resulting records and then they screened the full texts of the retrieved records from the title and abstract screening phase according to the eligibility criteria. Any conflict was managed by discussion between the two authors. We excluded Louie 2012 as it shared a duplicate population with Louie 2011; we selected Louie 2011 for its broader outcomes, as illustrated in Figure 1.

Data Extraction We first extracted the general and baseline data of the included studies like study design, country, inclusion criteria, type of diet, age, body mass

index, gestational age, prevalence of gestational diabetes, and prevalence of hypertension, as shown in Table 2 and Table 3. Next, we extracted the outcomes related to our outcomes. Maternal outcomes included changes in fasting and two-hour

postprandial glucose levels, the change in A1C levels, the need for insulin therapy, the gestational age at delivery (in weeks), the gestational weight gain in kilograms, the number of patients with excess weight gain during pregnancy, the change in high-density lipoprotein (HDL) levels, low-density lipoprotein (LDL) levels, total cholesterol levels, triglyceride levels, and the rate of cesarean delivery. Neonatal outcomes included birth length in centimeters, birth weight in kilograms, the number of large for gestational age neonates, the number of small for gestational age neonates, the incidence of macrosomia, and the incidence of preterm delivery. Data were extracted independently by two reviewers using a standardized form that included elements such as PICOS and outcomes [11,13,16,17,20,23-36,47-51].

Quality Assessment Two authors independently assessed the risk of bias in each study using the Cochrane “Risk of Bias 2” tool for randomized controlled trials (RoB 2) which consists of five domains: randomization, deviation from intended intervention, missing data, outcome measurement, and selection of reported outcomes, as depicted in Figure 2. Each domain was assessed and judged as to whether it had a low, high, or unclear risk of bias. Then, an overall judgment was determined for each study. Reviewers calibrated on the first five studies to ensure agreement on the risk of bias assessment [11,23].

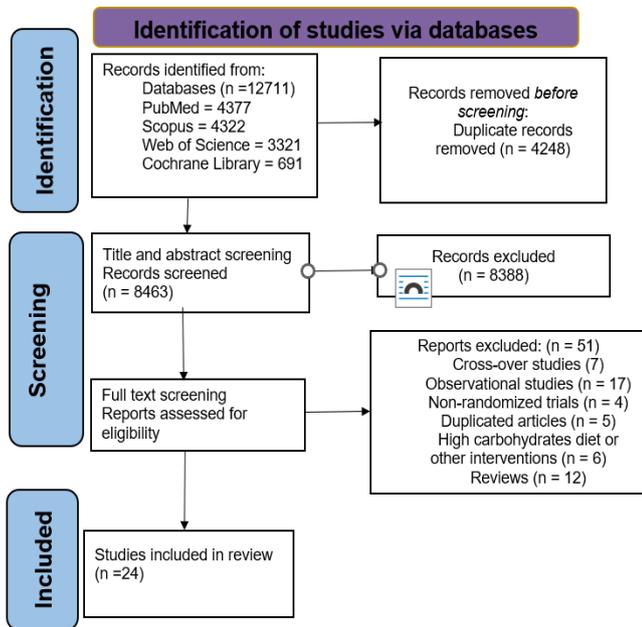


Figure 1: PRISMA flow diagram of study screening and selection.

Table 2: General details of all included studies.

Author and year	Study Design, country	Participants and main inclusion criteria	Intervention	Control
Castilla et al. [23]	RCT, Spain	Pregnant women aged 18–45 years with GDM and gestational age more than 35 weeks	Protein 20% of the total daily calorie amount, CHO 40%, and fat 40% (n=75)	Protein 20% of the total daily calorie amount, CHO 55% and fat 25% in the control diet (n=75)
Cypryk et al. [11]	RCT, Poland	Pregnant women treated at the Outpatient Clinic	Low carbohydrate diet, in which the daily supply of energy derived from carbohydrates was 45% of energy, 25% of energy came from protein and 30% from fat (n=15)	High carbohydrate diet, in which the daily contribution of carbohydrates was over 60% of energy intake, 25% of energy came from protein and 15% from fat (n=15)
Hernandez et al. [13]	RCT, USA	Pregnant women with GDM, and singleton pregnancies, aged between 20 and 39 years old, and had a BMI of 26–42 kg/m ² at the time of diagnosis	LC/CONV, 40% carbohydrate/45% fat/15% protein (n=23)	CHOICE, 60% carbohydrate/25% fat/15% protein (n=23)
Mijatovic et al. [29]	RCT, Australia	Pregnant women with GDM aged 18–45 y with a singleton pregnancy, between 24 and 32 weeks of gestation	Lower carbohydrate diet (n=24)	“The routine diet” (n=22)
Trout et al. [34]	RCT, USA	Women with GDM aged 18–45 controlled by diet, or using oral hypoGlycemic drugs	Carbohydrate-restricted diet (35–40% of total calories) (n=37)	“The usual pregnancy diet” (carbohydrate intake 50–55% of total calories) (n= 31)
Geiker et al. [28]	RCT, Denmark	Women aged more than 18 years, with a prepregnancy BMI of 28–45 and a singleton pregnancy	HPLGI: low in Glycemic Index (maximum mean of 55 Glycemic Index units from the total diet (n= 141) and high protein (25% -28% of total energy consumed)	No instructions concerning the Glycemic Index (moderate Glycemic Index) and moderate protein content (18% of total energy consumed) (n= 138)
Goletzke et al. [36]	RCT, USA	Pregnant women aged 18-42 years and singleton pregnancy with a BMI more than or equal to 30 or a body fat >35%	Low Glycemic Load diet (n = 39)	High Glycemic Load diet (n=34)

Grant et al. [25]	RCT, Canada	Pregnant women with GDM aged 18–45 years	Low Glycemic Index diet (n = 23)	Intermediate- and high-GI foods (n = 24) reflecting the usual intake of typical pregnancy patients
Hu et al. [31]	RCT, China	Pregnant women with GDM at 23 to 35 weeks gestation	Patients received low-GI staple foods and nutritional education. N= 66 (low GI of less than 5)	Patients in the control group received a routine staple food (white rice) diet the same as a normal diabetic control diet for patients with GDM and nutritional education (n=74)
Bruno et al. [35]	RCT, Italy	Women with singleton pregnancy, and aged more than 18 with a pre-pregnancy BMI ≥ 25 kg/m ² ,	Macronutrient composition of 55% carbohydrates (80% complex carbohydrates with a low glycaemic Index and 20% simple carbohydrates), 20% protein and 25%fat in addition to physical intervention (n=96)	The women in the control group received a simple nutritional booklet regarding lifestyle (n=95).
Petrella et al. [24]	RCT, Italy	Women aged more than 18 years with a pre-pregnancy BMI of 25 kg/m ² and single pregnancy.	Therapeutic Lifestyle Changes Program (diet, and exercise) the diet composition of 55% carbohydrate (80% complex with low-Glycemic Index and 20% simplex), 20% protein and 25% fat with moderately low saturated fat levels(n=33)	No intervention (n=30); a simple nutritional booklet about lifestyle.
Louie et al. [27]	RCT, Australia	Women aged 18–45 years diagnosed with GDM, with an otherwise healthy singleton pregnancy, were eligible for the study.	Low Glycemic Index (target GI ≤ 50)	High-fiber content and moderate GI, similar to the Australian population average (target GI=60)
Ma et al. [17]	RCT, China	Women aged between 18 and 40 years, and an incident GDM patient diagnosed at 24–26 weeks of gestation.	Low-Glycemic Load	The Control group received an individualized general dietary intervention
Moses et al. [33]	RCT, Australia	Inclusion criteria were age 18 – 40 years (inclusive), singleton pregnancy, no previous GDM, and nonsmoker.	Low Glycemic Index	High Glycemic Index
Moses et al. [47]	RCT, Australia	Women at 20 weeks of gestation with a singleton pregnancy, aged more than 18 years	Low Glycemic Index	Routine eating diet
Perera et al. [26]	RCT, Mexico	Women with gestational age ≤ 29 weeks, had GDM or pregestational type 2 DM	Low Glycemic Index	All CHO types (individual food plan based on CHO restriction (40– 45% of total intake), using a CHO counting strategy (basic level)
Rhodes et al. [48]	Pilot RCT, USA	Subjects were pregnant women with a pre-pregnancy or first trimester body mass Index between 25 to 45 and aged more than 25 years.	Low Glycemic Load	Low fat
Zhang et al. [49]	RCT, China	Women aged 18 to 45 years, with BMI ≥ 24 kg/m ² .	Low Glycemic Index (target GI ≤ 55)	The Control group received an individualized general dietary intervention
Facchinetti et al. [50]	RCT, Italy	Women between the 9th and 12th week of gestation with body mass Index (BMI) ≥ 25 m/kg ² , aged >18 years, and with a singleton pregnancy	Caloric restriction consisted of the prescription of a low-GI, low-saturated fat diet with a total intake of 1500 kcal/d	All of the women received a general nutritional booklet regarding the correct lifestyle, namely about proper food intake without a specific caloric restriction, following the Italian guidelines. (N = 22)
Menichini et al. [51]	RCT, Italy	Women between the 9th and 12th week of pregnancy with body mass Index (BMI) ≥ 25 kg/m ² , aged ≥ 18 years, and carrying a singleton pregnancy.	Caloric restriction consisted of a low Glycemic Index, and low saturated fat diet with a total intake of 1700 kcal/day.	General nutritional booklet concerning proper food intake without specific caloric restriction, following Italian guidelines
Markovic et al. [32]	RCT, Australia	Women >18 years of age between 12–20 weeks of gestation and at high risk of GDM with an otherwise healthy single pregnancy were eligible for the study.	Low Glycemic Index	High fiber moderate Glycemic Index

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Walsh et al. [30]	RCT, Ireland	Secundigravid pregnant women over 18 years of age, who had previously given birth to a macrosomic infant (birth weight > 4 kg), were recruited before the 18th week of gestation.	Low Glycemic Index	Routine antenatal care without any formal dietary advice
Lv et al. [16]	RCT, China	The inclusion criteria were as follows: (1) singleton gestation; (2) no metabolic disease, and no liver and kidney dysfunction; (3) no history of diabetes before pregnancy; (4) junior high school diploma or above; (5) no diabetes health education from professional nutrition physicians; and (6) no use of insulin	Food exchange group based on the concept of GL	Traditional Food Exchange
Louie et al. [27]	RCT, Australia	All women who attended the Royal Prince Alfred Hospital GDM antenatal clinic from June 2010 to November 2011 were approached for recruitment, and ten women aged 18–45 years, who had been diagnosed with GDM.	Low Glycemic Index	High Glycemic Index

GDM = Gestational Diabetes Mellitus, BMI = Body Mass Index, GI = Glycemic Index, GL = Glycemic Load, CHO = Carbohydrate

Table 3: Baseline data of pregnant women in all included studies.

Author and Year	Age (years)				Body mass index (Kg/m ²)				Gestational age (weeks)				Prevalence of Gestational Diabetes		Prevalence of Hypertension	
	Intervention		Control		Intervention		Control		Intervention		Control		Intervention	Control	Intervention	Control
	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Event (total)	Event (total)	Event (total)	Event (total)
Castilla et al. [23]	33.5 (3.7)	75	32.1 (4.4)	75	25.4 (5.7)	75	26.6 (5.5)	75	30.4 (3)	75	30.1 (3.5)	75	75 (75)	75 (75)	4 (75)	10 (75)
Cypryk et al. [11]	28.7 (3.7)	15	28.7 (3.7)	15	NR	NR	NR	NR	29.2 (5.4)	15	29.2 (5.4)	15	15 (15)	15 (15)	NR	NR
Hernandez et al. [13]	32 (4.8)	23	33 (4.8)	23	32 (4.8)	23	32 (4.8)	23	31.7 (0.48)	23	32.3 (0.48)	23	23 (23)	23 (23)	NR	NR
Mijatovic et al. [29]	32.5 (4.41)	24	34.2 (4.22)	22	25.8 (2.45)	24	27.8 (7.04)	22	28.4 (2.45)	24	28.6 (2.81)	22	24 (24)	22 (22)	NR	NR
Trout et al. [34]	30.09 (6.15)	37	29.63 (5.19)	31	33.84 (8.84)	37	31.8 (8.68)	31	29.17 (2.78)	37	30.5 (2.85)	31	37 (37)	31 (31)	NR	NR
Geiker et al. [28]	31 (5)	141	30 (5)	138	Pre-pregnancy BMI in the range of 28–45				12.4 (2.3)	141	13.3 (1.2)	138	12 (141)	6 (138)	1 (102)	0 (94)
Goletzke et al. [36]	29.3 (5.2)	28	28.3 (6)	34	33.1 (6.26)	28	32.2 (4.13)	34	NR	NR	NR	NR	NR	NR	NR	NR
Grant et al. [25]	34 (0.46)	21	34 (5.16)	22	27 (4.58)	21	26 (4.69)	22	29 (3.21)	21	29 (2.35)	22	15 (21)	17 (22)	NR	NR
Hu et al. [31]	30.3 (4.9)	66	29.7 (3.7)	74	21.2 (2.5)	66	20.9 (3.4)	74	27 (2.7)	66	27.9 (3.8)	74	66 (66)	74 (74)	NR	NR
Bruno et al. [35]	31.5 (5)	96	30.8 (5.5)	95	33.9 (5.7)	69	34.5 (6.8)	62	10.69 (1.1)	96	10.8 (1.3)	95	13 (69)	23 (62)	2 (69)	13 (62)
Petrella et al. [24]	31.5 (4.2)	33	32.4 (5.9)	30	32.1 (5)	33	32.9 (6.2)	30	NR	NR	NR	NR	7 (33)	16 (28)	1 (33)	7 (28)
Louie et al. [27]	34 (4.1)	47	32.4 (4.5)	45	23.9 (4.4)	47	24.1 (5.7)	45	29 (4)	47	29.7 (3.5)	45	47 (47)	45 (45)	NR	NR
Ma et al. [17]	30.1 (3.8)	41	30 (3.5)	42	21.9 (3.14)	41	21.15 (2.75)	42	27.9 (1.1)	42	27.5 (1.1)	41	47 (47)	48 (48)	NR	NR
Moses et al. [33]	30.8 (3.9)	31	31.3 (4.53)	32	32 (6.68)	31	32.8 (7.92)	32	30.3 (1.11)	31	29.9 (1.13)	32	31 (31)	32 (32)	NR	NR
Moses et al. [47]	29.9 (5.16)	296	29.9 (5.02)	280	24.3 (5.16)	296	24.7 (5.02)	280	16.5 (1.72)	296	16.1 (1.67)	280	22 (296)	21 (280)	NR	NR
Perera et al. [26]	32.3 (4.8)	61	31.8 (5.3)	46	30.5 (5.2)	61	32 (6.3)	46	22.5 (4.9)	61	20.7 (6.7)	46	29 (61)	23 (46)	NR	NR

Citation: Greg J. Marchand, Daniela Gonzalez Herrera, Mckenna Robinson, Emily Kline, Sarah Mera, Michelle Koshaba, Nidhi Pulicherla, Brooklynn O'Connell, Fatma Ibrahim, Katelyn Sainz. The Effect of Lower Carbohydrate and Lower Glycemic Index Diets in Maternal and Neonatal Outcomes among Pregnant Women: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Journal of Pediatrics, Perinatology and Child Health. 10 (2026): 19-39.

Rhodes et al. [48]	33.7 (3.9)	25	33.2 (3.7)	21	32.1 (4.6)	25	31.2 (3.1)	21	19.8 (5)	25	19.6 (4.3)	21	NR	NR	NR	NR
Zhang et al. [49]	28.1 (3.6)	200	28 (3.7)	200	28.4 (3)	200	28 (3)	200	12.2 (2.2)	200	12.4 (2.2)	200	45 (200)	43 (200)	45 (200)	32 (200)
Facchinetti et al. [50]	32.6 (4.7)	81	32.2 (5)	75	34.1 (6.7)	81	34 (6.3)	75	NR	NR	NR	NR	27 (81)	21 (75)	10 (81)	6 (75)
Menichini et al. [51]	NR	36	NR	46	NR	36	NR	46	NR	NR	NR	NR	17 (36)	22 (46)	6 (36)	4 (46)
Markovic et al. [32]	35.7 (4.7)	72	34.9 (4.1)	67	25.2 (5.2)	72	25.2 (5.2)	67	17.5 (2)	72	17.7 (1.7)	67	10 (72)	11 (67)	NR	NR
Walsh et al. [30]	32 (4.2)	383	32 (4.2)	396	26.8 (5.1)	383	26.8 (4.8)	398	13 (2.3)	383	12.9 (2.2)	398	7 (350)	9 (371)	NR	NR
Lv et al. [16]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Louie et al. [27]	NR	NR	NR	NR	29.4 (1.79)		20		33.5 (2.24)		20		NR	NR	NR	NR

Statistical Analysis We first performed an analysis to investigate the low carbohydrate diet, then we performed the analysis to investigate the low glycemic index or low glycemic load diets. We performed the analysis using the Review Manager™ software, version 5.3.5. The qualitative variables were analyzed using risk ratio (RR) with a 95% confidence interval (CI) while the quantitative variables were analyzed using mean difference (MD) with 95% CI or by using standardized mean difference (SMD) with 95% CI only in case of using different units or scales. The results were considered significant when the P value < 0.05. Missing data were addressed by contacting study authors and imputing standard deviations from standard errors when necessary. Publication bias was evaluated using funnel plots for outcomes with more than 10 studies. For studies with multiple intervention arms, we combined similar arms or selected the primary arm for analysis. We used the fixed effect model in those cases where there was no significant heterogeneity between studies. We used the random effects model only in cases of significant heterogeneity. The heterogeneity was determined by the Cochrane Q test and I² test. The outcomes were considered heterogeneous only when P < 0.1 and I² > 50% [37]. When significant heterogeneity was present, we tried to solve the heterogeneity by doing a sensitivity test to exclude the most likely article responsible for the heterogeneity [37].

Results

Our database search resulted in 12,711 records. From those, 8,463 records entered the title and abstract screening after removing duplicates (4,248 records). Only 75 records were eligible for the full-text screening, which resulted in the inclusion of 24 studies which met our eligibility criteria, as illustrated in Figure 1.

General and Baseline Characteristics of the Included Studies Our review included 24 studies with a total population of 3795 pregnant women; 1909 of those had a low carbohydrate or low glycemic index diet and 1886 had a control diet consisting of more carbohydrates or a higher glycemic index [11,13,16,17,20,23-36,47-51]. Five studies

investigated the low carbohydrate diet [11,13,23,29,34] and the other 19 studies examined the low glycemic index or low glycemic load diets [16,17,20,24-28,30-33,35,36,47-51]. Regarding the low carbohydrate studies, there were five studies with a total population of 340 pregnant women (174 had a low carbohydrate diet and the other 166 had a higher carbohydrate diet) [11,13,23,29,34]. Two studies were performed in the United States [13, 34], one in Spain [23], one in Poland [11], and one in Australia [29]. All five of these studies included only patients suffering from gestational diabetes. Regarding the studies investigating the low glycemic index diets, there were 19 studies with a total population of about 3455 pregnant women (1735 had low glycemic index or glycemic load diet and 1720 had higher glycemic index or glycemic load diet) [16,17,20,24-28,30-33,35,36,47-51]. Four studies were performed in Australia [27,32,33,47], four in Italy [24,35,50,51], five in China [16,17,20,31,49], two in the United States [36,48], one in Canada [25], one in Denmark [28], one in Mexico [26], and one in Ireland [30]. In four of these studies, the entire population had gestational diabetes [17,27,31,33], while the rest of the studies included some women with and without gestational diabetes. Table 1 and Table 2 show the full details of the general and baseline data of the included studies.

Risk of Bias Assessment Out of the 24 studies included, four studies had a low overall risk of bias [29-32], three had a high overall risk of bias [13,17,25], and the rest had some concerns about the overall risk of bias [11,16,20,23,24,26,27,28,33-36,47-51]. Regarding the domains of RoB assessment, all studies were of low risk of bias regarding the missing outcome data and the measurement of the outcome domains. Regarding the randomization process domain, ten studies did not give clear information regarding the allocation concealment and the methods of randomization [16,20,25,26,31,34-36,48,49,50], and one study had a high risk of bias [17]. As expected, a reasonable person will tend to notice a change in the food they eat on a daily basis, so in 13 studies there was significant concern that the patients and/or caregivers not being significantly blinded during the

Study ID	D1	D2	D3	D4	D5	Overall
Castilla et al. 2013	+	!	+	+	+	!
Cypryk et al. 2007	!	!	+	+	!	!
Hernandez et al. 2023	+	!	+	+	●	●
Mijatovic et al. 2020	+	+	+	+	+	+
Trout et al. 2016	!	+	+	+	!	!
Geiker et al. 2022	+	+	+	+	!	!
Goletzke et al. 2021	!	!	+	+	!	!
Grant et al. 2011	!	!	+	+	●	●
Hu et al. 2014	!	+	+	+	!	!
Bruno et al. 2017	+	!	+	+	+	!
Petrella et al. 2013	+	+	+	+	!	!
Louie et al. 2011	+	+	+	+	+	+
Ma et al. 2015	●	+	+	+	!	●
Moses et al. 2009	!	!	+	+	!	!
Moses et al. 2013	+	+	+	+	+	+
Perera et al. 2012	!	!	+	+	+	!
Rhodes et al. 2010	!	!	+	+	+	!
Zhang et al. 2019	!	!	+	+	+	!
Facchinetti et al. 2019	+	!	+	+	+	!
Menichini et al. 2020	+	!	+	+	+	!
Markovic et al. 2016	+	+	+	+	+	+
Walsh et al. 2012	+	!	+	+	+	!
Lv et al. 2019	!	!	+	+	!	!
Louie et al. 2012	+	!	+	+	!	!

Legend
 ● Low risk
 ! Some concerns
 ● High risk
 D1: Randomisation process
 D2: Deviations from the intended interventions
 D3: Missing outcome data
 D4: Measurement of the outcome
 D5: Selection of the reported result

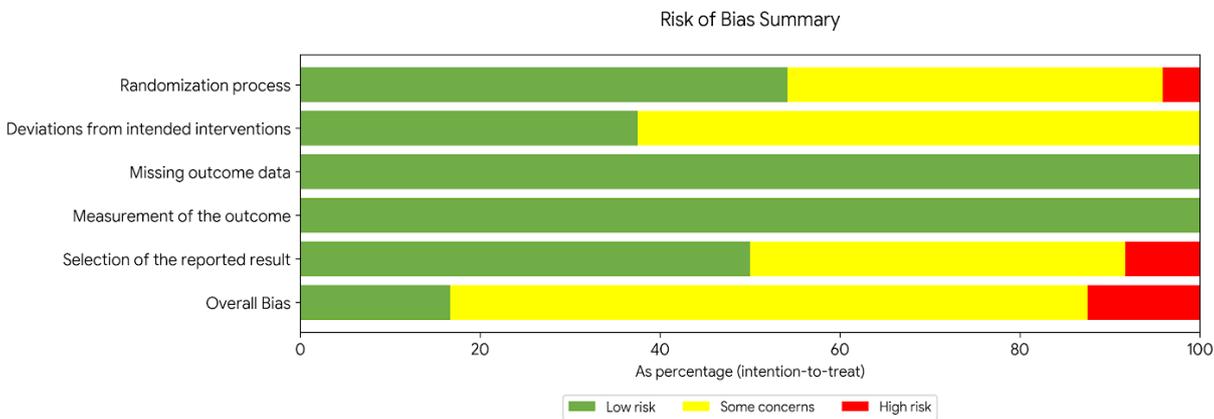


Figure 2: Cochrane “Risk of Bias 2” assessment of the included studies.

trials, therefore, there was some risk of bias in that area [11,16,20,23,25,27,31,32,34,35,49,50,51]. Regarding the selection of reported results, ten studies had some concerns about the registration of the clinical trials or mentioning all specific outcomes [16,17,20,27,31,32,34-36,49], and two studies had a high risk of bias [13,25]. Figure 2 shows the full details of the risk of bias assessment.

Maternal and Neonatal Outcomes in Studies Investigating Low Carbohydrate Diets In the maternal outcomes, we found that there were no significant differences in all studied maternal outcomes, including cesarean delivery (RR 0.93, 95% CI 0.68 to 1.27, P=0.64), fasting blood glucose level (MD 1.64, 95% CI -1.29 to 4.57, P=0.27), gestational age at delivery (MD 0.09, 95% CI -0.22 to 0.4, P=0.58), gestational weight gain (MD -0.62, 95% CI -1.28 to

0.04, P=0.07), and insulin therapy (RR 1.03, 95% CI 0.8 to 1.33, P=0.81). All outcomes were homogeneous; therefore, we used the fixed effect model in all cases, as seen in Table 3.

Also, in neonatal outcomes, we found no significant differences in all studied outcomes, including birth length (MD -1.04, 95% CI -2.14 to 0.06, P=0.06), birth weight (MD -24.82, 95% CI -15.64 to 104.00, P=0.71), incidence of large for gestational age (RR 0.71, 95% CI 0.29 to 1.72, P=0.44), small for gestational age (RR 0.96, 95% CI 0.49 to 1.85, P=0.89), and macrosomia (RR 0.53, 95% CI 0.2 to 1.44, P=0.21). All outcomes were homogeneous; therefore, we again used the fixed effect model in all cases, as seen in Table 3.

Maternal and Neonatal Outcomes in Studies Investigating the Low Glycemic Index or Low Glycemic Load Diets In maternal outcomes, many outcomes were significant and favored the low glycemic diet. Regarding weight parameters, gestational weight gain (SMD -0.14, 95% CI -0.21 to -0.07, P=0.0002) and the number of patients with excess weight gain during pregnancy (RR 0.79, 95% CI 0.68 to 0.9, P=0.0006) significantly favored the low glycemic diet group, as shown in Figure 3 and Figure 4. Gestational weight gain outcome was homogeneous; however, the number of patients with excess weight gain was heterogeneous, therefore, the random effect model was used. Heterogeneity was resolved by excluding Perera et al. (P=0.49, I²=0%), and

the outcome remained significant (P=0.0006). Table 3 shows the full details.

Regarding the diabetes profile data, only the change in the two-hour postprandial blood glucose level change was significantly lower in the low glycemic diet group (SMD -0.4, 95% CI -0.53 to -0.28, P<0.00001), and the outcome was homogeneous (P=0.19, I²=32%), as shown in Figure 5 and Table 3. The difference in fasting blood glucose levels (SMD -0.15, 95% CI -0.39 to 0.09, P=0.21), HbA1c levels (MD 0.03, 95% CI -0.02 to 0.08, P=0.2), and the need for insulin therapy (RR 0.94, 95% CI 0.78 to 1.14, P=0.52) showed no significant differences between the two groups. Both HbA1c and insulin therapy outcomes were homogeneous and a fixed effect model was used; however, the fasting blood glucose analysis was heterogeneous, and therefore, a random effect model was used. We could not solve the heterogeneity by the leave-one-out method, as detailed in Table 3.

In lipid profile parameters, the change in total cholesterol (MD -0.11, 95% CI -0.15 to -0.07, P<0.00001), triglycerides (MD -0.15, 95% CI -0.21 to -0.1, P<0.00001), and HDL (MD 0.08, 95% CI 0.05 to 0.12, P<0.00001) significantly favored the low glycemic index group, as shown in Figure 6. Only the change in LDL did not favor either group (MD 0.02, 95% CI -0.01 to 0.05, P=0.19). All lipid profile outcomes were homogeneous and a fixed effect model was used, as seen in Table 3.

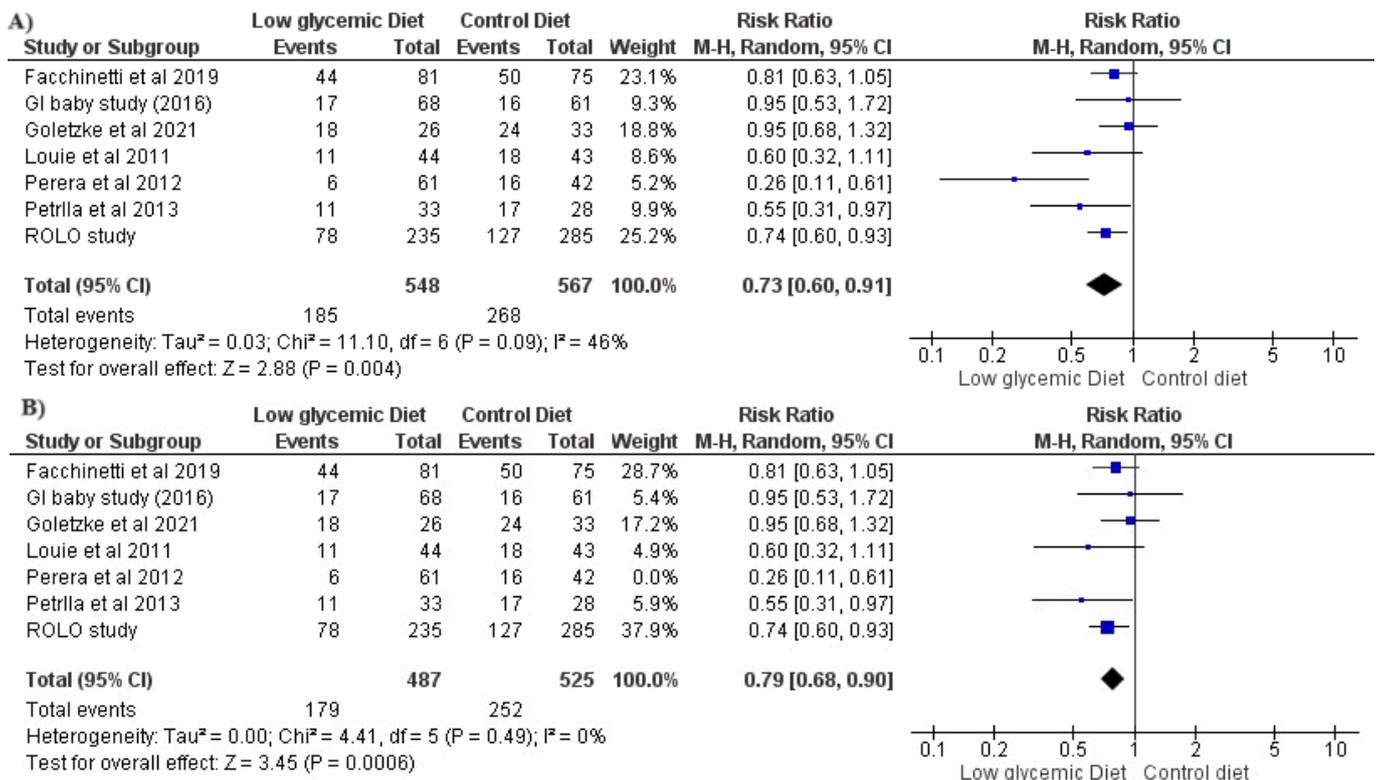


Figure 3: Excess weight gain outcome comparing lower glycemic index diets to higher glycemic diets.

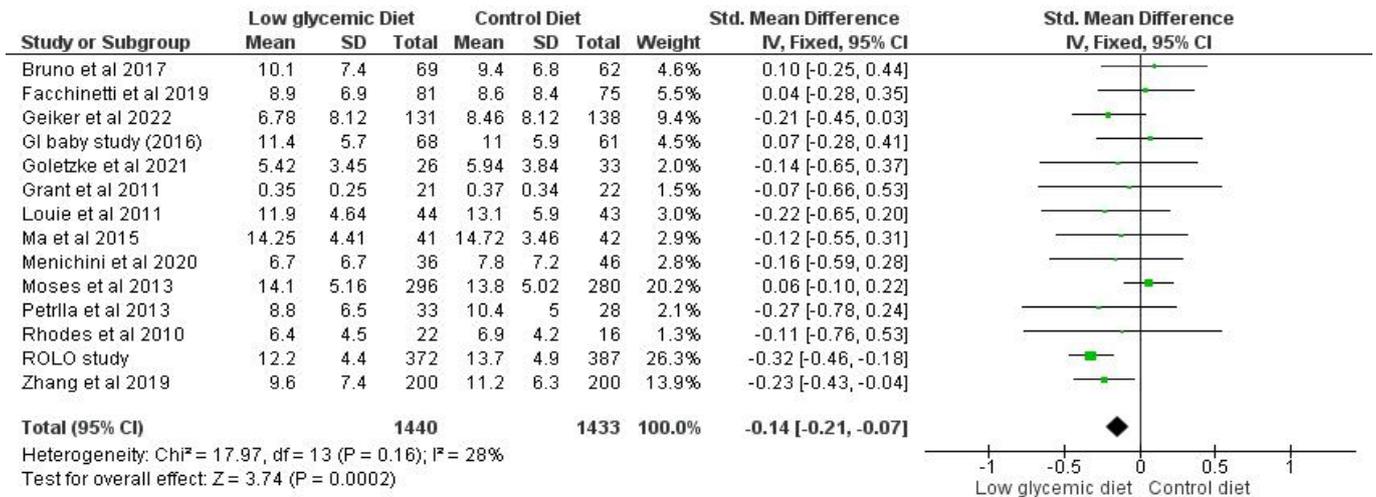


Figure 4: Gestational weight gain outcome comparing lower glyceimic index diets to higher glyceimic diets.

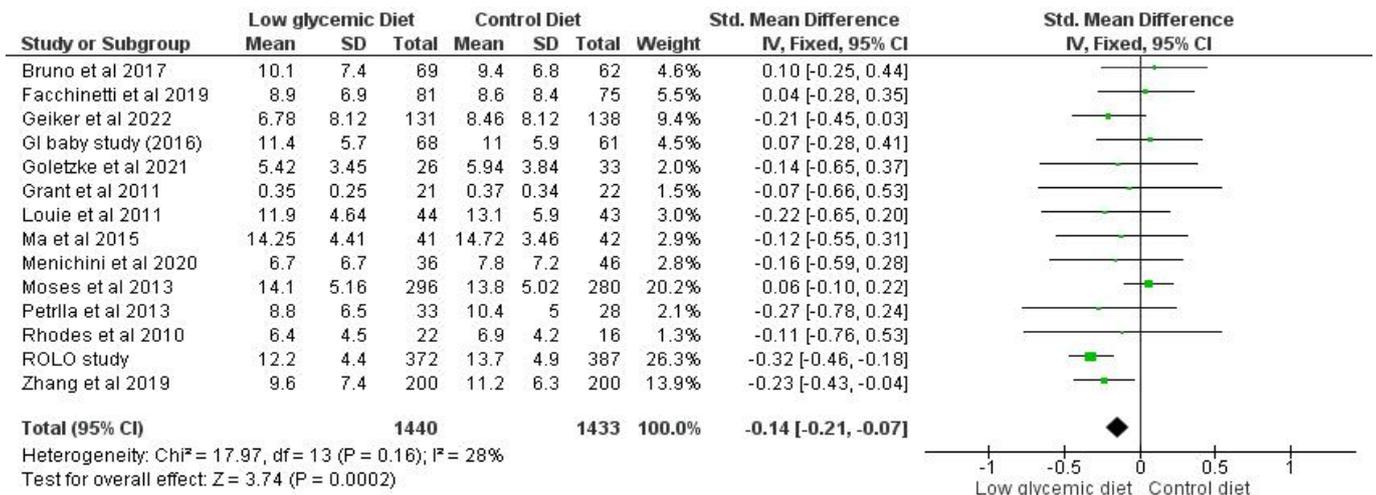


Figure 5: Two hour postprandial glucose level outcome comparing lower glyceimic index diets to higher glyceimic diets.

The outcomes of the incidence of cesarean delivery (RR 0.8, 95% CI 0.64 to 1, P=0.05) and gestational age at time of delivery (MD 0.1, 95% CI -0.14 to 0.33, P=0.43) showed no significant differences between the two groups. The cesarean delivery outcome was homogeneous (P=0.21, I²=28%); however, the gestational age at delivery was heterogeneous (P=0.0005, I²=68%) and the heterogeneity was solved by leaving Perera et al. out from the analysis (P=0.16, I²=31%). The analysis remained non-significant (P=0.67), as detailed in Table 3.

In neonatal outcomes, only the incidence of large for gestational age babies (RR 0.7, 95% CI 0.5 to 0.98, P=0.04) and the rate of preterm births (RR 0.55, 95% CI 0.4 to 0.77, P=0.0004) were significantly lower in the low glyceimic group compared to the control group, as shown in Figure 7 and Table 3. Both outcomes were homogeneous (P=0.14, I²=35%) and (P=0.14, I²=34%), respectively. However, the

other neonatal outcomes, including birth weight (MD -0.01, 95% CI -0.12 to 0.09, P=0.8), newborn length (MD -0.02, 95% CI -0.45 to 0.4, P=0.92), and small for gestational age (RR 1, 95% CI 0.69 to 1.45, P=0.99), showed no significant differences between the groups, as detailed in Table 3.

Discussion

Principal Findings Our systematic review and meta-analysis found that a low-carbohydrate diet was not different from a higher-carbohydrate diet in maternal or neonatal outcomes. In contrast, lower glyceimic index or lower glyceimic load diets were associated with clinically meaningful improvements in several key outcomes: reduced postprandial glucose, lower gestational weight gain and excess weight gain, improved lipid profiles, fewer large-for-gestational-age neonates, and a marked reduction in preterm delivery (RR 0.55, 95% CI 0.40–0.77).

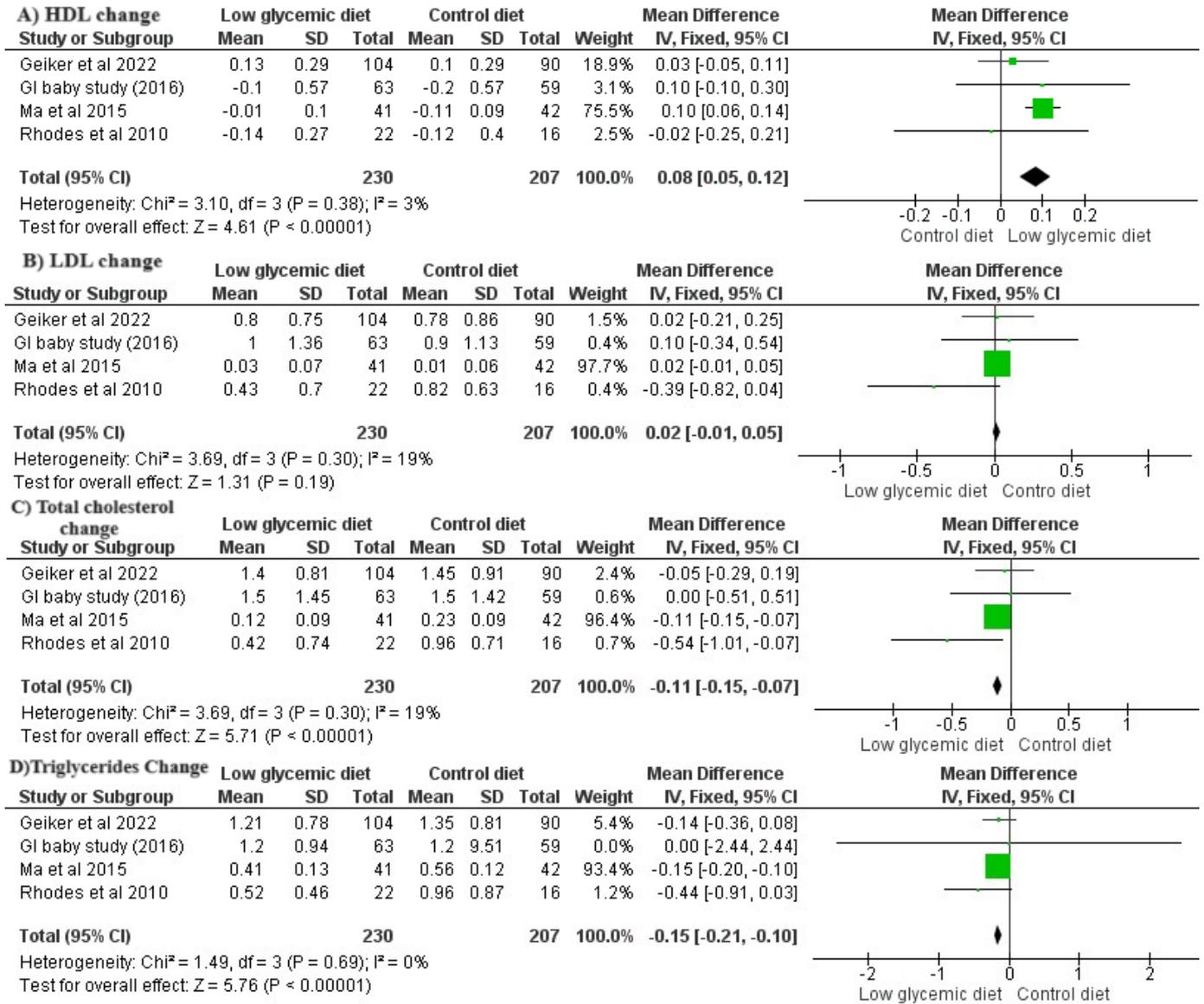


Figure 6: Lipid profile parameters outcome comparing lower glycemic index diets to higher glycemic diets.

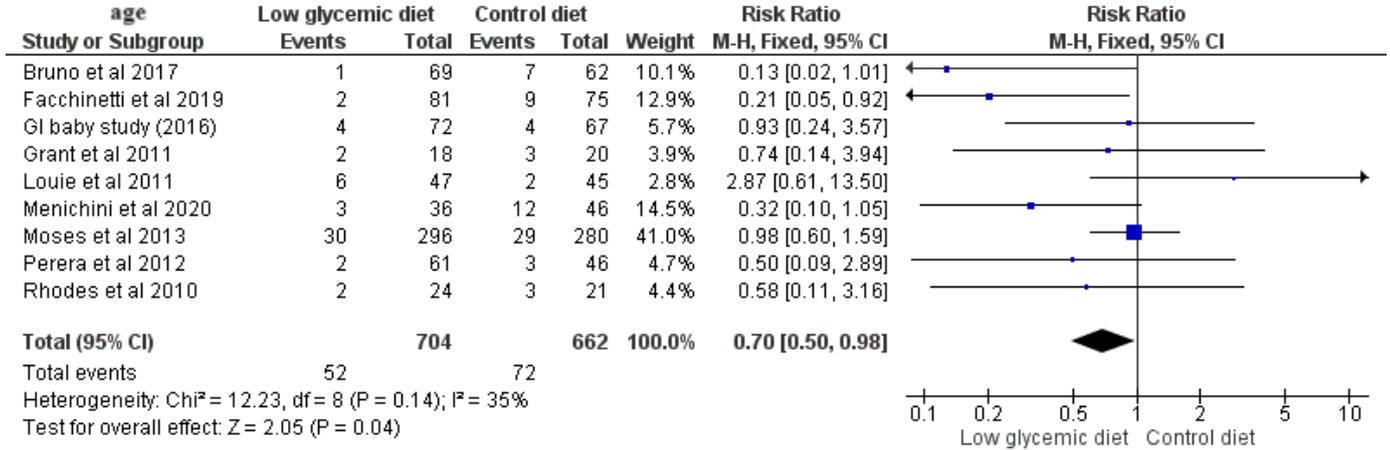
Comparison with Existing Literature Most previous systematic reviews investigated the effect of low carbohydrate or low glycemic diets in improving maternal and neonatal outcomes in only gestational diabetes patients [12,13,38-40] or women at high risk of gestational diabetes [19]. Only Zhang et al. (2018) investigated low glycemic index diets in both healthy and gestational diabetes pregnant women [18]. Regarding the low carbohydrate diet, the studies that investigated low carbohydrate diets included only women suffering from gestational diabetes. Therefore, our results were in line with the recent systematic review and meta-analysis by Wong et al. in 2024 [12]. Wong et al. found that low carbohydrate diets did not influence the maternal or neonatal outcomes in gestational diabetes [12]. However, our study included only randomized controlled trials, whereas

Wong et al. also included retrospective and cross-over trials [12]. Many authors have explained the lack of a difference in outcomes between low carbohydrate and higher carbohydrate diets by decreased compliance in these diets among women in the included studies. Mijatovic et al. [29] reported that only a small percentage of pregnant women (about 20%) could strictly adhere to eating less than 135 grams of carbohydrate every day [29]. Another hypothesis came from Zhang et al. in 2018 [18], who stated that lower glycemic diets have a diminished effect on women with gestational diabetes.

This could help explain why we saw no changes in the low carbohydrate diet group, which contained only patients with gestational diabetes.

Other authors have theorized that foods with a lower

A) large for gestational age



B) Preterm

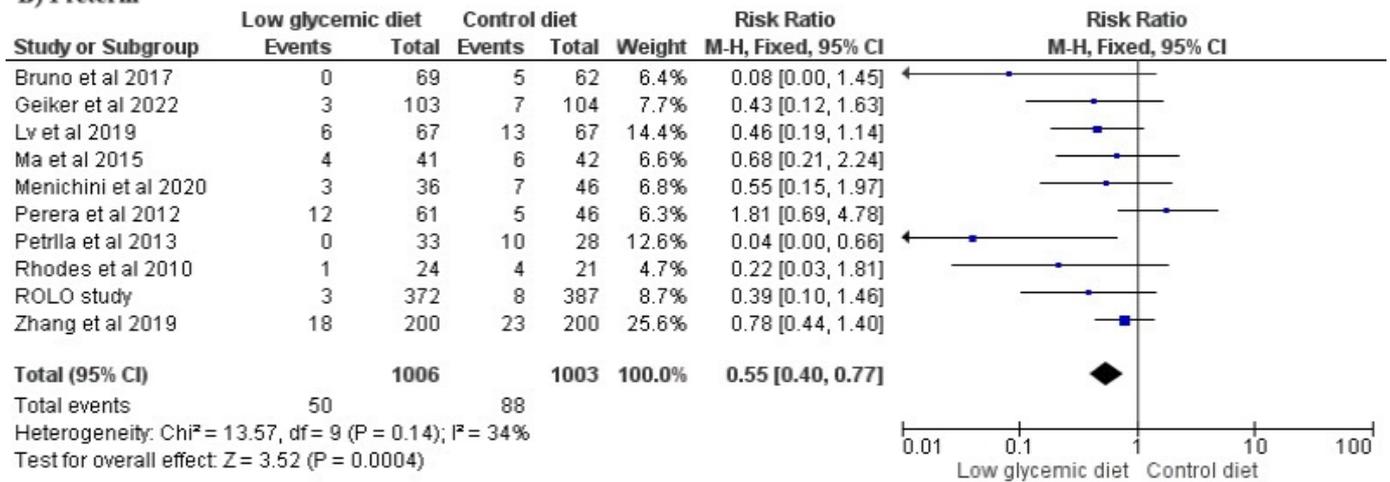


Figure 7: Large for gestational age and preterm delivery outcomes comparing lower glycemic index diets to higher glycemic diets.

glycemic index or lower glycemic load are absorbed more slowly than foods with higher glycemic index during transit through the gastrointestinal tract and that this can result in a slower release of glucose, promoting a more stable insulin response [41]. In addition, many foods in lower glycemic index or lower glycemic load diets are richer in vitamins and minerals, and thus may result in a healthier, more balanced diet during pregnancy, which could also improve outcomes [42]. This could also help explain our results of improving maternal and neonatal outcomes in the low glycemic load or glycemic index diets, with no improvement in the low carbohydrate diets. In 2017, a systematic review by Carolan-Olah et al. [43] found that low glycemic index diets were very effective in the management of serum glucose levels. This is in line with our results in improving two-hour postprandial serum glucose levels compared to higher glycemic index or glycemic load diets. Our findings differed from Carolan-Olah et al. [43] in that we did not find the differences they saw in fasting blood glucose levels, the need for insulin therapy,

or HbA1c levels. The most recent meta-analysis on this topic, Wong et al. [12] in 2024, showed that there were no differences between low glycemic index or lower glycemic load diets in decreasing the need for insulin therapy, fasting blood glucose, or two-hour postprandial glucose levels [12]. This agreed with a 2023 meta-analysis from Liu et al. [19], which found no significant difference between low glycemic index or glycemic load diets in improving fasting blood glucose, HbA1c, or insulin levels. However, they did not investigate the effect of these diets on two-hour postprandial serum glucose levels, which showed a significant difference in our analysis. Weight gain increases during pregnancy which, if in excess, increases the risk of maternal and fetal complications [44]. We found that low glycemic index or low glycemic load diets were associated with decreased gestational weight gain and a decreased number of women with excess weight gain. These findings were also seen in the recent meta-analysis by Liu et al. [19] in 2023. The finding of a decreased incidence of large for gestational age babies to mothers with

lower glycemic diets seems self-explanatory, as many studies have shown a direct correlation between diabetes with unmet glycemic targets and macrosomia [45,46]. However, our study found that the decrease in macrosomia to mothers on a low glycemic index or low glycemic load diet did not reach statistical significance, in contrast to Liu et al. and Wong et al. [12,19].

Strengths and Limitations Our main strength is that our study is the only one that included a large sample of both pregnant women with and without gestational diabetes, and that we included only randomized controlled trials. A key limitation is the reliance on variable definitions of 'low carbohydrate' or 'low glycemic index' across studies, which may introduce heterogeneity but also reflects clinical practice, limiting comparability. Additionally, the inclusion of pilot studies, while meeting RCT criteria, may contribute to smaller sample sizes and potential bias. No sensitivity analysis for lifestyle modifications was performed due to the limited number of studies. Non-blinding, common in dietary trials, may overestimate effect. The limited number of studies prevented us from separately stratifying data for mothers with and without gestational diabetes. Further, exercise is well known to have a beneficial effect on glucose levels, and we did not exclude studies that included a change in lifestyle or exercise routine in addition to the change in diet. Therefore, it is possible these variables have affected our data. Another limitation includes the fact that higher levels of bias were seen in this study than would normally be seen in a meta-analysis that was limited to randomized trials. We believe this was largely because the patients were being randomized to a specific diet, not a drug, so difficulties in masking what the patient was eating were to be expected.

Conclusions and Implications Lower glycemic index or load diets were associated with improvements in postprandial glucose control, gestational weight gain, lipid parameters, rates of large-for-gestational-age infants, and a clinically important reduction in preterm delivery. In contrast, low-carbohydrate diets showed no significant benefits, possibly due to limited statistical power and poor long-term adherence. The observed decrease in preterm birth is unexpected and requires confirmation in large, pragmatic trials, but if verified it could substantially strengthen the case for routine low-GI dietary advice in pregnancy.

Declarations

Ethics Approval and Consent to Participate

This manuscript has been reviewed by the institutional IRB board at Marchand Institute and was found to be exempt from IRB review (January 2024). Data used was exempt from consent to participate or publish secondary to the nature of the study being a systematic review, retrospectively looking at previously published data.

Consent for Publication

Data used was exempt from consent to participate or publish secondary to the nature of the study being a systematic review, retrospectively looking at previously published data.

Availability of Data and Material

As this is a meta-analysis, no new data was created and our work centered on analyzing previously published data from other studies. We will be happy to share our spreadsheets with other researchers wishing to save time when analyzing this data in the future. We will respond to any reasonable requests made to requests@marchandinstitute.org.

Competing Interests

Authors declare no competing interests. All authors have no financial disclosures.

Funding

No authors received any payment for this work; all work was volunteer.

Authors' Contributions

- GJM: Conceptualization, Methodology, Validation, Resources, Writing – Review & Editing, Supervision, Project administration
- DGH: Investigation, Data curation, Formal analysis, Writing – Original draft, Visualization
- MR: Investigation, Data curation, Formal analysis, Writing – Review & Editing
- EK: Investigation, Data curation, Software, Visualization
- SM: Investigation, Data curation, Validation
- MK: Data curation, Formal analysis, Visualization
- NP: Investigation, Data curation, Writing – Review & Editing
- BO: Investigation, Data curation, Software
- KS: Conceptualization, Methodology, Validation, Writing – Review & Editing, Supervision

Acknowledgements

The Marchand Institute for Minimally Invasive Surgery would like to acknowledge the efforts of all the students, researchers, residents, and fellows at the institute who put their time and effort into these projects without compensation, only for the betterment of women's health. We firmly assure them that the future of medicine belongs to them.

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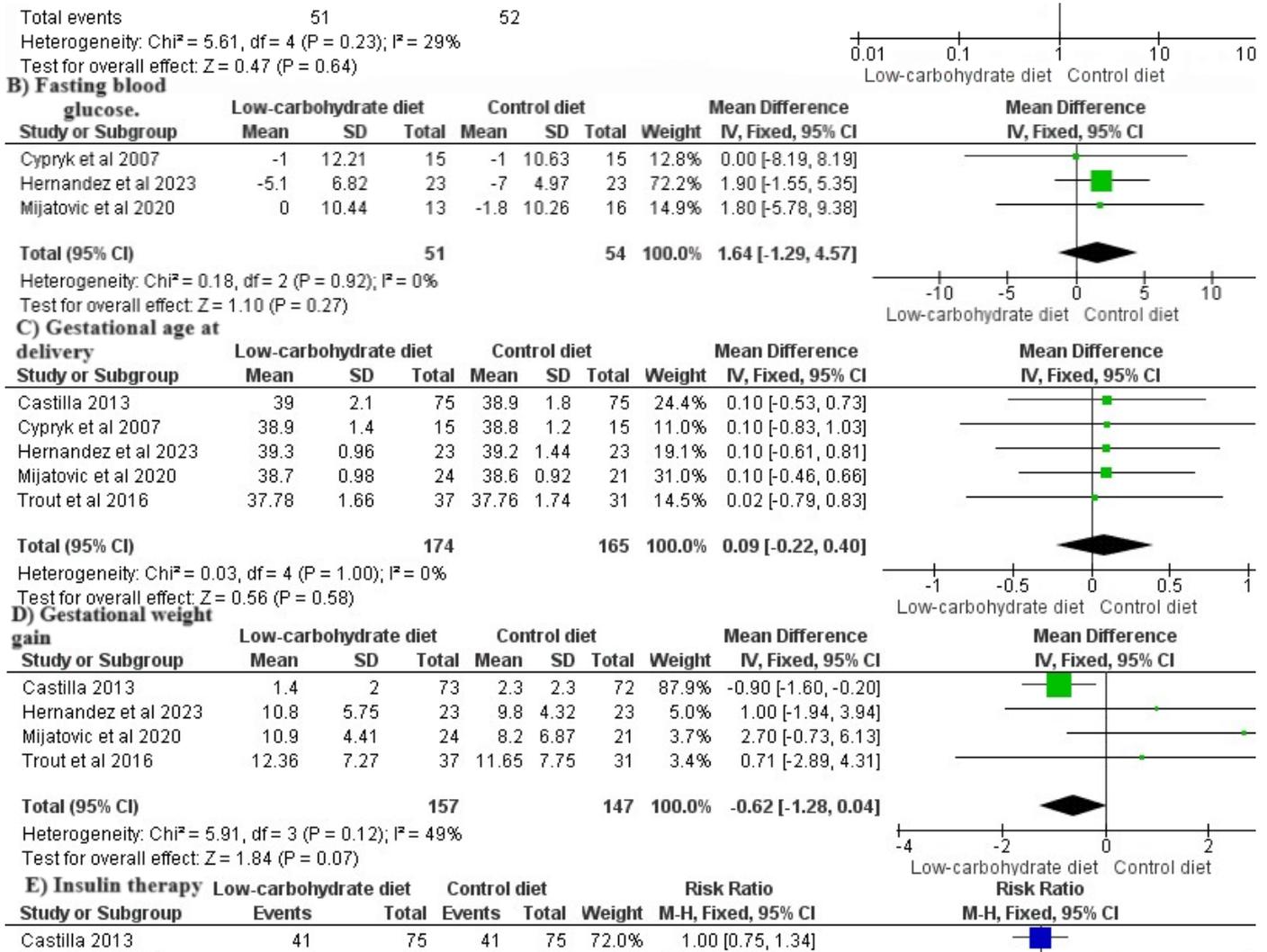
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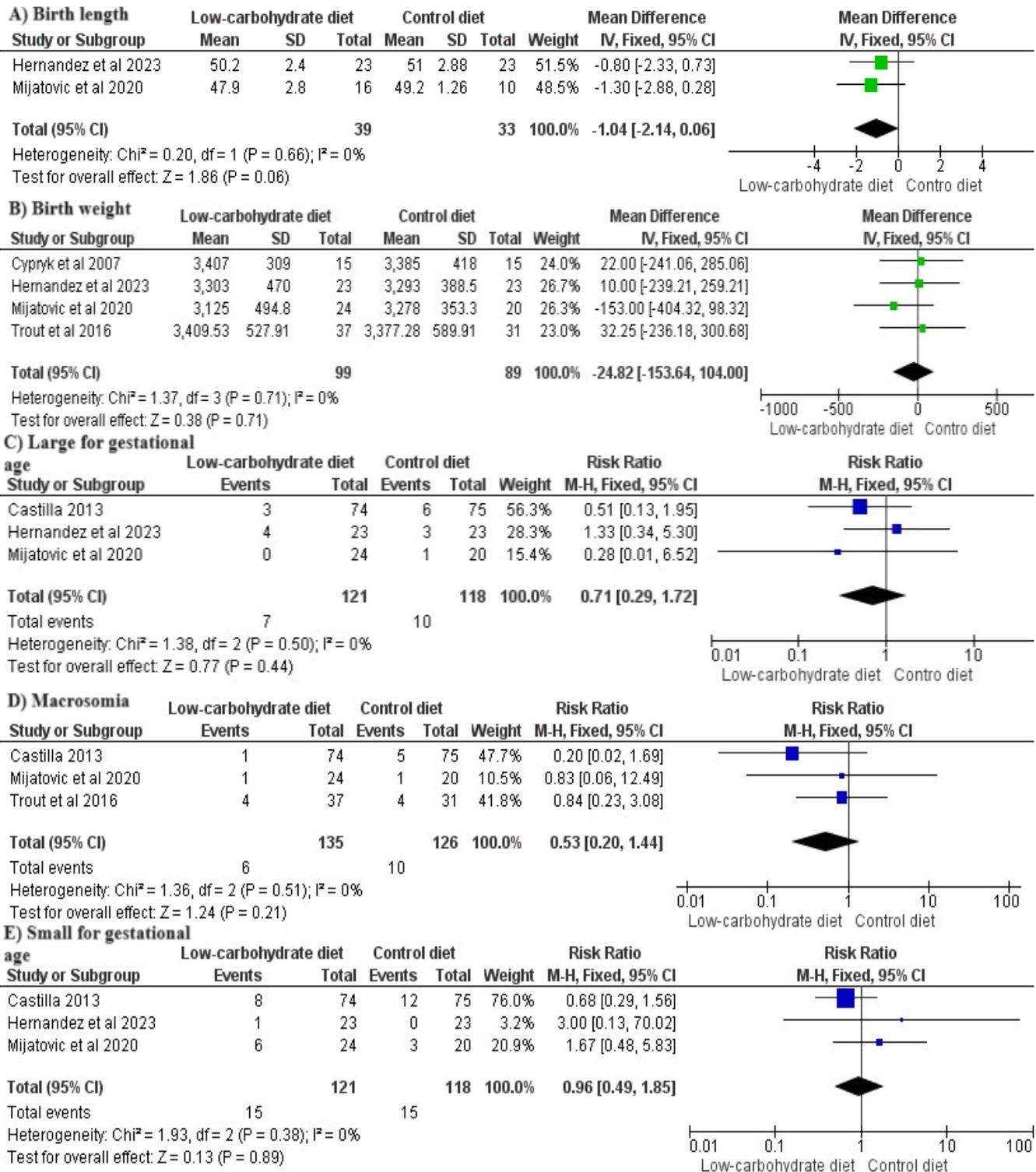
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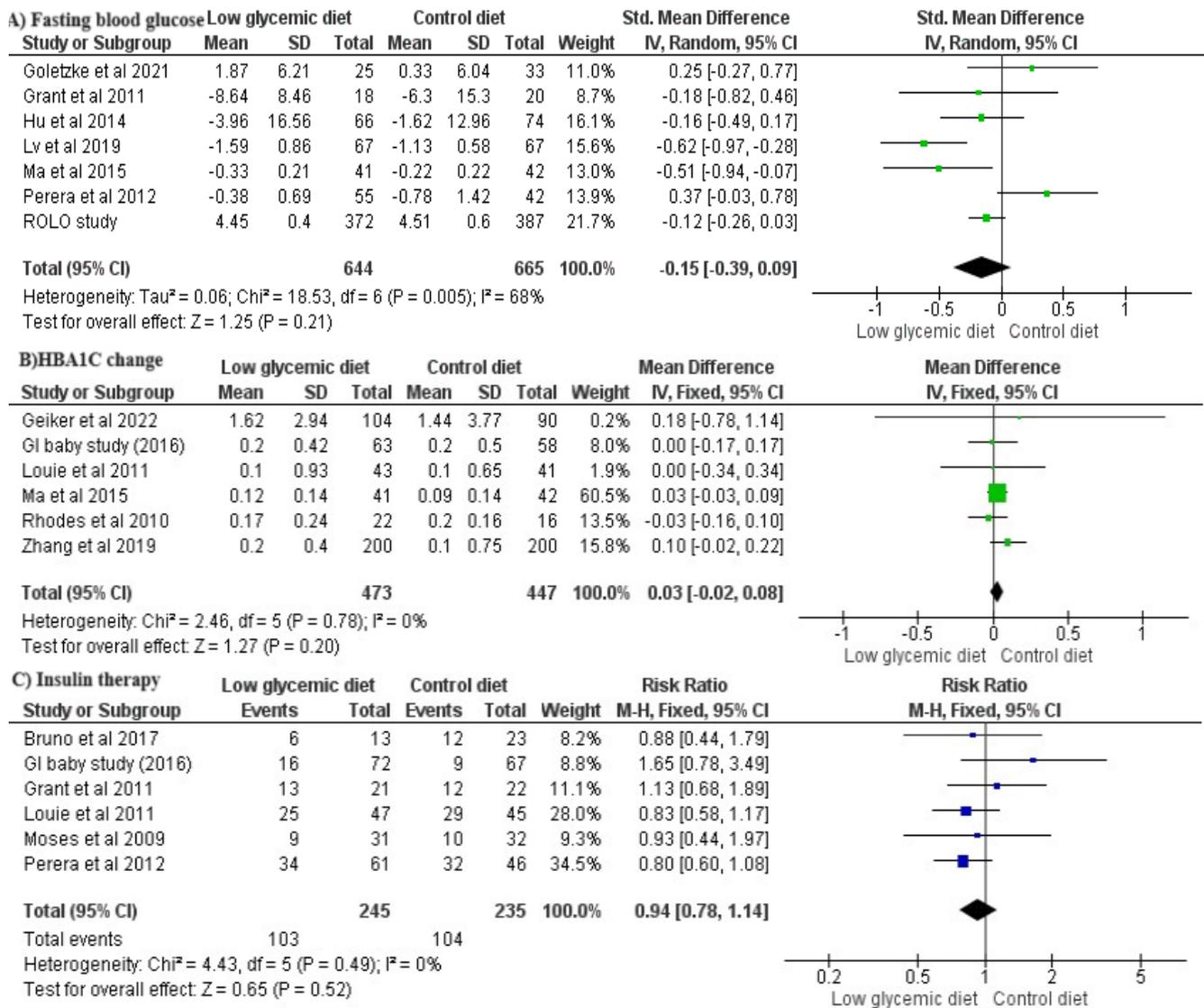
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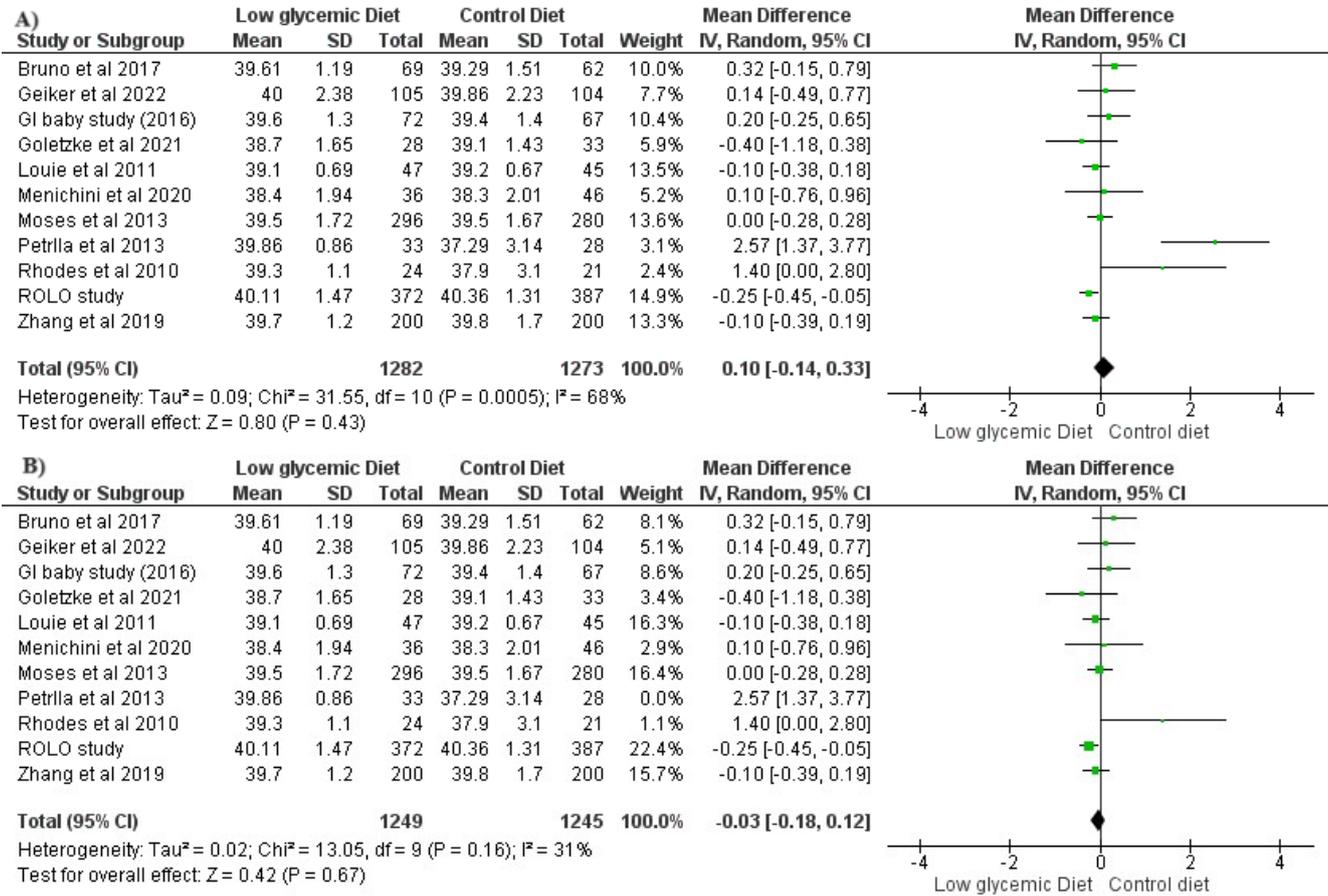
Supplemental Figure 1: Maternal outcomes comparing low carbohydrate diets to higher carbohydrate diets.



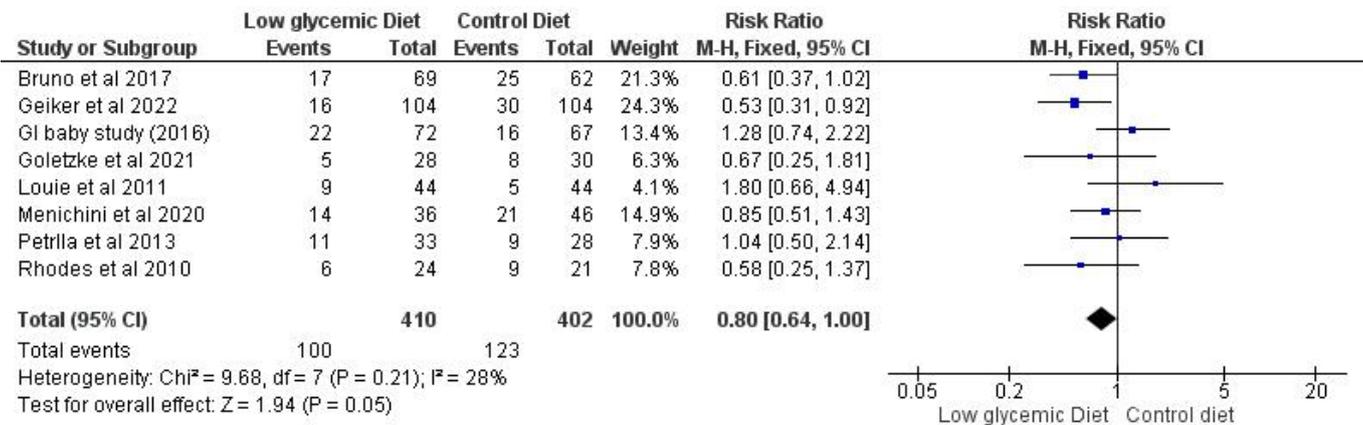
Supplemental Figure 2: Neonatal outcomes comparing low carbohydrate diets to higher carbohydrate diets.



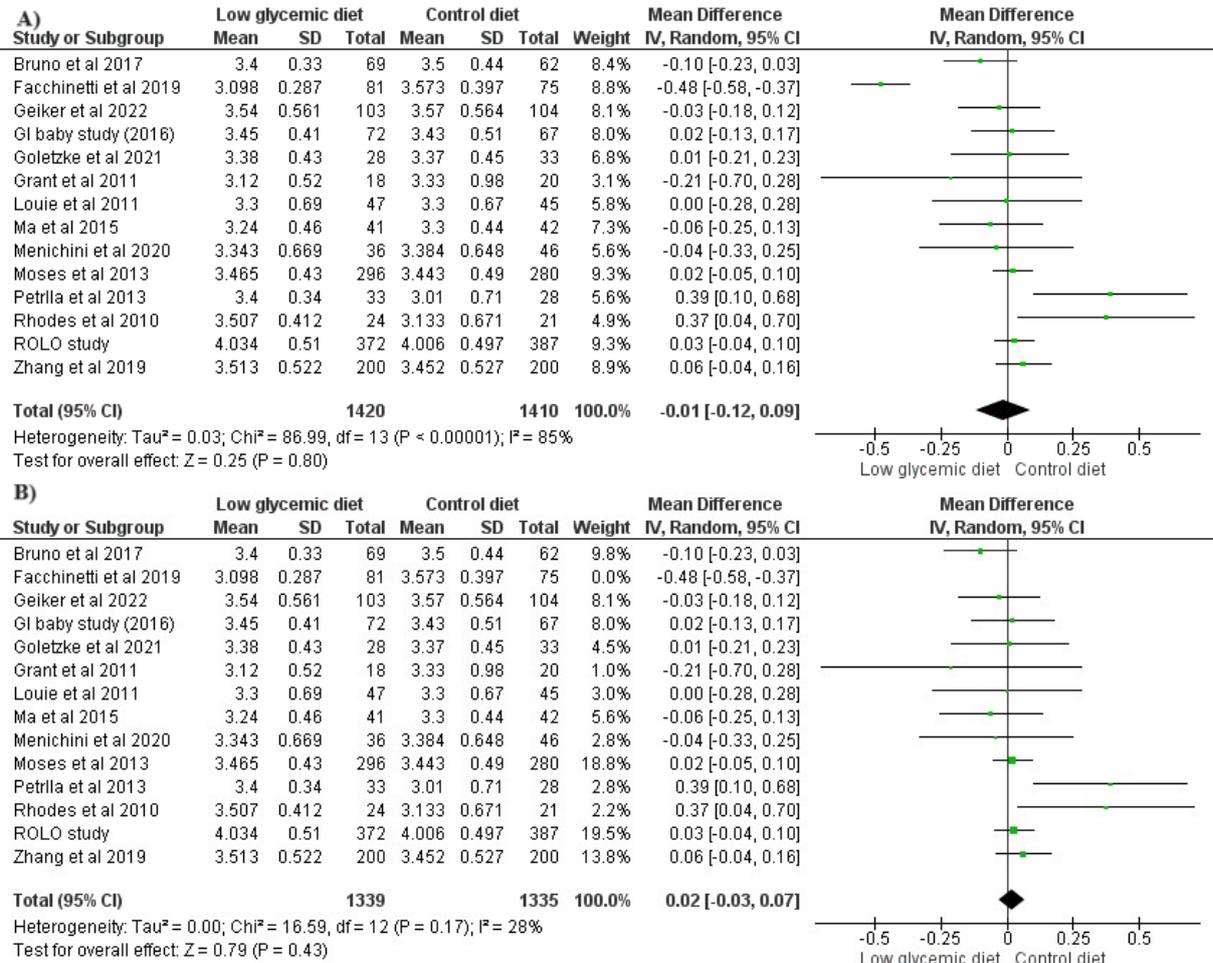
Supplemental Figure 3: Diabetic outcomes comparing low glycemic index diets to higher glycemic index diets.



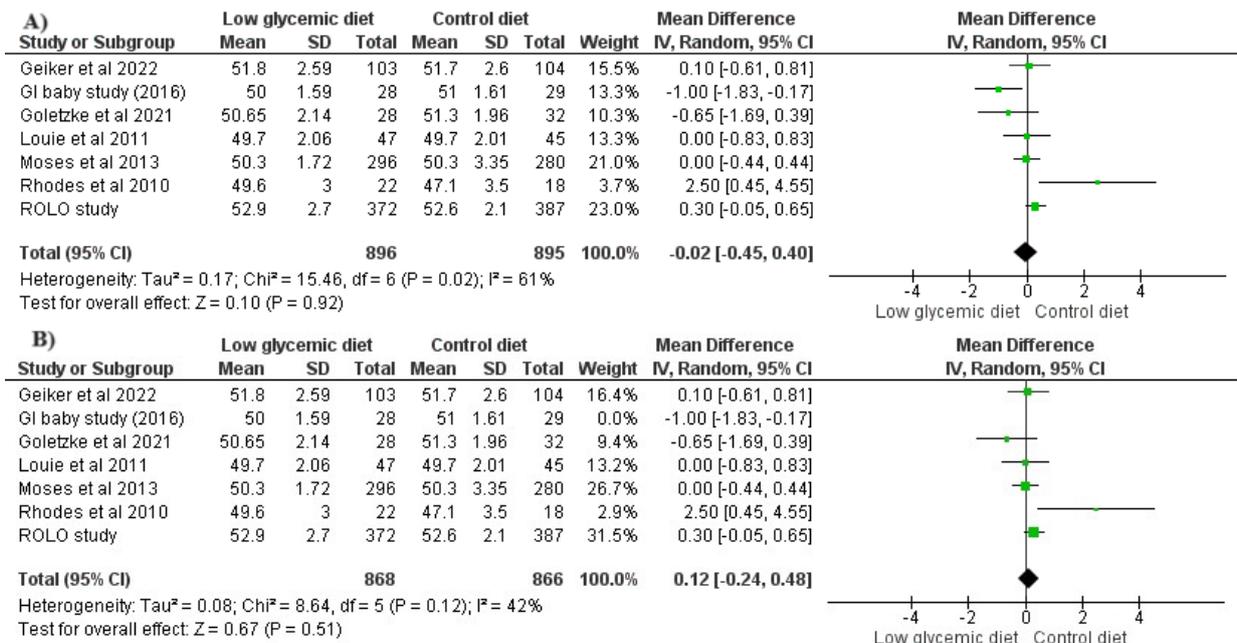
Supplemental Figure 4: Birth gestational age comparing low glycemic index diets to higher glycemic index diets.



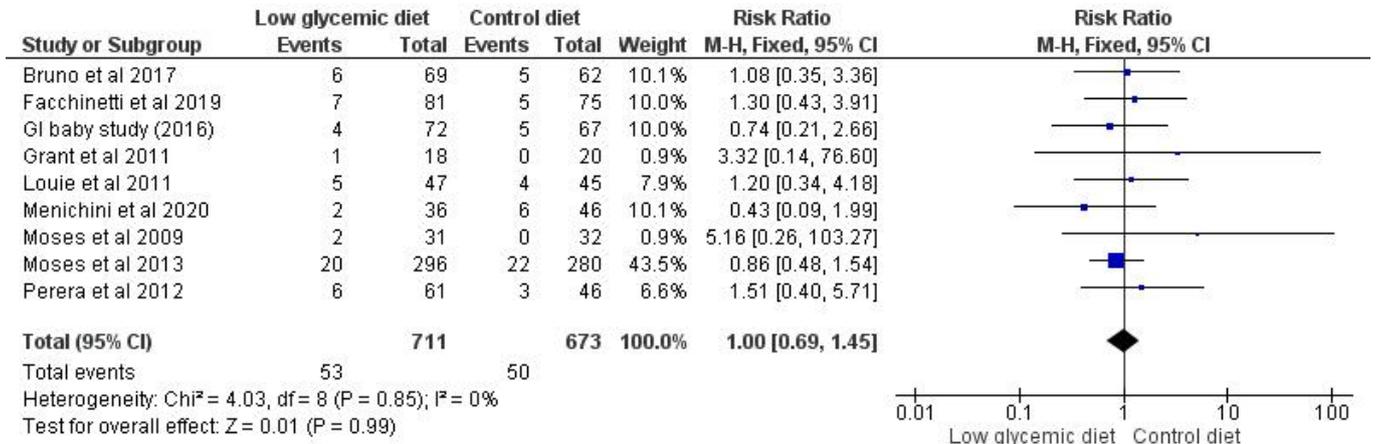
Supplemental Figure 5: Cesarean section rates comparing low glycemic index diets to higher glycemic diets.



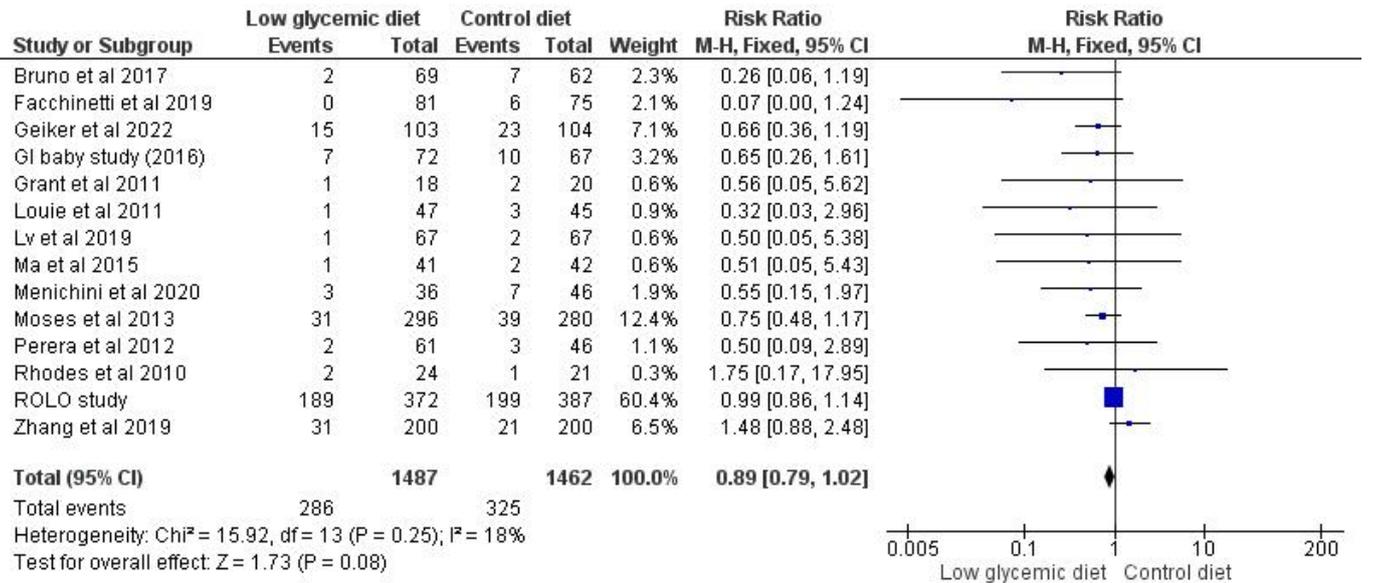
Supplemental Figure 6: Birth weights comparing low glycemic index diets to higher glycemic index diets.



Supplemental Figure 7: Newborn length comparing low glycemic index diets to higher glycemic index diets.



Supplemental Figure 8: Small for gestational age comparing low glyceemic index diets to higher glyceemic index diets.



Supplemental Figure 9: Macrosomia comparing low glyceemic index diets to higher glyceemic index diets.