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Counseling and Behavioral Interventions for Healthy Weight and Weight Gain in Pregnancy

Evidence Report and Systematic Review for the US Preventive Services Task Force

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IMPORTANCE Counseling and active behavioral interventions to limit excess gestational weight gain (GWG) during pregnancy may improve health outcomes for women and infants. The 2009 National Academy of Medicine (NAM; formerly the Institute of Medicine) recommendations for healthy GWG vary according to prepregnancy weight category.

OBJECTIVE To review and synthesize the evidence on benefits and harms of behavioral interventions to promote healthy weight gain during pregnancy to inform the US Preventive Services Task Force recommendation.

DATA SOURCES Ovid MEDLINE and the Cochrane Library to March 2020, with surveillance through February 2021.

STUDY SELECTION Randomized clinical trials and nonrandomized controlled intervention studies focused on diet, exercise, and/or behavioral counseling interventions on GWG.

DATA EXTRACTION AND SYNTHESIS Independent data abstraction and study quality rating with dual review.

MAIN OUTCOMES AND MEASURES Gestational weight–related outcomes; maternal and infant morbidity and mortality; harms.

RESULTS Sixty-eight studies (N = 25 789) were included. Sixty-seven studies evaluated interventions during pregnancy, and 1 evaluated an intervention prior to pregnancy. GWG interventions were associated with reductions in risk of gestational diabetes (43 trials, n = 19 752; relative risk [RR], 0.87 [95% CI, 0.79 to 0.95]; absolute risk difference [ARD], −1.6%) and emergency cesarean delivery (14 trials, n = 7520; RR, 0.85 [95% CI, 0.74 to 0.96]; ARD, −2.4%). There was no significant association between GWG interventions and risk of gestational hypertension, cesarean delivery, or preeclampsia. GWG interventions were associated with decreased risk of macrosomia (25 trials, n = 13 990; RR, 0.77 [95% CI, 0.65 to 0.92]; ARD, −1.9%) and large for gestational age (26 trials, n = 13 000; RR, 0.89 [95% CI, 0.80 to 0.99]; ARD, −1.3%) but were not associated with preterm birth. Intervention participants experienced reduced weight gain across all prepregnancy weight categories (55 trials, n = 20 090; pooled mean difference, −1.02 kg [95% CI, −1.30 to −0.75]) and demonstrated lower likelihood of GWG in excess of NAM recommendations (39 trials, n = 14 271; RR, 0.83 [95% CI, 0.77 to 0.89]; ARD, −7.6%). GWG interventions were associated with reduced postpartum weight retention at 12 months (10 trials, n = 3957; mean difference, −0.63 kg [95% CI, −1.44 to −0.01]). Data on harms were limited.

CONCLUSIONS AND RELEVANCE Counseling and active behavioral interventions to limit GWG were associated with decreased risk of gestational diabetes, emergency cesarean delivery, macrosomia, and large for gestational age. GWG interventions were also associated with modest reductions in mean GWG and decreased likelihood of exceeding NAM recommendations for GWG.

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Supplemental content

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The prevalence of overweight and obesity is increasing among women of childbearing age and pregnant women in the US, similar to trends observed in nonpregnant populations. Data suggest that obesity rates during pregnancy in the US increased from 13% in 1993 to 24% in 2015, and in the same year, nearly half of all women entered pregnancy with a body mass index (BMI) category of overweight (24%) or obese (24%).[1,2]

Gestational weight gain is usually defined as change in weight measured before pregnancy (prepregnancy) or during the first trimester to weight measured at the end of pregnancy (eg, prior to delivery). Prepregnancy BMI is independently associated with many adverse pregnancy outcomes. Many observational studies report strong associations between elevated prepregnancy BMI and adverse pregnancy outcomes.[3-11] In 2009, the National Academy of Medicine (NAM; formerly the Institute of Medicine) recommended that women begin pregnancy with a normal BMI and made recommendations for healthy gestational weight gain (GWG), which varied according to prepregnancy weight category (25-35 lb for normal weight, or BMI 18.5-24.9 [calculated as weight in kilograms divided by height in meters squared]; 15-25 lb for overweight, or BMI 25.0-29.9; and 11-20 lb for obese, or BMI ≥30.0).[12] Approaches to achieving recommended GWG include preconception counseling and weight loss for women with overweight or obesity; counseling about healthy weight gain during pregnancy; adherence to NAM recommendations for GWG; and/or providing women at risk of excess GWG with lifestyle interventions.[13] Guidelines also note that abnormally high or low BMI and excessive GWG is associated with pregnancy complications. In response to NAM and other recommendations on GWG, there has been a proliferation of randomized clinical trials on the effect of interventions on GWG published in the last decade.[14,15]

The US Preventive Services Task Force (USPSTF) has not previously made a recommendation on healthy weight gain during pregnancy. This review synthesizes current evidence to inform a USPSTF recommendation on this topic.

Methods

Scope of the Review

This review addressed 3 key questions (KQs) (**Figure 1**) examining the effectiveness of counseling and active behavioral interventions to promote healthy weight gain during pregnancy on health-related outcomes (KQ1), weight-related outcomes (KQ2); and potential harms of interventions (KQ3). Full methods, including data analysis methods, are available in the full evidence report.[17]

Data Sources and Searches

Searches of Ovid MEDLINE, the Cochrane Central Register of Controlled Trials, and the Cochrane Database of Systematic Reviews through February 2021 (eMethods 1 in the Supplement). Reference list review of relevant systematic reviews supplemented the searches. Ongoing surveillance was conducted to identify major studies published since March 2020 that may affect the conclusions or understanding of the evidence and related USPSTF recommendation. The last surveillance, conducted on February 5, 2021, identified no additional studies. All searches were limited to articles published in English.

Study Selection

Two investigators independently reviewed titles, abstracts, and full-text articles using predefined eligibility criteria (eTable 1 in the Supplement). Populations included adolescent and adult women who were pregnant or planning a pregnancy, with normal weight (BMI of 18.5-24.9), overweight (BMI of 25-29.9) or obesity (BMI ≥30), based on prepregnancy weight categories as defined by the World Health Organization. Women with low prepregnancy BMI (underweight) were outside the scope of this review. Studies of interventions vs controls (eg, usual care, attention control, minimal intervention) were included (eTable 7 in the Supplement). Interventions were categorized as active (consisting of a structured, physical element that could include a counseling component [eg, supervised exercise programs, prescribed exercise or dietary programs, or intensive weight management] or counseling only. Intervention intensity was categorized as low (<2 contacts during the intervention period), moderate (3-11 contacts), or high (≥12 contacts). Outcomes were classified as weight-related intermediate outcomes (GWG, exceeding or adhering to NAM GWG recommendations, and postpartum weight loss or retention) or health outcomes (maternal morbidity or mortality, infant morbidity or mortality). Harms were anxiety, depression, maternal musculoskeletal injuries, stigma, and those related to insufficient weight gain, including infants small for gestational age. Randomized clinical trials (RCTs) and nonrandomized controlled intervention studies were considered for harms; only RCTs were eligible for analysis in all other outcomes.

Data Abstraction and Quality Rating

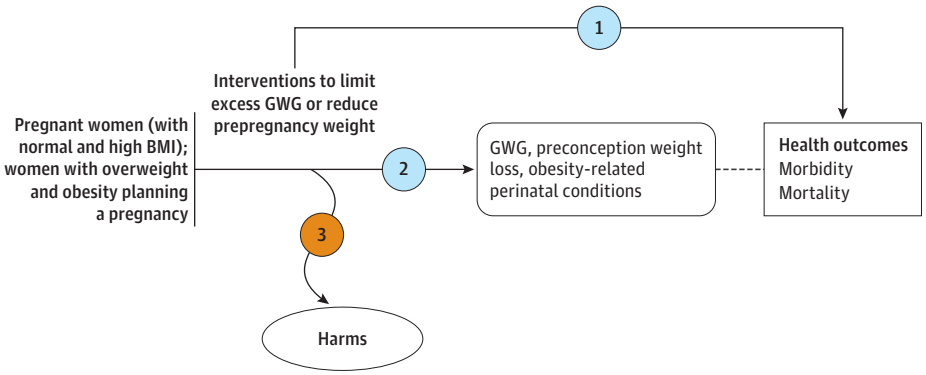
One investigator abstracted details about each study's design, patient population, setting, interventions, analysis, follow-up, and results. A second investigator reviewed abstracted data for accuracy. Two investigators independently assessed the quality of each study as good, fair, or poor using predefined criteria developed by the USPSTF (eMethods 2 in the Supplement).[16] Discrepancies were resolved through consensus. In accordance with the USPSTF Procedure Manual, poor-quality studies with critical methodological limitations were excluded.[16]

Data Synthesis

Data were synthesized separately for each KQ by outcome. Only RCTs were considered for meta-analysis. Nonrandomized controlled intervention studies were not pooled; these studies did not affect the findings that are described in the full report. For both continuous and dichotomous outcomes, random-effects meta-analyses were conducted using the profile likelihood method using Stata version 14 (StataCorp).

For continuous data, meta-analysis of RCTs was conducted to combine the mean difference between the intervention and the control groups. For mean GWG, the mean difference adjusted for baseline characteristics was used in the meta-analysis when available; otherwise, the mean difference in weight change from baseline to follow-up was used. Because imbalance in baseline weight was generally not observed, sensitivity analysis was not conducted using the difference in follow-up weights. If necessary, mean weight change was calculated based on reported baseline and follow-up weights; when not reported, the correlation between baseline and follow-up weights was assumed to be the average

Figure 1. Analytic Framework: Counseling and Behavioral Interventions for Healthy Weight and Weight Gain in Pregnancy



Key questions

1
a. Do interventions to limit excess gestational weight gain improve health outcomes among pregnant women and their infants?
b. Do interventions to reduce prepregnancy weight in women who are overweight or obese improve health outcomes among women who become pregnant and their infants?
c. Does the effectiveness of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

2
a. Do interventions to limit excess gestational weight gain reduce gestational weight gain, postpartum weight retention, or obesity-related adverse perinatal conditions among pregnant women and their infants?
b. Do interventions to reduce prepregnancy weight in women who are overweight or obese improve weight outcomes or reduce obesity-related adverse perinatal conditions among women who become pregnant and their infants?
c. Does the effectiveness of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

3
a. What are the harms of interventions to limit excess gestational weight gain among pregnant women and their infants?
b. What are the harms of interventions to reduce prepregnancy weight among women who are overweight or obese?
c. Do the harms of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

Evidence reviews for the US Preventive Services Task Force (USPSTF) use an analytic framework to visually display the key questions that the review will address to allow the USPSTF to evaluate the effectiveness and safety of a preventive service. The questions are depicted by linkages that relate interventions and outcomes. A dashed line indicates a health outcome that immediately follows an intermediate outcome. For additional information see the USPSTF Procedure Manual.[16] BMI indicates body mass index; GWG, gestational weight gain.

correlation calculated from studies that reported this information. Missing standard deviations were imputed, if necessary, by assuming the same coefficient of variation at baseline and follow-up; the standard deviations at baseline and follow-up were similar in studies that reported both. For dichotomous outcomes with at least 5 trials, sufficient sample size, and comparable outcomes, risk ratios were combined across eligible studies.

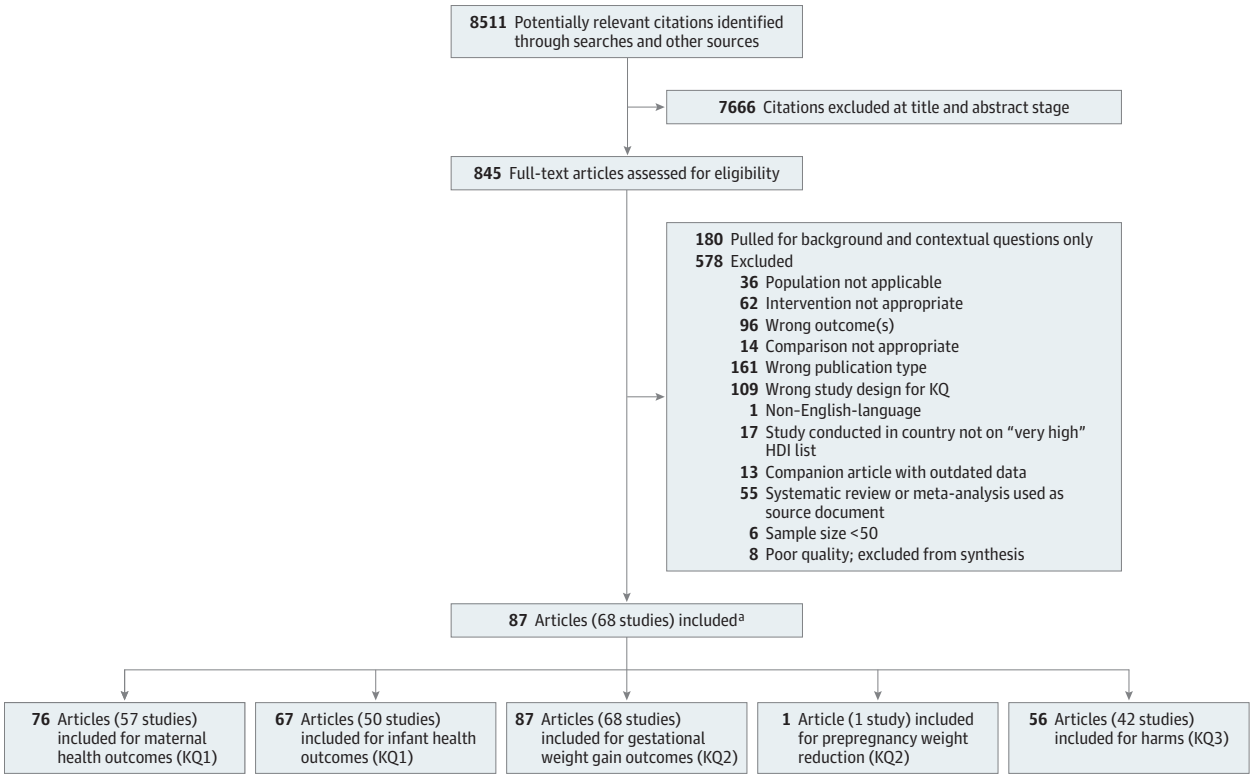
Stratified analyses were conducted when sufficient data were available on BMI category (normal, overweight, obese, overweight or obese combined, or mixed BMI populations), GWG assessment time point (28 weeks, 34-36 weeks, 36 weeks up to delivery, and at delivery), intervention type (counseling-only or active), intervention intensity (low, moderate, or high), and study quality (good or fair). Statistical heterogeneity was assessed with the Cochran Q-test and the I^2 statistic to detect the proportion of total variability in point estimates.[18] The *P* value for subgroup interaction was calculated to test for subgroup differences. Interactions between interventions and sociodemographic characteristics could not be assessed because of sparse data. Results were considered statistically significant if the *P* value was less than .05, based on 2-sided testing.

Results

A total of 8511 unique citations and 845 full-text articles were reviewed. Across all KQs, 64 RCTs (N = 24 829)[19-82] and 4 nonrandomized controlled intervention studies (N = 960)[83-86] met criteria for this systematic review (**Figure 2**).

Across all studies, sample sizes ranged from 50 to 2261 (N = 25 789; median n = 230). Mean sample ages ranged from 18.6 years to 33.8 years (median, 30.4 [SD, 2.8] years), with study eligibility criteria ranging from 14 to 49 years (eTable 2 in the Supplement). Twenty-eight of 68 included studies (41%) enrolled more than 20% of patients from diverse backgrounds, including those who were socioeconomically disadvantaged, racial or ethnic minorities, rural populations, or others defined by the National Institute on Minority Health and Health Disparities as populations adversely affected by disparities.[87] There were no studies exclusively of pregnant adolescents or women with advanced maternal age. Studies enrolled women in 3 prepregnancy BMI categories: mixed (all BMI categories), overweight and obesity only, and obesity only.

Figure 2. Literature Search Flow Diagram: Counseling and Behavioral Interventions for Healthy Weight and Weight Gain in Pregnancy



Targeted searches for the contextual questions are not included in diagram. HDI indicates Human Development Index; KQ, key question.

[a] Some included publications are counted in multiple sections.

All studies evaluated pregnancy interventions except for 1 study of a prepregnancy intervention; 1 study included a preconception component.[70,88] The majority of interventions were counseling-only (45 studies),[20-24,31-36,38-40,46-48,51-58,60,62,64-70,74-79,81,82,84-86,89-99] and were rated as moderate-intensity (23 studies)[20,22,31,33,38,39,46,47,51-54,57,58,62,69,70,74-76,82,84,85,89,91,93-96] or high-intensity (34 studies)[19,21,25-30,34,37,40-45,48-50,56,59,61,63,66,67,71-73,77-81,83,86,90,92,98-105] (eTable 3 in the Supplement). The remaining 22 studies[19,25-30,37,41-45,49,50,59,61,63,71-73,80,83,100-105] used active interventions (eTable 3 in the Supplement).

The duration of follow-up ranged from 14 weeks to 12 months postpartum; the majority (77%) of studies enrolled pregnant women early in their second trimester and followed them up until at least 36 weeks' gestation (eTable 4 in the Supplement). Fifteen RCTs and 1 nonrandomized controlled intervention study were rated good-quality, and 49 RCTs and 3 nonrandomized controlled intervention studies were rated fair-quality (eTables 5 and 6 in the Supplement). Given the nature of the interventions and comparisons, many participants and clinicians could not be blinded. Methodological limitations included unclear reporting of randomization and allocation concealment (eMethods 2 in the Supplement).

Benefits for Health Outcomes

Key Question 1a. Do interventions to limit excess gestational weight gain improve health outcomes among pregnant women and their infants?

Key Question 1b. Do interventions to reduce prepregnancy weight in women who are overweight or obese improve health outcomes among women who become pregnant and their infants?

Key Question 1c. Does the effectiveness of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

Maternal Health Outcomes

Gestational Diabetes | Forty-three trials (n = 19 752) of counseling-only and active interventions vs controls reported on gestational diabetes (**Table 1**; eFigure 1 in the Supplement).[20,24,26,28-34,36-39,41,44,46,48-53,55-60,62-65,67,69-74,78-80,82] Gestational diabetes criteria varied among studies and included criteria based on country-specific guidelines (15 trials)[29,31,39,44,49-51,53,55,59,65,67,72,80,82]; International Association of Diabetes and Pregnancy Study Groups criteria using the 1-step approach to diagnosis with a 75-g glucose load (18 trials)[20,24,30,33,34,37,38,41,46,52,56,60,63,69,70,73,74,78]; and review of medical records (8 trials).[28,36,57,58,62,64,71,79] Two trials used unclear criteria to define gestational diabetes.[26,32]

Gestational weight gain interventions were associated with decreased risk of gestational diabetes vs control (43 trials; relative risk [RR], 0.87 [95% CI, 0.79 to 0.95]; I^2 = 16.4%; absolute risk difference [ARD], −1.6% [95% CI, −2.5% to −0.7%]) (Table 1; eFigure 1 in the Supplement). In stratified analyses, there were no statistically significant interactions between effects of GWG

Table 1. Summary of Pooled Findings: Maternal Health Outcomes (Key Question 1)

BMI category[a]	No. of trials	Effect size, RR (95% CI)	I^2, %	ARD, %
Gestational diabetes mellitus				
Overall	43	0.87 (0.79-0.95)	16.4	−1.6
Normal only	1	0.99 (0.65-1.50)	NA	NA
Overweight only	0	NA	NA	NA
Obese only	11	0.98 (0.84-1.13)	0	NA
Overweight-obese combined	11	0.80 (0.67-0.94)	0	NA
Mixed	20	0.83 (0.69-0.97)	26.5	NA
Gestational hypertension				
Overall	28	0.87 (0.70-1.04)	32.5	−0.8
Normal	6	0.46 (0.21-0.93)	40.8	NA
Overweight	2	0.71 (0.25-2.06)	0	NA
Obese	10	0.93 (0.70-1.25)	0	NA
Overweight-obese combined	12	0.98 (0.67-1.18)	0	NA
Mixed categories	9	0.81 (0.54-1.14)	55	NA
Cesarean delivery[b]				
Overall	34	0.98 (0.91-1.04)	10.8	−0.7
Normal only	5	1.02 (0.81-1.27)	0	NA
Overweight only	3	0.78 (0.44-1.34)	23	NA
Obese only	9	0.98 (0.82-1.21)	13	NA
Overweight-obese combined	15	1.02 (0.89-1.16)	24	NA
Mixed	17	0.98 (0.87-1.07)	15.4	NA
Emergency cesarean delivery[c]				
Overall	14	0.85 (0.74-0.96)	0	−2.4
Preeclampsia				
Overall	27	0.98 (0.84-1.13)	0	0.1
Normal only	2	0.87 (0.43-1.55)	0	NA
Overweight only	0	NA	NA	NA
Obese only	10	1.09 (0.79-1.70)	0	NA
Overweight-obese combined	6	1.00 (0.73-1.35)	0	NA
Mixed	12	0.93 (0.72-1.17)	0	NA

Abbreviations: ARD, absolute risk difference; BMI, body mass index; NA, not applicable; RR, risk ratio.

[a] Studies enrolled participants of mixed (all BMI categories), overweight and obesity only, and obesity only but could present outcomes by individual BMI category. Stratified analyses were conducted when sufficient data were available on individual BMI categories. Some studies were included in multiple categories.

[b] Reported as any cesarean delivery (type not specified), excluding emergency or elective.

[c] Stratified analysis by BMI category not conducted.

interventions on likelihood of gestational diabetes and BMI category, intervention type, or intensity.

Gestational Hypertension | Twenty-eight RCTs (n = 14 875) reported rates of gestational hypertension (Table 1; eFigure 2 in the Supplement).[24,28,31-34,38,39,41,51,52,55-58,60,62-64,67,69-71,73,77,79,80,82] Gestational hypertension was defined as persistent or repeated measures of blood pressure greater than or equal to 140/90 mm Hg after 20 weeks' gestation (a definition generally consistent with the US guideline).[106]

Gestational weight gain interventions were not associated with reduced likelihood of gestational hypertension compared with controls (28 trials; RR, 0.87 [95% CI, 0.70 to 1.04]; I^2 = 32.5%; ARD, −0.8% [95% CI, −1.9% to 0.2%]) (Table 1; eFigure 2 in the Supplement). However, stratified analysis showed statistically significant interactions between effects of GWG interventions on risk of gestational hypertension and intervention type and intensity (P<.001 for interactions) but not BMI category. There were statistically significant effects in the active (7 trials; RR, 0.60 [95% CI, 0.41 to 0.82]; I^2 = 0%; P < .001) and high-intensity (12 trials; RR, 0.69 [95% CI, 0.50 to 0.91]; I^2 = 23.5%; P = .006) intervention subgroups.

Cesarean Delivery | Forty-six RCTs (n = 19 573) reported effects of GWG interventions on rates of cesarean delivery (Table 1; eFigure 3 in the Supplement).[20,22-24,26,28-34,36-40,44,49-52,55-59,61-65,67,69,71-73,75,77-80,82,100] Thirty-four trials[20,22,26,28-30,33,34,36,38-41,44,49-52,56-59,61-65,67,69,71,73,78,79,82] reported on the outcome of cesarean delivery not specified as emergency or elective (n = 15 908); 12 trials[24,31,32,37,44,52,55,72,75,77,80] specified elective cesarean delivery (n = 6222); and 14 trials[24,31,32,37,38,44,52,55,56,67,72,75,77,80] reported emergency cesarean delivery (n = 7520), though only 1 trial[78] reported indications for emergency cesarean delivery (eTable 4 in the Supplement).

Gestational weight gain interventions were not associated with decreased likelihood of cesarean delivery (not specified as emergency or elective) vs controls (34 trials; RR, 0.98 [95% CI, 0.91 to 1.04]; I^2 = 10.8%; ARD, −0.7% [95% CI, −2.4% to 0.8%])

Table 2. Summary of Pooled Findings: Infant Health Outcomes (Key Question 1)

BMI category[a]	No. of trials	Effect size, RR (95% CI)	I^2, %	ARD, %
Macrosomia				
Overall	25	0.77 (0.65-0.92)	38.3	−1.9
Normal only	5	0.73 (0.51-1.30)	0	NA
Overweight only	0	NA	NA	NA
Obese only	3	1.00 (0.68-1.26)	0	NA
Overweight-obese combined	7	0.83 (0.68-1.04)	0	NA
Mixed	14	0.76 (0.56-0.93)	0	NA
Large for gestational age				
Overall	26	0.89 (0.80-0.99)	0	−1.3
Normal only	1	0.87 (0.64-1.27)	NA	NA
Overweight only	0	NA	NA	NA
Obese only	7	0.88 (0.59-1.19)	12	NA
Overweight-obese combined	8	0.87 (0.64-1.20)	0	NA
Mixed	10	0.92 (0.75-1.11)	0	NA
Preterm birth[b]				
Overall	33	0.93 (0.81-1.07)	2.2	−0.2
Normal only	1	1.14 (0.64-2.03)	NA	NA
Overweight only	0	NA	NA	NA
Obese only	5	1.72 (0.95-4.78)	0	NA
Overweight-obese combined	8	0.77 (0.47-1.07)	0	NA
Mixed	19	0.94 (0.79-1.09)	0	NA

Abbreviations: ARD, absolute risk difference; BMI, body mass index; NA, not applicable; RR, risk ratio.

[a] Studies enrolled participants of mixed (all BMI categories), overweight and obesity only, and obesity only but could present outcomes by individual BMI category. Stratified analyses were conducted when sufficient data were available on individual BMI categories. Some studies were included in multiple categories.

[b] Reported as any preterm birth (<37 weeks, <36 weeks, or not reported).

(Table 1; eFigure 3 in the Supplement). However, GWG interventions were associated with reduced risk of emergency cesarean delivery (14 trials; RR, 0.85 [95% CI, 0.74 to 0.96]; I^2 = 0%; ARD, −2.4% [95% CI, −4.2% to −0.3%]) (Table 1). A separate analysis was not conducted for elective cesarean delivery alone because of lack of reporting on indication. In stratified analyses, there were no statistically significant interactions between associations of GWG interventions with likelihood of cesarean delivery and BMI category, intervention type, or intensity.

Preeclampsia | Twenty-seven RCTs (n = 17 538) reported effects of GWG interventions on rates of preeclampsia (Table 1; eFigure 4 in the Supplement).[20,24,28,31,36,38,39,44,51-53,55,57,58,62-64,67,69,70,72,73,77,79,80,82] Most studies defined preeclampsia as gestational hypertension accompanied by proteinuria (greater than 300 mg/24 h). The remaining 6 trials[57,58,62-64,82] reported preeclampsia as clinically distinct from gestational hypertension but did not provide a formal definition.

Interventions for GWG were not associated with reduced risk of preeclampsia vs controls (27 trials; RR, 0.98 [95% CI, 0.84 to 1.13]; I^2 = 0%; ARD, 0.1% [95% CI, −0.6% to 0.5%]) (Table 1; eFigure 4 in the Supplement). In stratified analyses, there were no statistically significant interactions between effects of GWG interventions on likelihood of preeclampsia and BMI category, intervention type, or intensity.

There were no effects of GWG interventions on the remaining maternal outcomes (postpartum hemorrhage, perineal trauma, or maternal death); events were uncommon and estimates were imprecise. See the full report for details.[17]

Infant Health Outcomes

Macrosomia | Twenty-five trials (n = 13 990) evaluated effects of GWG interventions on risk of macrosomia. Macrosomia was defined as term infants weighing more than 4 kg (21 RCTs[22,25,27,28,30,33,38,53,57,59,62-64,67,71-73,77,79,80,107]) or 4.5 kg (6 RCTs),[24,37,38,51-53] with 2 trials[38,53] reporting outcomes using both definitions (eTable 4 in the Supplement).

Gestational weight gain interventions were associated with decreased risk of macrosomia vs controls (25 trials; RR, 0.77 [95% CI, 0.65 to 0.92]; I^2 = 38.3%; ARD, −1.9% [95% CI, −3.3% to −0.7%]) (**Table 2**; eFigure 5 in the Supplement). Stratified analyses showed statistically significant interactions between effect of GWG interventions on risk of macrosomia and intervention intensity (P = .03 for interaction) but not BMI category or intervention type. Statistically significant effects were demonstrated in the high-intensity intervention subgroup (14 trials; RR, 0.65 [95% CI, 0.49 to 0.84]; I^2 = 37%).

Large for Gestational Age | Twenty-six RCTs (n = 13 000) reported the outcome of large for gestational age (LGA) infants, defined as birth weight greater than the 90th percentile for gestational age (Table 2; eFigure 6 in the Supplement).[20,24,32-34,37-40,44,49,50,52,53,56,58,65,67,69,72-74,77-80] Gestational weight gain interventions were associated with decreased risk of LGA (26 trials; RR, 0.89 [95% CI, 0.80 to 0.99]; I^2 = 0%; ARD, −1.3% [95% CI, −2.3% to −0.3%]) (Table 2; eFigure 6 in the Supplement). In stratified analyses, effect estimates of GWG interventions on likelihood of LGA did not differ by BMI category, intervention type, or intensity.

Table 3. Summary of Pooled Findings: Weight Outcomes (Key Question 2)

BMI category[a]	No. of trials	Effect size (95% CI)	I^2, %	ARD, %
Mean gestational weight gain				
Overall	55	MD, −1.02 (−1.30 to −0.75)	60.3	NA
Normal only	8	MD, −0.48 (−0.96 to −0.21)	0.0	NA
Overweight only	10	MD, −0.89 (−1.54 to −0.32)	15.5	NA
Obese only	18	MD, −1.63 (−2.45 to −0.91)	63.0	NA
Overweight-obese combined	20	MD, −0.90 (−1.38 to −0.46)	31.1	NA
Mixed	28	MD, −0.81 (−1.16 to −0.46)	60.7	NA
Exceeding NAM recommendations for gestational weight gain[b]				
Overall	39	RR, 0.83 (0.77 to 0.89)	63.8	−7.6
Normal only	9	RR, 0.74 (0.56 to 0.88)	38.7	NA
Overweight only	5	RR, 0.91 (0.78 to 1.01)	0	NA
Obese only	8	RR, 0.81 (0.66 to 0.97)	58.5	NA
Overweight-obese combined	13	RR, 0.85 (0.76 to 0.94)	13.7	NA
Adherence to NAM recommendations for gestational weight gain[c]				
Overall	19	RR, 1.10 (0.89 to 1.35)	84.3	4.2
Normal only	1	RR, 1.15 (0.94 to 1.41)	NA	NA
Overweight only	0	NA	NA	NA
Obese only	3	RR, 1.27 (1.05 to 1.80)	0	NA
Overweight-obese combined	4	RR, 1.27 (0.94 to 1.84)	39	NA
Mixed	11	RR, 0.95 (0.68 to 1.31)	88	NA
Postpartum weight retention, 12 mo[d]				
Overall	10	MD, −0.63 (−1.44 to −0.01)	65.5	NA
Normal only	0	NA	NA	NA
Overweight only	0	NA	NA	NA
Obese only	2	MD, −0.12 (−2.35 to 1.98)	0.0	NA
Overweight-obese combined	3	MD, −1.38 (−4.26 to 0.88)	82.2	NA
Mixed	5	MD, −0.69 (−1.39 to 0.11)	40.5	NA

Abbreviations: ARD, absolute risk difference; BMI, body mass index; MD, mean difference; NA, not applicable; NAM, National Academy of Medicine (formerly the Institute of Medicine); RR, risk ratio.

[a] Studies enrolled participants of mixed (all BMI categories), overweight and obesity only, and obesity only but could present outcomes by individual BMI category. Stratified analyses were conducted when sufficient data were available on individual BMI categories. Some studies were included in multiple categories.

[b] Mixed BMI category removed from analysis, as participants would be double-counted in other categories.

[c] Adherence defined as neither gaining excessive weight nor not gaining sufficient weight.

[d] See full report[17] for postpartum weight retention follow-up at less than 12 months.

Preterm Birth | Thirty-three RCTs (n = 16 974) reported on the outcome of preterm birth (Table 2; eFigure 7 in the Supplement). Preterm birth was defined as delivery at less than 37 weeks in 24 trials[20,22,24,25,27-30,34,36-40,52,56,57,67,69,73,77-79,102] and less than 36 weeks in 4 trials[62-64,71]; 5 trials did not report a definition (eTable 4 in the Supplement).[33,44,60,65,75] Gestational weight gain interventions were not associated with a lower risk of preterm birth (33 trials; RR, 0.93 [95% CI, 0.81 to 1.07]; I^2 = 2.2%; ARD, −0.2% [95% CI, −1.1% to 0.7%]) (Table 2; eFigure 7 in the Supplement). In stratified analyses, effect estimates of GWG interventions on likelihood of preterm birth did not differ by BMI category, intervention type, or intensity.

There were no associations of GWG interventions with the remaining infant outcomes (respiratory distress syndrome, shoulder dystocia, neonatal intensive care unit admission, neonatal death, or infant growth during the first year); events were uncommon and estimates were imprecise. See the full report for details.[17]

Benefits for Weight Outcomes

Key Question 2a. Do interventions to limit excess gestational weight gain reduce gestational weight gain, postpartum weight retention, or obesity-related adverse perinatal conditions among pregnant women and their infants?

Key Question 2b. Do interventions to reduce prepregnancy weight in women who are overweight or obese improve weight outcomes or reduce obesity-related adverse perinatal conditions among women who become pregnant and their infants?

Key Question 2c. Does the effectiveness of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

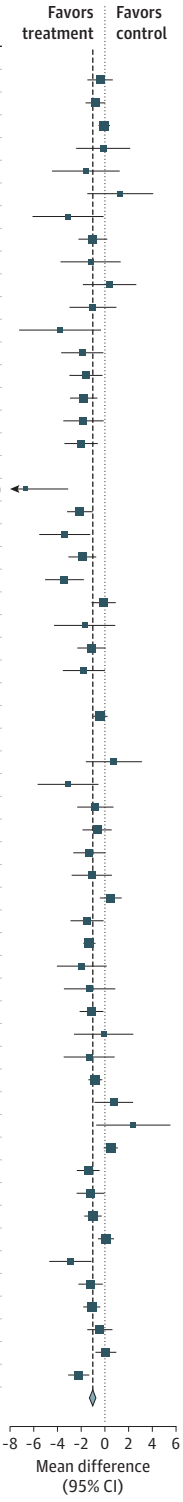
Mean GWG

Fifty-five trials evaluated effects of GWG interventions on mean GWG (**Table 3**, **Figure 3**).[19,20,22-31,33-41,43,45-53,55-60,62-68,71-76,78-82] Gestational weight gain interventions were associated with reduced GWG during pregnancy of approximately 1 kg vs controls (55 trials; n = 20 090; pooled mean difference [MD], −1.02 kg [95% CI, −1.30 to −0.75]; I^2 = 60.3%) (Table 3, Figure 3).

High-intensity interventions were associated with greater effects on GWG (28 trials; MD, −1.47 kg [95% CI, −1.78 to −1.22]; I^2 = 13.0%) than were moderate-intensity (18 trials; MD, −0.32 kg [95% CI, −0.71 to −0.04]; I^2 = 17.6%) or low-intensity (9 trials; MD, −0.64 kg [94% CI, −1.44 to 0.02]; I^2 = 48.4%; P < .001 for interaction) interventions. Subgroup analyses according to BMI category demonstrated slightly higher effect estimates among

Figure 3. Healthy Weight and Weight Gain During Pregnancy Meta-analysis of Trials: Mean Gestational Weight Gain

Source	Outcome assessment time point	Intervention type/intensity	Mean gestational weight gain				Mean difference (95% CI)
			Treatment		Control		
			No.	Mean (SD)	No.	Mean (SD)	
Overweight/obese							
Luoto et al,[53] 2011	36 wk to delivery	Counseling/moderate	219	13.80 (5.80)	180	14.20 (5.10)	-0.40 (-1.47 to 0.67)
Harrison et al,[46] 2013	28 wk	Counseling/moderate	121	5.96 (2.83)	107	6.76 (3.44)	-0.80 (-1.62 to 0.03)
Dodd et al,[39] 2014	36 wk to delivery	Counseling/moderate	1080	9.39 (5.74)	1072	9.44 (5.77)	-0.05 (-0.54 to 0.44)
Hawkins et al,[47] 2014	Delivery	Counseling/moderate	33	17.73 (5.74)	35	17.87 (3.49)	-0.14 (-2.42 to 2.14)
Petrella et al,[60] 2014	Delivery	Counseling/low	33	8.80 (6.50)	30	10.40 (5.00)	-1.60 (-4.45 to 1.25)
Garnaes et al,[41] 2016	Delivery	Active/high	46	10.50 (5.22)	45	9.20 (7.99)	1.30 (-1.48 to 4.08)
Herring et al,[48] 2016	36 wk to delivery	Counseling/high	33	8.70 (6.60)	33	12.30 (6.40)	-3.10 (-6.09 to -0.11)[a]
McCarthy et al,[55] 2016	34-36 wk	Counseling/low	159	8.59 (5.38)	154	9.60 (5.59)	-1.01 (-2.23 to 0.21)
Seneviratne et al,[73] 2016	36 wk to delivery	Active/high	37	12.00 (5.30)	37	13.20 (5.80)	-1.20 (-3.73 to 1.33)
Bruno et al,[33] 2017	34-36 wk	Counseling/moderate	69	9.50 (6.40)	62	9.10 (6.70)	0.40 (-1.85 to 2.65)
Peccei et al,[58] 2017	36 wk to delivery	Counseling/moderate	180	11.20 (10.46)	92	12.20 (6.14)	-1.00 (-2.98 to 0.98)
Redman et al,[66] 2017	34-36 wk	Counseling/high	37	9.03 (5.59)	17	12.80 (6.18)	-3.77 (-7.22 to -0.32)
Willcox et al,[81] 2017	34-36 wk	Counseling/high	45	7.80 (4.70)	46	9.70 (3.90)	-1.90 (-3.68 to -0.12)
Cahill et al,[34] 2018	36 wk to delivery	Counseling/high	119	8.05 (5.60)	121	9.64 (5.40)	-1.59 (-2.98 to -0.20)
Gallagher et al,[40] 2018	Delivery	Counseling/high	97	7.89 (4.07)	99	9.67 (4.17)	-1.78 (-2.93 to -0.63)
Phelan et al,[63] 2018	34-36 wk	Active/high	129	9.40 (6.90)	127	11.20 (7.00)	-1.80 (-3.50 to -0.10)
Van Horn et al,[78] 2018	34-36 wk	Counseling/high	140	10.00 (6.00)	140	12.00 (6.00)	-2.00 (-3.41 to -0.59)
Obese							
Wolff et al,[82] 2008	34-36 wk	Counseling/moderate	23	6.60 (5.50)	27	13.30 (7.50)	-6.70 (-10.31 to -3.09)
Vinter et al,[80] 2011	34-36 wk	Active/high	123	7.00 (4.14)	115	9.10 (4.36)	-2.10 (-3.18 to -1.02)
Bogaerts et al,[31] 2013	Delivery	Counseling/moderate	134	10.12 (6.91)	63	13.50 (7.30)	-3.38 (-5.53 to -1.23)
Renault et al,[67] 2013	36 wk to delivery	Counseling/high	284	9.00 (6.36)	141	10.90 (5.52)	-1.90 (-3.07 to -0.73)
Vesco et al,[79] 2014	PP 2 wk	Counseling/high	55	5.00 (4.10)	57	8.40 (4.70)	-3.40 (-5.03 to -1.77)
Koivusalo et al,[51] 2016	Delivery	Counseling/moderate	144	7.60 (4.86)	125	7.70 (3.67)	-0.10 (-1.12 to 0.92)
Daly et al,[37] 2017	34-36 wk	Active/high	34	6.20 (6.00)	42	7.90 (4.80)	-1.70 (-4.28 to 0.88)
Simmons et al,[74] 2017	34-36 wk	Counseling/moderate	225	7.67 (4.53)	79	8.80 (4.70)	-1.13 (-2.32 to 0.06)
Okesene-Gafa et al,[56] 2019	36 wk to delivery	Counseling/high	100	9.70 (6.60)	101	11.40 (6.30)	-1.76 (-3.54 to 0.02)[a]
Normal weight							
Dodd et al,[38] 2019	36 wk to delivery	Counseling/moderate	316	11.30 (4.00)	313	11.70 (3.80)	-0.37 (-0.97 to 0.23)[a]
Mixed population							
Polley et al,[64] 2002	36 wk to delivery	Counseling/low	57	14.55 (7.15)	53	13.78 (5.43)	0.76 (-1.60 to 3.12)
Asbee et al,[23] 2009	Delivery	Counseling/low	57	13.00 (5.70)	43	16.10 (7.00)	-3.10 (-5.66 to -0.54)
Haakstad et al,[45] 2011	36 wk to delivery	Active/high	52	13.00 (4.00)	53	13.80 (4.00)	-0.80 (-2.33 to 0.73)
Phelan et al,[62] 2011	36 wk to delivery	Counseling/moderate	179	15.01 (5.75)	184	15.66 (6.19)	-0.65 (-1.88 to 0.58)
Barakat et al,[26] 2012	36 wk to delivery	Active/high	40	12.50 (3.20)	43	13.80 (3.10)	-1.30 (-2.66 to 0.06)
Hui et al,[49] 2012	Delivery	Active/high	102	14.10 (6.00)	88	15.20 (5.90)	-1.10 (-2.80 to 0.60)
Althuizen et al,[22] 2013	34-36 wk	Counseling/moderate	123	11.60 (4.10)	123	11.10 (3.20)	0.50 (-0.42 to 1.42)
Rauh et al,[65] 2013	36 wk to delivery	Counseling/low	167	14.10 (4.10)	83	15.60 (5.80)	-1.50 (-2.89 to -0.11)
Ruiz et al,[71] 2013	36 wk to delivery	Active/high	481	11.90 (3.80)	481	13.20 (4.30)	-1.30 (-1.81 to -0.79)
Barakat et al,[29] 2014	Delivery	Active/high	107	11.72 (4.06)	93	13.66 (9.62)	-1.94 (-4.04 to 0.16)
Hui et al,[49] 2012	Delivery	Active/high	57	13.99 (5.82)	56	15.28 (5.92)	-1.28 (-3.45 to 0.88)
Ronnberg et al,[68] 2014	Delivery	Counseling/low	192	14.19 (4.45)	182	15.31 (5.38)	-1.12 (-2.12 to -0.12)
Daley et al,[35] 2015	36 wk to delivery	Counseling/low	34	12.00 (4.50)	34	12.10 (5.90)	-0.10 (-2.59 to 2.39)
Gesell et al,[43] 2015	36 wk to delivery	Active/high	68	8.85 (5.57)	67	10.17 (7.06)	-1.32 (-3.47 to 0.83)
Barakat et al,[28] 2016	36 wk to delivery	Active/high	382	12.10 (3.70)	383	12.90 (4.50)	-0.80 (-1.38 to -0.22)
Skouteris et al,[75] 2016	34-36 wk	Counseling/moderate	130	12.82 (6.66)	131	12.07 (6.76)	0.75 (-0.88 to 2.38)
Smith et al,[76] 2016	34-36 wk	Counseling/moderate	24	13.60 (5.60)	21	11.20 (5.10)	2.40 (-0.73 to 5.53)
Assaf-Balut et al,[24] 2017	36 wk to delivery	Counseling/low	434	9.90 (4.70)	440	9.40 (4.30)	0.50 (-0.10 to 1.10)
Sagedal et al,[72] 2017	Delivery	Active/high	296	14.40 (6.20)	295	15.80 (5.70)	-1.40 (-2.36 to -0.44)
Bacchi et al,[25] 2018	36 wk to delivery	Active/high	70	12.70 (2.60)	70	13.90 (4.30)	-1.20 (-2.38 to -0.02)
Barakat et al,[27] 2018	36 wk to delivery	Active/high	227	12.30 (3.60)	202	13.30 (4.10)	-1.00 (-1.73 to -0.27)
Olson et al,[57] 2018	36 wk to delivery	Counseling/moderate	1126	13.73 (15.44)	563	13.73 (10.68)	0.10 (-0.57 to 0.77)[a]
Aguilar-Cordero et al,[19] 2019	36 wk to delivery	Active/high	65	8.30 (4.95)	64	11.20 (5.35)	-2.90 (-4.68 to -1.12)
Al Wattar et al,[20] 2019	36 wk to delivery	Counseling/moderate	553	6.80 (5.60)	585	8.30 (6.40)	-1.20 (-2.22 to -0.18)[a]
Barakat et al,[30] 2019	36 wk to delivery	Active/high	234	12.20 (3.70)	222	13.30 (4.10)	-1.10 (-1.82 to -0.38)
Daley et al,[36] 2019	36 wk to delivery	Counseling/low	305	10.30 (5.90)	311	10.70 (6.90)	-0.42 (-1.48 to 0.64)[a]
Kunath et al,[52] 2019	NR	Counseling/moderate	946	14.10 (5.30)	939	14.10 (5.20)	0.09 (-0.79 to 0.97)[a]
Pelaez et al,[59] 2019	36 wk to delivery	Active/high	100	11.50 (3.50)	201	13.70 (4.10)	-2.20 (-3.09 to -1.31)
Overall: $I^2 = 60.3\%$							-1.02 (-1.30 to -0.75)



Dashed line indicates the overall effect. NR indicates not reported; PP, postpartum.

[a] Adjusted mean difference.

women with obesity (18 trials; MD, −1.63 [95% CI, −2.45 to −0.91]; I^2 = 63.0%) compared with other BMI categories (overweight, 10 trials; MD, −0.89 [95% CI, −1.54 to −0.32]; I^2 = 15.5%; overweight and obesity combined, 20 trials; MD, −0.90 [95% CI, −1.38 to −0.46]; I^2 = 31.1%; mixed weight categories, 28 trials; MD, −0.81 [95% CI, −1.16 to −0.46]; I^2 = 60.7%; or normal weight, 8 trials; MD, −0.48 [95% CI, −96 to −0.21]; I^2 = 0.0%) (Table 3). There was no association between effects of GWG interventions and overall prepregnancy BMI category (Table 3, Figure 3).

In stratified analyses, the were no statistically significant interactions between effects of GWG interventions on mean GWG and intervention type, study quality, or timing of weight gain assessment.

Exceeding NAM Recommendations for GWG

Thirty-nine RCTs (n = 13 955) reported the outcome of GWG in excess of NAM recommendations (Table 3; eFigure 8 in the Supplement).[21-23,25,27-30,32,34-37,41,43,48-50,52,54,55,57,59,61-66,68,71,74-76, 78-81,95] Interventions were associated with decreased likelihood of gaining weight in excess of NAM recommendations (39 trials; RR, 0.83 [95% CI, 0.77 to 0.89]; I^2 = 63.8%; ARD, −7.6% [95% CI, −11.0% to −4.6%]) (Table 3; eFigure 8 in the Supplement). Stratified analysis showed statistically significant interactions between effects of GWG interventions on excess weight gain and intervention type (P = .003) and intensity (P<.001 for interaction) but not for BMI category. There were statistically significant effects in the active (15 trials; RR, 0.73 [95% CI, 0.67 to 0.80]; I^2 = 0%) and high-intensity (22 trials; RR, 0.74 [95% CI, 0.69 to 0.79]; I^2 = 0%) intervention subgroups.

Adherence to NAM Recommendations for GWG

Nineteen RCTs (n = 5835) reported on the outcome of rates of adherence to GWG guidelines by prepregnancy BMI category according to ranges recommended by the NAM (ie, neither gaining excessive weight nor failing to gain sufficient weight (Table 3; eFigure 9 in the Supplement).[23,29,32,36,38,43,55,58,60-62,64,68,71,74,75,77,79,80] There was no difference between GWG interventions and controls in likelihood of adherence to NAM recommendations for GWG (19 trials; RR, 1.10 [95% CI, 0.89 to 1.35]; I^2 = 84.3%), although statistical heterogeneity was substantial (Table 3; eFigure 9 in the Supplement). In stratified analyses, there were not statistically significant interactions between effects GWG interventions and adherence to NAM recommendations by BMI category, intervention type, or intensity.

Postpartum Weight Retention

Thirteen RCTs (n = 4841) evaluated the effects of GWG interventions on postpartum weight retention (PPWR) (Table 3; eFigure 10 in the Supplement). Gestational weight gain interventions were associated with statistically significantly less PPWR at 12 months (10 trials; MD, −0.63 kg [95% CI, −1.44 to −0.01]; I^2 = 65.5%)[22,90,92-94,96,97,99,101,102] but not at 6 months postpartum (3 trials; MD, −0.85 kg [95% CI, −3.67 to 0.81]; I^2 = 70.6%)[62,92,105] or less than 6 months postpartum (9 trials; MD, −0.81 kg [95% CI, −2.40 to 0.55]; I^2 = 84.4%).[42,64,65,82,91,93,94] In stratified analyses, effect estimates of GWG interventions on likelihood of PPWR did not differ by BMI category at follow-up time of up to 6 months or 12 months.

Harms of Interventions

Key Question 3a. What are the harms of interventions to limit excess gestational weight gain among pregnant women and their infants?

Key Question 3b. What are the harms of interventions to reduce prepregnancy weight among women who are overweight or obese?

Key Question 3c. Do the harms of these interventions differ by age, race/ethnicity, socioeconomic status, parity, smoking status, or BMI category?

Evidence on harms associated with GWG interventions was very limited, with most studies not reporting harms (**Table 4**; eTable 4 in the Supplement). In general, there were no serious harms related to the interventions, including depression or anxiety, and most trials noted no differences between groups in the rates of adverse events, including SGA.

Discussion

The evidence from this report is summarized in Table 4. Evidence on effects of GWG interventions on maternal outcomes was most robust for gestational diabetes, gestational hypertension, preeclampsia, and cesarean delivery. Active or counseling-only GWG interventions were associated with decreased risk of GDM and emergency cesarean delivery. While there was no overall association between GWG interventions and risk of gestational hypertension, stratified analyses indicated that high-intensity and active interventions were associated with decreased rates of gestational hypertension, suggesting a possible dose effect. There was no association of GWG interventions with preeclampsia, a multisystem syndrome with less clear associations with BMI.[108] Evidence on effects of GWG interventions on infant outcomes was most robust for macrosomia, LGA, and preterm birth. Gestational weight gain interventions were associated with decreased risk of macrosomia and LGA.

Gestational weight gain interventions were associated with slightly less overall gestational weight gain vs controls. The effects of interventions on GWG were greater in trials of high-intensity interventions compared with moderate- or low-intensity interventions. The effects of GWG interventions on gestational weight gain also were greater in women in the obese and overweight categories compared with women with normal prepregnancy BMI, although the overall interaction between BMI and GWG was not statistically significant.

Gestational weight gain interventions were associated with decreased likelihood of weight gain in excess of NAM recommendations vs controls, with some evidence of a dose-response relationship. The findings support the obesity and behavioral intervention literature that demonstrates more promising effects of interventions that offer more frequent patient contact.[109,110]

There was no significant association between GWG interventions and likelihood of adhering to NAM recommendations for GWG. The discrepancy between the effects of GWG interventions on exceeding guidelines vs adhering to guidelines could be attributable to an increased likelihood of some women not adhering to NAM recommendations because they did not gain enough weight. However, data were not available to verify this, as most studies did not report the proportion of women with less GWG than recommended. Gestational weight gain interventions were associated

Table 4. Summary of Evidence

Outcome category	Outcome	No. of studies (observations)	Summary of findings[a]	Consistency and precision	Other limitations	Strength of evidence	Applicability
KQ1: Benefits for health outcomes							
Maternal health outcomes	Gestational diabetes	43 RCTs (n = 19 752)	Reduced rates of gestational diabetes (43 trials; RR, 0.87 [95% CI, 0.79 to 0.95]; I^2 = 16.4%; ARD, −1.6% [95% CI, −2.5% to −0.7%]) No effect when stratified by prepregnancy BMI subgroups, intervention type, or intensity	Consistent; reasonably precise	Variation in diagnostic criteria for gestational diabetes; differences in study groups by maternal BMI	Moderate	Moderate
	Gestational hypertension	28 RCTs (n = 14 857)	Statistically significant effects when stratified by intervention type (active interventions, 7 trials; RR, 0.60 [95% CI, 0.41 to 0.82]; I^2 = 0%; P < .001) and intensity (high-intensity, 12 trials; RR, 0.69 [95% CI, 0.50 to 0.91]; I^2 = 23.5%; P = .006] but not BMI subgroup	Consistent; reasonably precise	Variation in timing of outcome assessment and follow-up; interventions heterogeneous and varied in intensity; variations in prepregnancy weight and other demographic characteristics	Moderate	Moderate
	Cesarean delivery	46 RCTs (n = 19 573)	No effect on rates of cesarean delivery (any type, 34 trials; RR, 0.98 [95% CI, 0.91 to 1.04]; I^2 = 10.8%; ARD, −0.7% [95% CI, −2.4% to 0.8%]); increased risk of emergency cesarean delivery [14 trials; RR, 0.85 [95% CI, 0.74 to 0.96]; I^2 = 0%; ARD, −2.4% [95% CI, −4.2% to −0.3%]) No effect when cesarean delivery (any type) stratified by BMI subgroup, intervention type, or intensity	Consistent; reasonably precise	Indication for cesarean delivery not reported in any study; unclear indications for cesarean delivery among the studies reporting statistical differences between groups, including lack of reporting of parameters to determine elective or emergency cesarean delivery	Moderate	Moderate
	Preeclampsia	27 RCTs (n = 17 538)	No association between interventions and rates of preeclampsia (27 trials; RR, 0.98 [95% CI, 0.84 to 1.13]; I^2 = 0.0%; ARD, 0.1% [95% CI, −0.6% to 0.5%]) No effect when stratified by BMI subgroup, intervention type, or intensity	Consistent; precise	Differences in follow-up duration and outcome assessment timing; low event rates; heterogeneous interventions; populations varied in prepregnancy weight and demographic characteristics	High	Moderate
Prepregnancy weight reduction outcomes	Weight outcomes	1 RCT (n = 326)	No effect on rates of excess GWG; increased GWG for intervention vs controls (13.2 [SD, 8.2] kg vs 10.3 [SD, 7.4] kg, P = .03)	NA	Only 1 study included; large confidence intervals in some analyses	Insufficient	Low
Infant health outcomes	Macrosomia	25 RCTs (n = 13 990)	Reduction in rates of macrosomia (25 trials; RR, 0.77 [95% CI, 0.65 to 0.92]; I^2 = 38.3%; ARD, −1.9% [95% CI, −3.3% to −0.7%]) Statistically significant effects when stratified by intervention intensity [high-intensity, 14 trials; RR, 0.65 [95% CI, 0.49 to 0.84]; I^2 = 37%; P = .03) but not BMI subgroup or intervention type	Consistent; imprecise	Varied definitions for outcome (<4000 g >4500 g); low event rates	Moderate	Moderate
	LGA	26 RCTs (n = 13 000)	Reduced rates of LGA (26 trials; RR, 0.89 95% CI, 0.80 to 0.99]; I^2 = 0%; ARD, −1.3% [95% CI, −2.3% to −0.3%]) No effect when stratified by BMI subgroup, intervention type, or intensity	Consistent; precise	Studies not powered to address LGA; low event rates	Moderate	Moderate
	Preterm birth	33 RCTs (n = 16 974)	No effect on rates of preterm birth (33 trials; RR, 0.93 [95% CI, 0.81 to 1.07]; I^2 = 2.2%; ARD, −0.2% [95% CI, −1.1% to 0.7%]) No effect when stratified by BMI subgroup, intervention type, or intensity	Consistent; precise	Studies not powered to address preterm birth; varied definitions used for preterm birth (<36 wk, 37 wk, or not reported); low event rates	Moderate	Moderate

(continued)

Table 4. Summary of Evidence (continued)

Outcome category	Outcome	No. of studies (observations)	Summary of findings[a]	Consistency and precision	Other limitations	Strength of evidence	Applicability
KQ2: Benefits for weight outcomes							
Gestational weight outcomes	Mean gestational weight gain	55 RCTs (n = 20 090)	Statistically significant effect when stratified by intervention intensity (moderate-intensity, 18 trials; MD, −0.32 kg [95% CI, −0.71 to −0.04]; I^2 = 17.6%; and high-intensity, 28 trials; MD, −1.47 kg [95% CI, −1.78 to −1.22]; I^2 = 13%; P < .001) but not BMI subgroup, intervention type, weight assessment time point, or intervention quality	Reasonably consistent direction within BMI categories but inconsistent magnitude of effect; imprecise	Variation in timing of outcome assessment (eg, from 1 mo prior to delivery to delivery); type of GWG not defined (eg, fat vs fluid retention); variation in prepregnancy weight categories enrolled; few studies report on enrollment or outcomes related to subgroups of importance (eg, SES or racial and ethnic minorities); heterogeneous interventions, components not always well-described; differences in timing of initiation, duration of intervention, or both	Moderate	Moderate
	Exceeding NAM recommendations for GWG[b]	39 RCTs (n = 13 955)	Lower likelihood of gaining weight in excess of NAM recommendations (39 trials; RR, 0.83 [95% CI, 0.77 to 0.89]; I^2 = 63.8%; ARD, −7.6% [95% CI, −11.0% to −4.6%]) Statistically significant effect for excess GWG and intervention type (active interventions, 15 trials; RR, 0.73 [95% CI, 0.67 to 0.80]; I^2 = 0%; counseling-only interventions, 24 trials; RR, 0.89 [95% CI, 0.82 to 0.98]; I^2 = 68.2%; P = .003) and intensity (high-intensity, 22 trials; RR, 0.74 [95% CI, 0.69 to 0.79]; I^2 = 0%; P < .001) but not BMI	Consistent; imprecise	Variation in timing of outcome assessment (eg, from 1 mo prior to delivery to delivery); type of GWG not defined (eg, fat vs fluid retention); variation in prepregnancy weight categories enrolled; few studies report on enrollment or outcomes related to subgroups of importance (eg, SES or racial and ethnic minorities); heterogeneous interventions, components not always well-described; differences in timing of initiation, duration of intervention, or both	Moderate	Moderate
	Adherence to NAM recommendations for GWG[c]	19 RCTs (n = 5835)	No effect on rates of adherence to NAM recommendations for GWG (19 trials; RR, 1.10 [95% CI, 0.89 to 1.35]; I^2 = 84.3%; ARD, 4.2% [95% CI, −1.2% to 10%]) No effect when stratified by BMI subgroup, intervention type, or intensity	Relatively consistent; imprecise	Variation in timing of outcome assessment (eg, from 1 mo prior to delivery to delivery); type of GWG not defined (eg, fat vs fluid retention); variation in prepregnancy weight categories enrolled; few studies report on enrollment or outcomes related to subgroups of importance (eg, SES or racial and ethnic minorities); heterogeneous interventions, components not always well-described; differences in timing of initiation, duration of intervention, or both	Low	Moderate
	Postpartum weight retention	13 RCTS (n = 4841)	Greater reductions in postpartum weight retention at follow-up time of 12 mo (MD, −0.63 kg [95% CI, −1.44 to −0.01]; I^2 = 65.5%) but not follow-up times <6 mo (MD, −0.81 kg [95% CI, −2.40 to 0.55]; I^2 = 84.4%) or 6 mo (MD, −0.85 kg [95% CI, −3.67 to 0.81]; I^2 = 70.6%) No effect when stratified by BMI subgroup at less than 6 mo or 12 mo	Reasonably consistent; imprecise	Differences in follow-up time; differing duration of interventions; limited or no reporting of known factors associated with postpartum weight retention (eg, breastfeeding); substantial heterogeneity of pooled estimates	Low	Moderate

(continued)

Table 4. Summary of Evidence (continued)

Outcome category	Outcome	No. of studies (observations)	Summary of findings[a]	Consistency and precision	Other limitations	Strength of evidence	Applicability
KQ3: Harms of interventions							
Harms	Depression and anxiety	10 RCTs (n = 2553)	Mixed effects reported for rates of depression and anxiety as measured by various, validated symptom scales	Inconsistent, imprecise	Not reported as harms of intervention; measured as changes in symptoms; heterogeneous intervention components, duration, intensity, and follow-up; few studies overall	Low	Moderate
	SGA	20 RCTs (n = 8977)	No difference in rates of SGA (20 trials; RR, 0.94 [95% CI, 0.80 to 1.10]; I^2 = 0.0%; ARD, -0.4% [95% CI, -1.7 to 1.0]) No differences between interventions during pregnancy vs usual care on low birth weight in 12 trials Statistically significant effect when stratified by intervention intensity but not BMI subgroup or intervention type	Consistent; reasonably precise	Studies not powered to address SGA; varied definitions used for SGA (<10% for gestational age) or low birth weight (<2500 g); low event rates	Moderate	Moderate

Abbreviations: ARD, absolute risk difference; BMI, body mass index; CCT, nonrandomized controlled intervention study; GWG, gestational weight gain; LGA, large for gestational age; MD, mean difference; NA, not applicable; NAM, National Academy of Medicine (formerly the Institute of Medicine); RCT, randomized clinical trials; RR, relative risk; SES, socioeconomic status; SGA, small for gestational age.

[a] Overall results stratified by prepregnancy BMI category, intervention type (behavioral counseling or active), and intervention intensity (low, moderate, high) when sufficient data reported.

[b] Mixed BMI category removed from analysis, as participants would be double-counted in other categories.

[c] Adherence defined as neither gaining excessive weight nor failing to gain sufficient weight.

with effects on PPWR at 12 months; effects on PPWR at 6 months were not statistically significant, but data were more limited and imprecise. Evidence on harms of GWG interventions was limited, but there was no association with increased risk of small for gestational age and no indication of serious harms.

Trials should be designed to examine the effects of weight loss interventions in diverse populations stratified by BMI and report outcomes according to population categories, including adolescents and women with advanced maternal age. Additional studies examining the effect of prepregnancy weight loss interventions are also an important next step.

Limitations

This review had several limitations. First, data were often not available for important groups defined by race or ethnicity, age (eg, adolescents, advanced maternal age), or socioeconomic status; study results were not stratified by these factors. No study was conducted exclusively in pregnant adolescents or women of advanced maternal age, and only 1 study conducted a weight loss intervention prior to pregnancy. Trials did not address issues of health care disparities, access to prenatal care (or lack thereof), or feasibility of interventions in settings where access to care is limited or arrival to care is delayed. More studies of underrepresented populations who may have higher risk of adverse outcomes are needed.[111,112]

Second, there was statistical heterogeneity in some pooled analyses due to variability in intervention components, comparison groups, and timing and method of assessment of outcomes, but results were consistent with stratified analyses. Because of anticipated heterogeneity, random-effects models were used, which results in wider confidence intervals than fixed-effects models when statistical heterogeneity is present, reflecting the greater uncertainty in estimates. In addition, the profile-likelihood method was used for conducting meta-analyses, which may be more reliable when statistical heterogeneity is present.[113]

Third, there were methodological limitations in the literature. Poor-quality trials were excluded because of serious flaws; results were similar in analyses stratified by study quality. Trials primarily focused on the effects of GWG interventions on mean GWG, an intermediate outcome, with less evidence on the direct effects of GWG interventions on maternal and infant health outcomes. Some stratified analyses were underpowered to evaluate subgroup effects. Additionally, some trials enrolled mixed populations of women with different BMI categories, limiting the usefulness of stratified analyses. Other factors could define intervention intensity (eg, session duration or frequency or type of intervention) but were difficult to categorize. Fourth, evidence on harms was limited, particularly for effects on psychological well-being and quality of life.

Conclusions

Counseling and active behavioral interventions to limit GWG were associated with decreased risk of gestational diabetes, emergency cesarean delivery, macrosomia, and large for gestational age. Gestational weight gain interventions were also associated with modest reductions in mean GWG and decreased likelihood of exceeding NAM recommendations for GWG.

ARTICLE INFORMATION

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Concept and design: Cantor, Jungbauer, McDonagh, Marshall, LeBlanc, Chou.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Cantor, Jungbauer, McDonagh, Blazina, Marshall, Weeks, Fu, Chou.
Critical revision of the manuscript for important intellectual content: Cantor, Jungbauer, Blazina, Marshall, LeBlanc, Chou.
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