Intervention strategies for preventing excessive gestational weight gain: systematic review and meta-analysis.

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Abstract

Interventions relevant to energy intake to prevent excessive gestational weight gain in pregnant overweight and obese women are important but scarce. This review synthesized healthy eating and physical activity strategies and their effects on excessive gestational weight gain prevention.

Methods: 23 randomized controlled trials that included healthy eating and/or physical activity as an intervention in healthy pregnant overweight or obese adult women and gestational weight gain as a primary or secondary outcome were reviewed.

Findings: Heathy eating and/or physical activity (21 studies, n = 6,920 subjects) demonstrated 1.81 kg (95% CI: -3.47, -0.16) of gestational weight gain reduction favoring intervention. Healthy eating (-5.77 kg, 95% CI: -9.34, -2.21, p = 0.02) had a larger effect size than combined healthy eating/physical activity (-0.82 kg, 95% CI: -1.28, -0.36, p = 0.0005) in limiting gestational weight gain. Physical activity did not show a significant pooled effect. Healthy eating with prescribed daily calorie and macronutrient goals significantly limited gestational weight gain by 4.28 kg and 4.23 kg, respectively.

Conclusion: Healthy eating and/or physical activity are effective in gestational weight gain control. Healthy eating with calorie and macronutrient goals are especially effective in limiting excessive gestational weight gain among pregnant overweight and obese women.

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Intervention Strategies for Preventing Excessive Gestational Weight Gain: Systematic Review and Meta-Analysis

Overweight and obesity is a worldwide public health issue for women. In Australia and England, 56% and 58% of adult women, respectively, are overweight or obese (1,2) and the prevalence rate of overweight and obesity among women in United States is even higher than 60% (3). Overweight and obesity results in an increased risk for cardiovascular disease and disability (4). During pregnancy, overweight and obesity can be manifested in the women's excessive gestational weight gain. The optimal total gestational weight gain during pregnancy recommended by the Institute of Medicine (IOM) for overweight women is 15-25 lbs. and for obese women 11-20 lbs. (5). About 56%-62% of overweight and obese women in United States who deliver a full-term, singleton infant gain more than the IOM recommended weight during pregnancy (6). Overweight/obesity and excessive gestational weight gain compound the overall burden of disease. Each is associated with many maternal and infant complications, including placental vascular dysfunction, placental inflammation, maternal gestational diabetes, Cesarean delivery, maternal gestational hypertensive disorders, and larger baby for the gestational age (7,8). Overweight and obese women are twice as likely as normal weight women to have excessive gestational weight gain (6). Health service costs related to outpatient visits, inpatient care, and prescribed medications for overweight and obese pregnant women are 23% to 37% higher as compared to pregnant women with normal weight (9). Interventions to prevent excessive gestational weight gain in overweight and obese women are needed.

Healthy Eating and Physical Activity Strategies for Weight Management

A general weight management strategy for pregnant women has been to establish healthy lifestyle patterns, including eating vegetables, fruits, grains and fat-free or low-fat dairy foods,

choosing water over juice/soda, controlling portion size, and engaging in regular exercise (10). The recent 2015-2020 Dietary Guidelines for Americans (11) recommends an intake of 1,800-2,400 kcal/day for non-pregnant women aged 19 to 45 depending on their physical activity level. The guidelines also recommend that females of 18-50 years old keep 20%-35% of daily calories from fat intake, 45%-65% from carbohydrate intake, 10-35% from proteins, and no more than 10% from added sugars and saturated fat. Prenatal weight management strategies for overweight and obese women related to total daily calories or calories from certain macronutrients, however, have not yet been established. First, data from a systematic review showed that pregnant women reported an average energy intake of 1,230 kcal/day in early and late pregnancy, but five of the 16 studies included in the review were conducted in developing countries and the energy intake was from pregnant women of all body mass index (BMI) categories (12). In contrast, another study based on the dietary data in the Pregnancy, Infection, and Nutrition Study in United States found that of the 1,231 pregnant women in the study the mean energy intake was 2,162 kcal/day and 33% of the women were overweight or obese (13). Second, overweight and obese women who desire to have weight loss often are recommended to follow a regimen of energy deficit ≥ 500 kcal/day or a total energy intake of 1,200-1,500 kcal/day (14). Restricting energy intake for overweight and obese women during pregnancy to achieve weight loss has been proposed but has not been a common practice. Using maternal and neonatal data on 275,708 full term and singleton cases, Beyerlein et al. (15) concluded that overweight and obese women were safe to have weight loss during pregnancy; their conclusions were based on the association of gestational weight gain and a ≤ 20% predicted risk of having small-for-gestational-age and large-for-gestational-age infants. Findings from other studies, however, indicate that gaining less than the IOM recommended weight during pregnancy in obese women may be associated with

preterm births and having small-for-gestational-age infants (16). Third, the American College of Obstetricians and Gynecologist (ACOG) recommends an additional intake of 300 kcal a day during the second and third trimesters for pregnant women (17). Jebeile et al. (15) found that energy intake of pregnant women remained the same in early and late pregnancy and therefore they recommended that additional energy intake should be avoided to prevent excessive weight gain. Pregnant women (mean BMI = 22.9 $\pm$ 3.0) in another study were found to have an additional energy intake of 144 kcal/day in the second and third trimesters as compared to their energy intake in the first trimester but no substantial change in fat intake (31.6% to 33.1%) throughout the pregnancy (18).

Another weight management challenge for pregnant overweight and obese women is related to limited guidelines for the intensity and frequency of physical activity. ACOG recommends aerobic and strength-conditioning exercises for healthy pregnant women without medical or obstetric problems at the moderate intensity and at the frequency of 20-30 minutes/day on most or all days of the week, but an upper level of exercise intensity has not been established (19). ACOG recommendations indicate that pregnant overweight and obese women may have decreased subjective work load and maximum exercise performance, and subsequently limited strenuous physical activity. Furthermore, some physical activities adopted by non-pregnant adults for weight management, such as contacts sports, water skiing, surfing, off-road cycling, and horseback riding, are unsafe for pregnant women; and monitoring heart-rate response to exercise and perceived exertion are recommended by ACOG. Findings from a recent review indicated that exercise training intensity of 40-60 minutes once a week was conducted in previous studies for pregnant overweight and obese women but under supervision and that fear

of harming self and the baby, pregnancy induced physical discomfort, and discouragement by other people were barriers to physical activity (20).

Findings from Previous Systematic Reviews

It has been reported in several systematic reviews that pregnant women who receive healthy eating and/or physical activity interventions have a risk reduction of excessive gestational weight gain of 20% (21) or an average of 0.91-5.37 kg less gestational weight gain (20,21,22,23,24,25,26,27,28,29,30) than women receiving no such interventions. Frameworks used to define healthy eating and physical activity, however, varied among review papers. Further, intervention effects on pregnant overweight and obese women were not consistently provided in previous reviews. For instance, Thangaratinam et al. (28) defined dietary interventions as those that involved low-carbohydrate diet, calorie restriction, low-fat diet, and lifestyle change. Analysis on dietary calories or calories from macronutrients, however, were not provided. Thangaratinam et al. (29) conducted another systematic review and defined dietary interventions as those typically demonstrating a balanced diet of carbohydrates, proteins, and fat, as well as maintenance of a food dietary; and physical activity interventions as light intensity resistance training, weight bearing exercises, and walking for 30 minutes (29). Their subgroup analysis on pregnant overweight and obese women showed that all interventions together demonstrated a reduction of gestational weight gain (14 studies, -2.1 kg, 95% CI: −3.46 to −0.75 kg, $P < 0.002$). Analysis on energy intake or macronutrients, however, were not provided. Muktabhant et al. (21) adopted a framework that included healthy eating plan, low glycemic diet, exercise intervention, health education, and lifestyle counselling in their review. They further grouped healthy eating interventions to four types (diet counseling only, diet intervention, diet and exercise counseling, and diet and specified exercise intervention) and exercise interventions

to supervised and unsupervised. They reported meta-analysis results only on two intervention types among pregnant overweight and obese women. They found that exercise intervention was not associated with mean gestational weight gain but diet and exercise counseling was effective in reducing gestational weight gain (11 studies, -0.71 kg, 95% CI: -1.34 to -0.08). Tanentsaph et al. (27) reviewed only dietary interventions that were defined as low-fat, low-carbohydrate or low-energy diets as well as dietary education about healthy eating and nutritional advice focusing on meeting the IOM weight gain recommendations. They found that calorie restriction was effective in limiting weekly gestational weight gain in pregnant obese women (2 studies, -0.26 kg, 95% CI: -0.42 to -0.09, p = 0.003), but the two studies included in their analysis published in 1975 and 1982. The review by Choi et al. (20) was focused on physical activity interventions which were grouped into three categories: supervised physical activity, supervised physical activity with counseling on diet and weight gain, and counseling on physical activity, diet, and weight gain. Only supervised physical activity with counseling on diet and weight gain showed a significant treatment effect among pregnant overweight and obese women compared with women in the control groups (2 studies, −1.17 kg, 95% CI: −2.14 to −0.21, p = 0.017). Finally, Flynn et al. (31) reviewed 13 randomized controlled trials and defined healthy eating strategies as counseling, individual feedback, and healthier dietary choices. They also identified nutrient components such as macronutrients and energy target as strategies, but they did not provide meta-analysis data to show the relationships of energy target and macronutrients to gestational weight gain.

Meta-analysis data from previous reviews indicated that healthy eating strategy was likely to have a larger effect size in restricting gestational weight gain compared to physical activity and combined healthy eating and physical activity strategies, but available data were

based on women of all BMI categories. Hill et al. (23) found from their review that healthy eating strategy was more effective in limiting excessive gestational weight gain than physical activity strategy (d = -0.71) or mixed intervention (d = -0.59). Thangaratinam et al. (28) found that dietary-related strategy overall was effective in restricting gestational weight gain (-3.36 kg, 95% CI: -4.73 to -1.99, $p < 0.00001$), but physical activity and mixed approach were not. The second review by Thangaratinam et al. (29) showed that all three strategies (healthy eating, physical activity, and mixed) were significantly effective in controlling gestational weight gain, but healthy eating strategy showed a larger effect size than the others.

Mixed findings were also reported in previous systematic reviews in relation to randomized controlled design (RCT) versus non RCT design. Tanentsapf et al. (27) stated that non RCT design could overestimate treatment effects (p.10). Streuling et al (25) found that the four RCTs included in their review collectively resulted in a non-significant reduction of gestational weight gain (-0.13 kg, 95% CI: -0.41 to 0.15, $p = 0.35$), but five non RCTs were effective in lowering gestational weight gain (-0.27 kg, 95% CI: -0.49 to -0.04, $p = 0.02$). Their analysis was based on studies of pregnant women of all BMI categories. Oteng-Ntim et al. (29), however, found that RCTs of combined lifestyle, healthy eating and physical activity (10 studies) for pregnant overweight and obese women could restrict gestational weight gain, but non RCTs (6 studies) showed weak evidence. RCT is a more rigorous design than non RCT in estimating treatment effects because the randomization controls for variance. Therefore, systematic reviews of studies with RCT designs will provide more accurate estimates.

In summary, weight management strategies for pregnant overweight and obese women are needed. Although collective evidence from previous systematic reviews indicate that healthy

eating and/or physical activity strategies are likely to help pregnant women limit excessive gestational weight gain, intervention details relevant to calorie control and physical activity intensity and frequency are yet to be studied. Furthermore, many previous reviews were not necessarily focused on pregnant overweight and obese women. The purpose of this systematic review and meta-analysis, therefore, was to analyze data from published studies using a RCT design on the prevention of excessive gestational weight gain specifically among pregnant overweight and obese women. The aims were to analyze (1) healthy eating and physical activity strategies, particularly relevant to calorie intake and calories from macronutrients and (2) effects of healthy eating and/or physical activity on gestational weight gain.

Methods

Search Strategy

The literature search was performed in PubMed and EBSCO (Academic Search Premier, CINAHL, MEDLINE, and PsyInfo) using 15 keyword combinations: (pregnancy OR gestation OR maternal) AND (diet OR nutrition OR exercise OR physical activity OR lifestyle) AND (excessive gestational weight gain or weight loss OR weight gain OR weight control OR obesity OR overweight) AND (intervention). The search was narrowed using filters of full-text, peer-reviewed, journal articles, female, human, English language, publication day to June 30, 2016, and clinical trial. A total of 740 articles were retrieved from EBSCO and 288 from PubMed. After removing duplications, 707 articles were retained.

Inclusion and Exclusion Criteria

Inclusion criteria were: 1) data-based studies with an RCT design; 2) exercise, diet, or both as the intervention; 3) sample was healthy overweight and/or obese pregnant adult women; and 4) gestational weight gain was a primary or secondary outcome. Exclusion criteria were: 1)

sub-study from RCTs; 2) systematic reviews; 3) meta-analyses; 4) interventions to increase pregnancy weight gain; and 5) weight management for pregnant women with an identified health problem (e.g., acquired immune deficiency, gestational diabetes). If an RCT produced multiple publications, only those that met the inclusion and exclusion criteria were selected.

Study Selection

First, the titles of 707 studies from the search result were screened by a team member and 152 articles were retained. Abstracts were then screened by the same member and those not meeting the inclusion criteria were removed. This resulted in 48 articles remaining. Two members reviewed the full text and removed 27 articles that had no data on gestational weight gain or included pregnant women of all BMIs. Any discrepancies were resolved by discussion and rechecking the full text. The remaining 21 articles along with 2 additional articles found from full-text references were included in the final analysis (Figure 1).

Data Extraction and Analysis

Pre-developed tables were used to collect information about healthy eating and physical activity strategies. Healthy eating strategies were divided into three categories: daily calories, daily macronutrients, and healthy eating patterns and behaviors. Physical activity was grouped into structured and supervised, structured but unsupervised, and unsupervised and self-help activities. Two team members independently reviewed each RCT and extracted data. The first author reviewed all extracted information and checked for information consistency.

Review Manager (RevMan) version 5.3 software was used to conduct meta-analysis. RevMan is recommended by the Cochrane Corporation (32) for high quality systematic review. RevMan was used to assess the effects of healthy eating and/or physical activity on gestational weight gain in kilograms. When there were three arms in an RCT, the intervention arms with

healthy eating and/or physical activity were combined and compared to the control arm that received no intervention but the usual care. Random effect models were used during meta-analysis. A standardized mean difference in gestational weight gain with a 95% confidence interval (CI) between the intervention and the control groups for each RCT was calculated. A pooled mean difference in gestational weight gain and its 95% CI from all pertinent RCTs was also calculated. Z statistic was used to estimate the overall effect size of the RCTs included in the analysis and the significance level was set at $P < 0.05$. To assess heterogeneity which indicated the degree to which studies included in an analysis were different from each other, I^2 statistic was calculated. An I^2 greater than 50% was considered high heterogeneity (27).

Assessment of Reporting Quality

Reporting quality of each RCT article was assessed in two steps. The first step was done by two team members and the second step was completed by the first author. First, each RCT article was evaluated as adequate, inadequate, or unclear in meeting five reporting quality criteria: 1) concealment of allocation, 2) blinding, 3) completeness of follow-up, 4) non-selective reporting, and 5) no other bias (33). Adequate concealment of allocation included both random generation of sequence and allocation concealment. Single blinding was assessed because blinding study participants in lifestyle intervention was not possible. Adequate single blinding meant outcome assessors did not know about participant allocation. To be adequate for completeness of follow-up, study withdrawal or loss of follow-up should be less than 20% and reasons for attrition were explained (27). If an intent-to-treat analysis was used and results were reported, then an RCT was evaluated as adequate for non-selective reporting (33). Adequate for no other bias was referred to as no significant differences ($p \geq 0.05$) between groups at baseline regarding demographics, OB history, and other psychosocial or behavior characteristics (33).

The second step in reporting quality assessment was to assign one of the 3 levels of risk for reporting bias for each RCT article: low (adequate quality in all 5 criteria), moderate (adequate quality in 2 to 4 criteria), and high risk (adequate in 0 to 1 criterion).

Results

Study Characteristics

Characteristics of the 23 RCTs are listed in Table 1. Among them, 9 were conducted in Europe (35,38,39,45,46,48,51,55,56), 6 in Australia (36,37,40,43,47,52), 5 in the U.S. (41,42,49,53,54), 1 in New Zealand (50), 1 in Canada (34), and 1 in Brazil (44). Eight RCTs included only pregnant obese women (BMI $\geq$ 30 kg/m^2) (34,36,46,48,53,54,55,56) and 15 enrolled both overweight (BMI = 25-29.9 kg/m^2) and obese women (35,37,38,39,40,41,42,43,44,45,47,49,50,51,52). Pregnant women were mostly recruited from antenatal facilities (clinics, ultrasound departments, obstetric units/departments, or registries of newly diagnosed pregnancies) and less frequently through mass email services, flyers, or Google advisements. In all RCTs participants were enrolled by 28 weeks of gestation. Gestational weight gain was the primary outcome for 13 RCTs (35,36,38,39,40,44,45,47,48,51,54,55,56) but a secondary outcome for 10 RCTs (34,37,41,42,43,46,49,50,52,53). Five RCTs were focused on healthy eating (43,47,49,53,56), 6 on physical activity (34,36,38,42,44,50), 12 on combined healthy eating and physical activity (35,37,39,40,41,45,46,48,51,52,54,55). Eleven RCTs had a sample size less than 100 (34,36,38,41,42,44,45,49,50,56), 7 had a sample size of 100-400 (35,39,40,43,47,48,51,53,54,55), and 3 included more than 1,000 subjects (37,46,52). In all RCTs but one (40) last body weight was measured between 34 weeks of gestation and delivery. All RCTs used IOM recommendations as gestational weight gain goals (not in Table 1). Some weight gain goals were vague, such as limiting excessive gestational weight gain or encouraged

to meet IOM guidelines (35,38,40,45). Others were concrete and measurable as limits (e.g., ≤ 11.2 Kg, ≤ 5kg, or ≤ 6-7 kg) (48,55,56), ranges (e.g., 7-11 kg) (43), or percentages (weight gain within 3% at randomization) (54).

Reporting Quality

Reporting quality assessment results are shown in Table 2. Sixteen RCTs were rated as adequate for concealment of allocation and completeness of follow-up. Eight RCTs were adequate for blinding and for non-selective reporting. Twenty RCTs presented no other bias relevant to group differences in baseline. Overall, 19 RCTs were rated as having moderate risk (34,35,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56) for reporting bias, 2 were rated as low risk (37,38), and 2 were rated as high risk (36,39).

Healthy Eating and Physical Activity Strategies

Table 3 lists healthy eating and physical activity strategies included in the 23 RCTs.

Healthy eating daily calories. Five RCTs included daily calorie goals: 4 on pregnant obese women (48,53,54,56) and all were effective in limiting gestational weight gain; and 1 on pregnant overweight and obese women and was effective only among obese women (45). For pregnant obese women, Reanult et al. (48) used a calorie goal of 1,200-1,675 kcal/day in their three-arm study that compared physical activity with or without healthy eating to no intervention. They also adopted Mediterranean diet regimen. Thornton et al. (53) adjusted daily calorie need based on body weight: 18-24 kcal/kg/day or ≥ 2,000 kcal/day. Vesco et al. (54) calculated daily calorie needs by adjusting gestational weeks: pre-pregnancy weight in kg x 30 kcal/kg/day x 0.7 + (10 kcal x gestational age in weeks). Their intervention followed the DASH diet recommendations and an unsupervised self-help physical activity component. The fourth RCT for obese pregnant women conducted by Wolff et al. (56) was focused on energy restriction. The

daily calorie goal in their RCT was modified by physical activity level: basal metabolic rate x 1.4 (physical activity level factor of 1.2 + 0.2 added to cover energetic cost of fetal growth). For pregnant overweight and obese women, Petrella et al. (45) set a calorie goal of 1,500 kcal/day, as well as an additional 200 kcal/day for obese pregnant women and 300 kcal/day for overweight pregnant women in response to physical activity.

Of the 5 RCTs with calorie goals, only Wolff et al. (56) reported actual calories consumed by study participants. The average daily calorie intake from enrollment to 36 weeks of gestation ranged from 7,491 kJ to 8,619 kJ (equivalent to 1,790 kcal to 2,060 kcal) in the intervention group and 9,233 kJ to 9,867 kJ (2,207 kcal to 2,358 kcal) in the control group. Daily calories consumed were also measured in three other RCTs that did not set calorie goals. Quelinckx et al (39) reported that daily calories consumed by pregnant women did not change much throughout 3 trimesters and they ranged from 1,826 kcal to 1,940 kcal in the two intervention groups as compared to 2,020-2,296 kcal consumed by the control group. Rhodes et al. (49) reported that pregnant overweight and obese women assigned to a low-glycemic diet consumed an average of 1,641 kcal/day as compared to the 1,665 kcal/day by the participants on a low-fat diet between 32 and 36 weeks of gestation. In Poston et al. study (46) pregnant obese women at 27-28 weeks of gestation consumed on average 7.5 MJ/day (equivalent to 1,791 kcal; standard care group) and 6.8 MJ/day (1,624 kcal; intervention group).

Healthy eating daily macronutrients. Six RCTs provided specific macronutrient goals (35,39,45,49,53,56) and 4 of the 6 studies showed significant effects in limiting gestational weight gain. Among them, Bogarts et al. (35) and Guelinckx et al. (39) set a lowest percentage of daily calories from protein (9-11%), in addition to 30-35% from fat and 50-55% from carbohydrate, for pregnant women with a BMI $\geq$ 29 kg/m^2. They also included an unsupervised

self-help physical activity component. Bogarts et al. study (35) showed a significant effect in limiting gestational weight gain. Guelinckx et al. (39) did not find a significant reduction in gestational weight gain even though women received interventions had better dietary habits than women receiving no intervention. Petrella et al. (45) set macronutrient goals as 20% of daily calories from protein, 25% from fat (of the 25%, 6% from saturated fat), and 55% from carbohydrate for pregnant overweight and obese women. Their study was effective only on obese women and they had an unsupervised self-help physical activity component. Rhodes et al. (49) compared a low-glycemic diet to a low-fat diet on pregnant women with a BMI $\geq$ 25 kg/m^2 but < 45 kg/m^2. The low-glycemic diet consisted of 45% of daily calories from carbohydrate, 20% from protein, and 35% from fat, and the low-fat diet was aimed at 25% from fat while keeping 20% from protein and 55% from carbohydrate. No significant difference in gestational weight gain was found by Rhodes et al. Wolff et al. (56) used a protocol that included 15-20% daily calories from protein, 30% from fat, and 50-55% from carbohydrate for obese pregnant women. Thornton et al. (53) reported setting macronutrient goals at 30% from protein, 30% from fat, and 40% from carbohydrate for pregnant obese women. Studies conducted by Wolff and Thornton were effective in reducing gestational weight gain.

Of the 6 RCTs with specific macronutrient goals, actual percentages of calories consumed from different macronutrients by pregnant overweight and obese women were assessed in 3 studies (39,49,56). Guelinkx et al. (39) found that, based on 7-day dietary records, study participants had a higher percentage of calories from protein (15-17% vs. 9-11%) and fat intake (34-38% vs. 30-35%) and a lower percentage of calories from carbohydrate intake (47-49% vs. 50-55%) than preset macronutrient goals. They also reported that their participants had 12-14% daily calories from saturated fat. In Rhode et al study (49), the average percentage of

daily calories from carbohydrate intake in the low-glycemic diet group was 48.8% as compared to the 45% goal, and the mean percentage of daily calories from fat intake was 27.9% in the low-fat diet group as compared to the 25% goal. Additionally, 9.6% and 9.1% of calories were from saturated fat consumed by women in the low-glycemic group vs. low-fat group. Pregnant women assigned to the intervention group in Wolff et al. study (56) had a lower percentage of daily calories from protein (15.1-17.5% vs.15-20%) and fat (24.2-29.7% vs. 30%) and a higher percentage from carbohydrate intake (55-58% vs. 50-55%) than the preset goals. Further, Poston et al. (45) did not set macronutrient goals but reported that their study participants had an intake of 12-13% of calories from saturated fat.

Other RCTs included general recommendations for macronutrients, such as balancing protein, fat, and carbohydrate (37,52), replacing carbohydrate rich foods with lower glycemic index foods (46), reducing fat and increasing fruits/vegetables (40,41,48), or eating protein, and reducing fat and carbohydrate (51).

Healthy eating patterns and behaviors. In addition to specified calorie and macronutrient goals, other healthy eating strategies were also found in the RCTs, such as food choices and quantities, preparation and cooking, and meal plans. Dodd et al. (37) and Szmeja et al. (52) recommended two servings of fruits, five servings of vegetables, and three servings of dairy/day. Others included meal plans (37,52), healthy recipes (37,47,52), high-fiber intake (41,51), eating three meals and three snacks a day with the last snack two hours after dinner (45), portion control (51), eating-out options (52), and checking nutrition facts and food labels (39,47).

Structured and supervised physical activity. Four studies included structured and supervised physical activity that was monitored by a trained exercise physiologist or coach. Only one of the 4 studies showed a significant effect on limiting gestational weight gain. Bisson et al.

(34) provided pregnant obese women with 36 individually supervised exercise sessions for 12 weeks and each session included 5-10 minutes of warm up, 15-30 minutes of treadmill walk, and 20 minutes of muscular work. Participants in their study self-monitored exercise intensity at 70% of heart rate or a perceived exertion score of 3-5/10. Garnæs et al. (38) guided pregnant women with a BMI $\geq$ 28 kg/m^2 to perform supervised endurance and resistance exercise three times/week from enrollment (12-18 weeks of gestation) to delivery. Endurance activities (35 minutes) included treadmill walking or jogging, and resistance training activities (25 minutes) involved large and pelvic floor muscles. Endurance training intensity was set to 80% of maximum capacity. Another supervised exercise intervention was described by Nascimento et al. (44) in which pregnant women (BMI $\geq$ 26 kg/m^2) performed individually or in group weekly light-to-moderate-intensity exercise for 40 minutes (stretch, lower and upper limb muscles) under the guidance of a physical therapist for a sequence of 22 exercises, as well as kept a heart rate $\leq$ 140. Studies by Bisson et al. (34), Garnæs et al. (38), and Nascimento et al. (44) did not find a significant effect of reducing total gestational weight gain near delivery time. Vinter et al. (55) gave pregnant obese women a 6-month free membership to a fitness center where physiotherapists provided one-hour per week training including aerobic and balance exercise and additional training using light weights and elastic bands. Their study were effective in gestational weight gain reduction, but they included a healthy eating strategy as well.

Structured but unsupervised physical activity. Seneviratne el al. (50) developed a home-based exercise intervention in which pregnant women between 20 to 35 weeks of gestation rode on a magnetic stationary bicycle for 15-30 minutes each time and for 3 to 5 sessions per week for a total of 67 sessions. The women were instructed to do a 5-minute warm-up and cool-down and were given a heart rate monitor to wear during cycling sessions and to maintain

exercise sessions at a moderate-intensity of 40-59% VO_2 reserve. Kong et al. (42) instructed pregnant overweight and obese women to walk at least 30 minutes/day for at least five days/week and walking in short bouts of at least 10 minutes (42). They provided treadmills for the women to use at home and logs to record location and duration of walking. Both studies conducted by Seneviratne (50) and Kong (42) did not find a significant effect of limiting gestational weight gain.

Unsupervised and self-help physical activity. Physical activity strategies in this category included advice and suggestions for being physically active by walking 11,000 steps/day (48); doing $\geq$ 30 minutes of moderate intensity activity most days of the week (41), three times/week (45); or 30-60 minutes/day (55). Some RCTs included broad and vague strategies, such as increasing physical activity level (36,37,46) and frequency (40).

Effects of healthy eating and/or physical activity on gestational weight gain

Overall effect. Rhodes et al. (49) found no difference in gestational weight gain between pregnant women receiving a low-glycemic diet and those on a low-fat diet. Simmons et al. (51) found that, among three intervention strategies, healthy eating was more effective than physical activity in limiting gestational weight gain (-2.6 kg), but no difference was found when comparing healthy eating with combined healthy eating and physical activity. Both RCTs were not included in the meta-analysis estimating the overall effect or in subgroup analysis because they did not have a control group receiving no healthy eating or physical activity intervention. Meta-analysis, therefore, included only 21 RCTs.

The 21 RCTs (healthy eating and/or physical activity) included a total of 3,559 women in the intervention groups and 3,361 in the control groups (Table 4). Overall, the 21 RCTs significantly resulted in an average of 1.81 kg (95% CI: -3.47 to -0.16, p = 0.03) of reduction in

gestational weight gain among pregnant overweight and obese women receiving an intervention as compared to those in the control setting without an intervention. Heterogeneity, however, was high (I^2 = 99%). Subgroup analyses were performed based on intervention types, and calorie and macronutrient goals.

Subgroup analysis on intervention type. Table 5 shows subgroup analysis results on healthy eating intervention. Four healthy eating only RCTs (44,47,53,56) demonstrated a significant reduction in gestational weight gain among women receiving the intervention as compared to women receiving no intervention (mean weight difference: -5.77 kg, 95% CI: -9.34 to -2.21, p = 0.002). Heterogeneity, however, was high (I^2 = 97%). Of the 4 healthy eating RCTs, 3 showed significant outcomes on gestational weight gain reduction (47,53,56). Quinlivan et al. (47) also included weighing pregnant women in each parental visit which was not routinely done in the country where the study was conducted and integrated their intervention in prenatal care. They found that women in the intervention group decreased carbonated drinks and juices and consumption of fast food. Thornton et al. (53) and Wolff et al. (56) included daily calories and macronutrient goals in their trials. Thornton et al (53) found that women who adhered to the nutrition protocol had lower gestational weight gain than those who had poor compliance. Women receiving healthy eating intervention conducted by Wolff et al. (56) demonstrated a significantly lower fat intake than women in the control group.

Table 6 shows subgroup analysis results of 6 physical activity RCTs (34,36,38,42,44,50). Physical activity interventions collectively did not produce a significant reduction in gestational weight gain (mean weight difference: -0.28 kg, 95% CI: -1.50 to 0.94, p = 0.65). Of these 6 RCTs, 5 adopted a structured physical activity regimen that required pregnant women to follow an exercise protocol and one used unsupervised self-help physical activity intervention. None of

the 6 RCTs showed a significant difference in gestational weight gain near delivery time between the intervention and the control groups. Of the 6 RCTs, 5 measured physical activity outcomes (34,36,38,42,50) and 2 showed no difference in physical activity among participants in the intervention group as compared to the control groups (36,38). The other 3 studies reported improving some aspects of physical activity, such as activity in bouts $\geq$ 10 minutes (34), cadence $\geq$ 80 steps/min and walking in bouts $\geq$ 8 minutes (42), and aerobic fitness (50). Adherence to exercise protocols in general was low. Bisson et al (34) reported that 20% of their study participants achieved 75% of the 36 exercise sessions. In Garnæs et al. study (38), 50% of the women achieved the exercise protocol. In Nascimento et al. study (44), 60% of the participants did 9-16 weeks of home exercise (total 22 weekly sessions). Only a third of the women in Seneviratne et al. intervention (50) completed 30 out of 67 exercise sessions.

Data in Table 7 are subgroup analysis findings on 11 RCTs that combined healthy eating and physical activity (35,37,39,40,41,45,46,48,52,54,55). Meta-analysis results showed that combined approach was significantly effective in reducing gestational weight gain (mean weight difference: -0.82 kg, 95% CI: -1.28 to -0.36, $p = 0.0005$). Of these 11 RCTs, 7 resulted in a significantly lower gestational weight gain among women who received the intervention as compared to those receiving no intervention (35,40,45,46,48,54,55). Common characteristics among these 7 successful RCTs were that they included clear goals for healthy daily macronutrients (35), daily calories (48,53,54) or physical activity (walk 11,000 steps/day, walk 30 min/day, physical activity 30-60 min/day) (45,48,54,55), and self-monitoring of eating and physical activity using food diaries, logbooks, or pedometers (35,40,46,48,54,55).

Subgroup analysis on calorie and macronutrient goals. Tables 8 and 9 show findings from subgroup analyses related to calorie (45,48,53,54,56) and macronutrient (35,39,45,53,56)

goals, respectively. Overall, healthy eating interventions with prescribed amount for daily calories (n = 5, mean weight difference: -4.28 kg, 95% CI: -7.59 to -0.97, p = 0.01) or macronutrients (n = 5, mean weight difference: -4.23 kg, 95% CI: -7.76 to -0.70, p = 0.02) were significantly effective in minimizing gestational weight gain. Heterogeneity for both subgroup analyses, however, were high ($I^2 \geq 90\%$). Of the 5 RCTs with calorie goals, 2 were healthy eating only interventions and 3 included calorie goals and unsupervised self-help physical activity. Three of the 5 RCTs with macronutrient goals included self-help physical activity (35,39,45).

Discussion

In this review, we found that 21 randomized controlled trials of healthy eating and/or physical activity limited an average of 1.81 kg of gestational weight gain among pregnant overweight and obese women receiving the intervention as compared to those receiving no intervention. This finding is in concert with those (-1.71 to -2.21 kg) found in previous reviews on pregnant overweight and obese women (26,29,30). Healthy eating intervention in our review had a larger effect size than those of physical activity alone or combined intervention in limiting gestational weight gain. This finding is aligned with 3 previous reviews even though the previous reviews were focused on women of all BMI categories (23,28,29).

A unique aspect of our review is assessing healthy eating strategies particularly related to daily calorie and macronutrient goals. We found that healthy eating strategies with daily calorie and macronutrient goals were effective in limiting gestational weight gain (-4.28 kg and -4.23 kg, respectively). It is, however, difficult to conclude what is the optimal daily calories or energy composition from different macronutrients for restricting excessive gestational weight gain because study design and calorie calculation varied across studies. Some studies used body

weight to estimate daily calories (45,53). Others adjusted calories by physical activity and gestational weeks (54,56). Renualt et al. (48) prescribed 1,200-1,675 kcal per day for pregnant obese women. This calorie range is nearly close to the 1,200-1,500 kcal/day recommended by the National Heart, Lung and Blood Institute for weight loss in adult non-pregnant women (14). Pregnant women receiving interventions were found to consume 1,624 kcal, 1641-1665 kcal, 1826-1920 kcal, and 1790-2060 kcal a day in 4 RCTs (39,46,49,56). None reported maternal and infant complications due to calorie restriction. It may seem that the calorie amount of 1,800 to 2,400 kcal/day for 19-45-years-old non-pregnant women recommended by the 2015-2020 Dietary Guidelines for Americans (11) is too high for overweight and obese women who want to restrict gestational weight gain. Hypocaloric intervention may be a prenatal weight management option for overweight and obese pregnant women. However, more research is needed to assess long-term effects on mothers and infants from limiting daily calories during pregnancy and the timing when calorie restriction is most effective and with the least amount of complications.

Several RCTs in our review set fat intake goals as 25-35% from daily calories (35,39,46,49,53,56) that was similar to the 20-35% recommended by the 2015-2020 Dietary Guidelines for Americans (11). Although the guidelines also recommend no more than 10% of daily energy from saturate fat and added sugars, only one study in our review specifically set saturated fat intake goal and that was 6% (45). Furthermore, women were found in our review to consume 9.1-9.6% (49) and 12-14% daily calories from saturated fat (39,46). For added sugars, none of the RCTs in our review included a dietary goal for added sugars. Several RCTs set calorie goals for carbohydrate intake as 40% to 55% (39,46.49,53,56) that were a little lower than the 45-65% from the 2015-2020 Dietary Guidelines for Americans (11). Some researchers raised concerns that consuming less than 118 g/day of carbohydrate may cause ketosis in

pregnant women (45). Others preferred reducing total carbohydrate by replacing high glycemic index carbohydrate with low glycemic index carbohydrate (49). Future research is needed to assess the relationship between consuming ≤ 10% daily calories from saturated fat and added sugar and excessive gestational weight gain prevention in overweight and obese women. More research is also needed to examine how calorie restriction during pregnancy alters biomedical markers such as blood sugar and insulin in overweight and obese women.

Physical activity only strategy in our meta-analysis showed a small and non-significant pooled effect size in restricting gestational weight gain (6 RCTs, -0.28 kg weight gain difference). The six physical activity RCTs in our review included five structured (34,38,42,44,50) and one self-help (36) physical activity interventions. All of them included less than 100 subjects and four studies reported low adherence to physical activity protocols (34,38,44,50). Small sample size and low compliance may have contributed to a low effect size of physical activity. Although some physical activity studies resulted in improving physical activity in pregnant overweight and obese women (34,42,50), others found barriers. Garnæs et al. (38) reported that pregnancy-related fatigue and nausea, limited previous physical activity training experience, difficulties in prioritizing time, and too comprehensive physical activity protocols were potential reasons for pregnant overweight and obese women in their RCT to have low adherence to physical activity. Other researchers found that physical activity decreased as pregnancy advanced (35,39,40). Based on our review findings, structured exercise programs with the intensity of 40-60 minutes/session and a frequency of weekly or 3-5 times per week for a total of 22-67 sessions are not effective in limiting excessive gestational weight gain. Physical activity strategies with clear goals for activity intensity and frequency, such as walking 30 minutes/day along with healthy eating strategies are more effective (45,48,54,55). Nevertheless,

further research may compare the effects of structured/supervised vs. unsupervised self-help physical activity programs on gestational weight gain restriction.

There are two limitations in this systematic review and meta-analysis. The review did not include pregnant women with under- or normal- weight and therefore strategies for gestational weight gain management found in the current review may not be applicable to these women. Only 10 RCTs provided last weight measure at delivery. Variation in total gestational weight gain among RCTs therefore is related to gestational weeks when the last body weight was assessed. Gestational weight gain in this review may not reflect the gestational weight gain for the whole pregnancy.

Conclusively, healthy eating and/or physical activity are useful strategies in limiting excessive gestational weight gain for pregnant overweight and obese women. Healthy eating is even more effective than physical activity or combined intervention. Setting both calorie and macronutrient goals may facilitate healthy eating behaviors and consequently better gestational weight management.

Conflict of Interest: All authors declare no conflict of interest.

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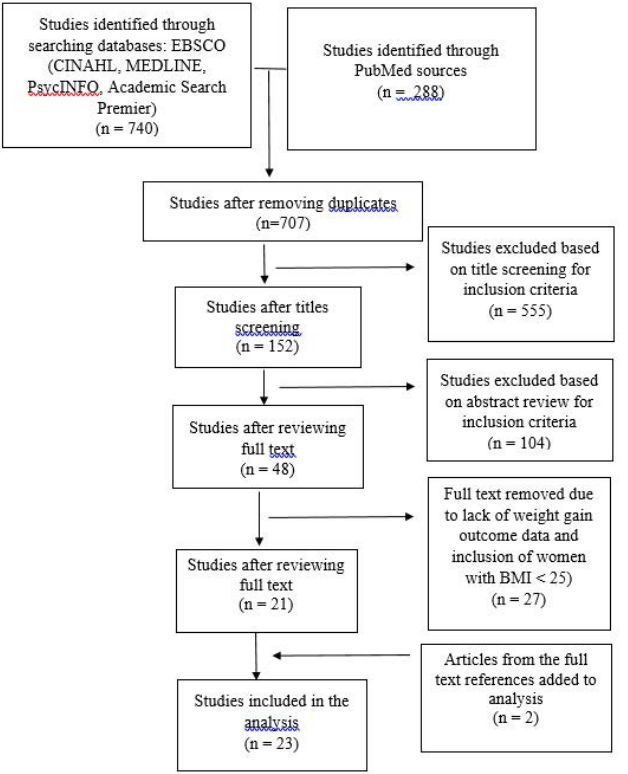


Figure 1. Deposition of Searched and Included Studies

Table 2. Reporting Quality of Randomized Clinical Trials (● Adequate ○ Inadequate X Not Clear)

Author	Allocation	Blinding	Completeness of Follow-Up	Non-Selective Reporting	No Other Bias	Overall Risk
Bisson et al., (34)	●	●	●	X	●	Moderate
Bogart et al., (35)	○	X	●	X	●	Moderate
Dekker-Nitert et al., (36)	○	X	○	○	●	High
Dodd et al., (37)	●	●	●	●	●	Low
Garnæs et al., (38)	●	●	●	●	●	Low
Guelinckx et al., (39)	X	X	X	X	●	High
Harrison et al., (40)	●	●	●	X	●	Moderate
Hawkins et al., (41)	○	X	●	●	●	Moderate
Kong et al., (42)	●	●	●	X	●	Moderate
McCarthy et al., (43)	●	○	●	X	●	Moderate
Nascimento et al., (44)	●	X	○	X	●	Moderate
Petrella et al., (45)	●	X	X	X	●	Moderate
Poston et al., (46)	●	X	●	●	●	Moderate
Quinlivan et al., (47)	●	●	○	X	●	Moderate
Renault et al., (48)	●	X	●	●	X	Moderate
Rhodes et al., (49)	○	●	●	●	o	Moderate
Seneviratne et al., (50)	●	X	●	X	●	Moderate
Simmons et al., (51)	●	●	●	●	X	Moderate
Szmija et al., (52)	○	X	○	●	●	Moderate
Thornton et al., (53)	●	X	○	X	●	Moderate
Vesco et al., (54)	○	X	●	X	●	Moderate
Vinter et al., (55)	●	X	●	X	●	Moderate
Wolff et al., (56)	●	X	●	X	●	Moderate

Table 3. Healthy Eating and Physical Activity Strategies in Randomized Controlled Trials for Overweight or Obese Pregnant Women

Authors Country	Healthy eating			Physical activity	
	Calories	Macronutrients	Healthy eating patterns & behaviors	Supervised	Unsupervised
Bisson et al. (34) Canada	• NR	• NR	• NR	• Individual, once a week • 36 sessions in 12 weeks • 60 min/session: warm up (5-10 min), treadmill walk (15-30 min), muscular work-out (5-10 min) • 70% of peak heart rate	• Encouraged to be active on non-training days
Bogarts et al. (35) Belgium	• NR	• 9-11% Protein 30-35% Fat 50-55% CHO	• Food labels	• NR	• Increasing PA level discussed
Dekker Nitert et al. (36) Australia	• NR	• NR	• Written information	• NR	• Individualized exercise plan, diaries to monitor • Monthly face-to-face exercise advice
Dodd et al. (37) Australia	• NR	• Balanced CHO, fat and protein • Reduce high fat	• Two (fruit), five (vegetables), and three (dairy) servings • Meal plan, preparation, healthy recipes, food substitutions	• NR	• Encouraged to increase walking and incidental activity.
Garnæs et al. (38) Norway	• NR	• NR	• NR	• Endurance training (35 min, 80% of max capacity; treadmill walking/jogging) • Resistance training (25 min, large and pelvic floor muscles)	• 50 min home-based exercise (35 min endurance and 15 min strength excise) $\geq$ 1/w

				• 3 times in group/week	
Guelinckx et al. (39) Belgium	• No restriction	• 9-11% Protein 30-35% Fat, 50-55% CHO • Limit energy-dense foods and saturated fatty acids	• Balanced diet • Increase low-fat dairy and whole-wheat grains • Nutrition facts labels	• NR	• Advice about exercise • How to increase PA
Harrison et al. (40) Australia	• NR	• Reduce fat,	• Pregnancy-specific dietary advice • increase fruits/vegetables	• NR	• Increase PA frequency
Hawkins et al. (41) USA	• NR	• Low saturated fat	• Low-literacy picture food guide: ethnic foods and glycemic index/fiber content and saturated fat • High fiber	• NR	• Personalized PA goals • ≥ 30 min of moderate-intensity activity on most days of the week via walking
Kong et al. (42) USA	• NR	• NR	• NR	• NR	• 150 mins/week walking spread to at least 30 min/day for at least 5 days • Short bouts of at least 10 min • Given treadmill/logs
McCarthy et al. (43) Australia	• NR	• NR	• Based on Australian Guide to healthy Eating	• NR	• NR

Nascimento et al. (44) Brazil	• NR	• NR	• Standardized nutrition counseling from Service of Nutrition and Dietetics	• Supervised 40 min exercise: light to moderate intensity (stretch, lower and upper limb muscles) • Heart beat did not exceed 140/min	• Safety of PA during pregnancy • Home exercise: 5 times/week
Petrella et al. (45) Italy	• 1500 kcal/day • Additional 300 kcal/day (overweight women) and 200 kcal/day (obese women) for PA adjustment	• 20% Protein 25% Fat 55% CHO	• Decreasing high-glycemic index substituted with healthy alternatives • Last snack two hours after dinner • Three meals and three snacks/day	• NR	• 30 min moderate intensity PA $\geq$ 3 times per week • Use “talk test” to monitor exercise intensity
Poston et al. (46) UK	• Healthy eating but not restrict energy intake	• Changing CHO-rich foods to those with a lower glycemic index	• Handbook: recommended foods and recipes	• NR	• Handbook and DVD • Increasing walking with a moderate intensity
Quinlivan et al. (47) Australia	• NR	• NR	• Reading food labels, shopping affordable foods, recipes for healthy diet	• NR	• NR
Renault et al. (48) Denmark	• 1,200-1,675 kcal/day	• Low fat diet	• Mediterranean diet recommended	• NR	• Daily step count of 11,000 (about 150% of the average steps of healthy lean pregnant women)

Rhodes et al. (49) USA	• NR	• Low-glycemic diet: 20% Protein 35% Fat 45% CHO • Low-fat diet: 20% protein, 25% fat, 55% CHO	• Low-CHO, low-glycemic index, low-fat cereals and snacks provided and arranged by study dieticians • Eat ad libitum	• NR	• NR
Seneviratne et al. (50) New Zealand	• NR	• NR	• NR	• NR	• Home-based cycling using magnetic stationary bicycle from 20 to 35 weeks of gestation • Heart rate monitor provided and worn during cycling • Moderate intensity (40-59% VO_2 reserve) • 15-30 min/session for a total of 67 sessions (3 to 5 session/week)
Simmons et al. (51) European Countries	• NR	• Eat protein, reduce fat, eat less carbohydrates	• Replace sugary drinks, eat more non-starchy vegetables, increase fibers • Watch portion size	• NR	• Be active every day, sits less, build strength, take more steps, be more active at weekends
Szmeja et al. (52) Australia	• NR	• Balance of CHO, saturated fats, fiber	• Two (fruit), five (vegetable), three (dairy) servings • Meal plans, healthy recipes, food substitutions, healthy	• NR	• DVD with information on exercise during pregnancy • The Exercise in Pregnancy book

			snacks, eating out options. • Serving sizes		• Increasing walking and incidental activity
Thornton et al. (53) USA	• 18-24 kcal/kg; ≥ 2,000 kcal/day	• 30% Protein 30% Fat 40% CHO	• Prescribed a balanced nutritional regimen	• NR	• NR
Vesco et al. (54) USA	• (Prepregnancy weight in kg x 30 Kcal/kg/day) x 0.7 + (10 Kcal x gestational age in weeks)	• NR	• DASH diet without sodium restriction	• NR	• 30 min moderate PA a day • Pedometer to record PA
Vinter et al. (55) Denmark	• Individually estimated energy requirements	• NR	• Dietary advice	• Free membership in a fitness center for 6 months (1-h/week with physiotherapists) • PA training: aerobic exercise, training with light weight and elastic bands and balanced exercise	• Moderate PA, 30-60 min/day • Pedometer
Wolff et al. (56) Denmark	• Energy intake: BMR x 1.4 (PA level factor of 1.2 + 0.2 added to cover energetic cost of fatal growth)	• 15-20% Protein 30% Fat 50-55% CHO	• Dietary supplement for vitamins and trace elements	• NR	• NR

NR: not reported; CHO: carbohydrate; PA: physical activity; BMR: Basal metabolic rate.

Table 4. Mean Difference in Gestational Weight Gain: Effect of Healthy Eating and/or Physical Activity (N = 21 studies)

	Diet and/or Exercise			Control				Mean Difference
Study or Subgroup	Mean [KG]	SD [KG]	Total	Mean [KG]	SD [KG]	Total	Weight	IV, Random, 95% CI [KG]
Bisson 2015	12.3	4	24	12.2	5.9	24	4.5%	0.10 [-2.75, 2.95]
Bogaerts 2016	10.1	6.9	134	13.5	7.3	63	4.8%	-3.40 [-5.55, -1.25]
Dekker Nitert 2015	7.87	4	19	8.28	6.1	16	4.2%	-0.41 [-3.90, 3.08]
Dodd, 2014	9.39	5.74	1080	9.44	5.77	1072	5.2%	-0.05 [-0.54, 0.44]
Garnaes, 2016	10.5	4.6	38	9.2	7	36	4.6%	1.30 [-1.41, 4.01]
Guelinkx, 2010	10.31	6.72	79	10.6	6.9	43	4.6%	-0.29 [-2.83, 2.25]
Harrison 2013	6	2.8	121	6.9	3.3	107	5.1%	-0.90 [-1.70, -0.10]
Hawkins 2014	17.73	1	32	17.87	0.59	34	5.2%	-0.14 [-0.54, 0.26]
Kong 2014	11.3	7.24	18	11.28	7.39	19	3.6%	0.02 [-4.69, 4.73]
McCarthy 2016	8.7	5.15	159	9.5	5.7	154	5.0%	-0.80 [-2.00, 0.40]
Nascimento 2011	10.3	5	39	11.5	7.4	41	4.5%	-1.20 [-3.96, 1.56]
Petrella 2014	8.8	6.5	33	10.4	5	28	4.5%	-1.60 [-4.49, 1.29]
Poston 2015	7.19	4.6	526	7.76	4.6	567	5.2%	-0.57 [-1.12, -0.02]
Quinlivan 2011	7	0.65	63	13.8	0.67	61	5.2%	-6.80 [-7.03, -6.57]
Renault 2014	10.66	7.39	272	11.53	6.36	141	5.0%	-0.87 [-2.24, 0.50]
Seneviratne 2016	12	5.3	37	13.2	5.8	37	4.6%	-1.20 [-3.73, 1.33]
Szmeja.2014	9.09	5.75	541	9.66	5.73	564	5.1%	-0.57 [-1.25, 0.11]
Thornton 2009	4.99	6.79	116	14.06	7.4	116	4.9%	-9.07 [-10.90, -7.24]
Vesco 2014	5	4.1	55	8.4	4.7	57	4.9%	-3.40 [-5.03, -1.77]
Vinter 2011	7.4	4.6	150	8.6	4.4	154	5.1%	-1.20 [-2.21, -0.19]
Wolff 2008	6.6	5.5	23	13.3	7.5	27	4.2%	-6.70 [-10.31, -3.09]
Total (95% CI)			**3559**			**3361**	**100.0%**	**-1.81 [-3.47, -0.16]**

Heterogeneity: Tau² = 13.74; Chi² = 1591.69, df = 20 (P < 0.00001); I² = 99%

Test for overall effect: Z = 2.15 (P = 0.03)

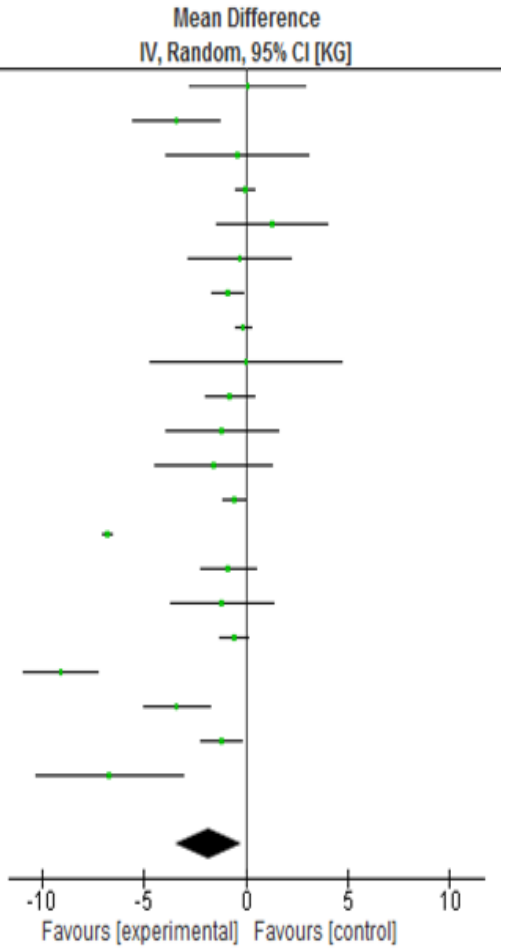


Table 5. Mean Difference in Gestational Weight Gain: Effect of Healthy Eating (N = 4 studies)

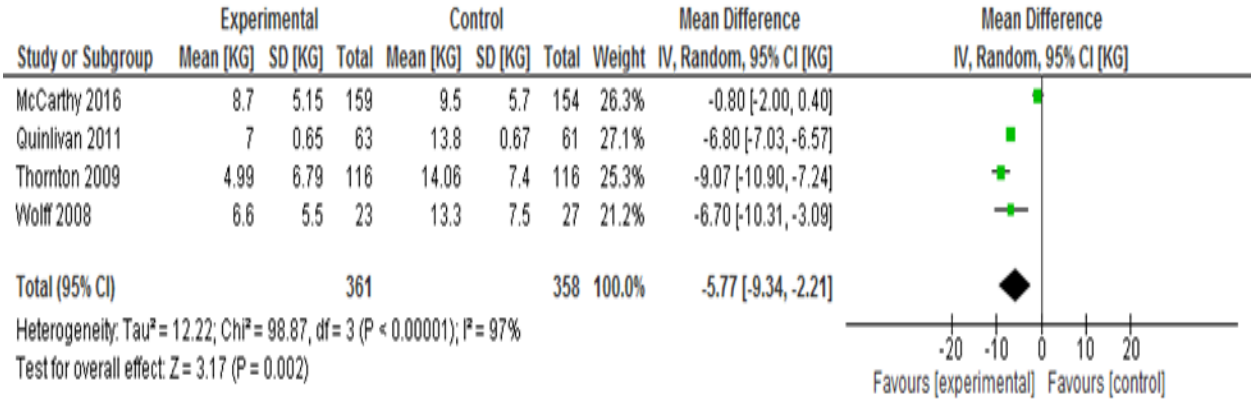
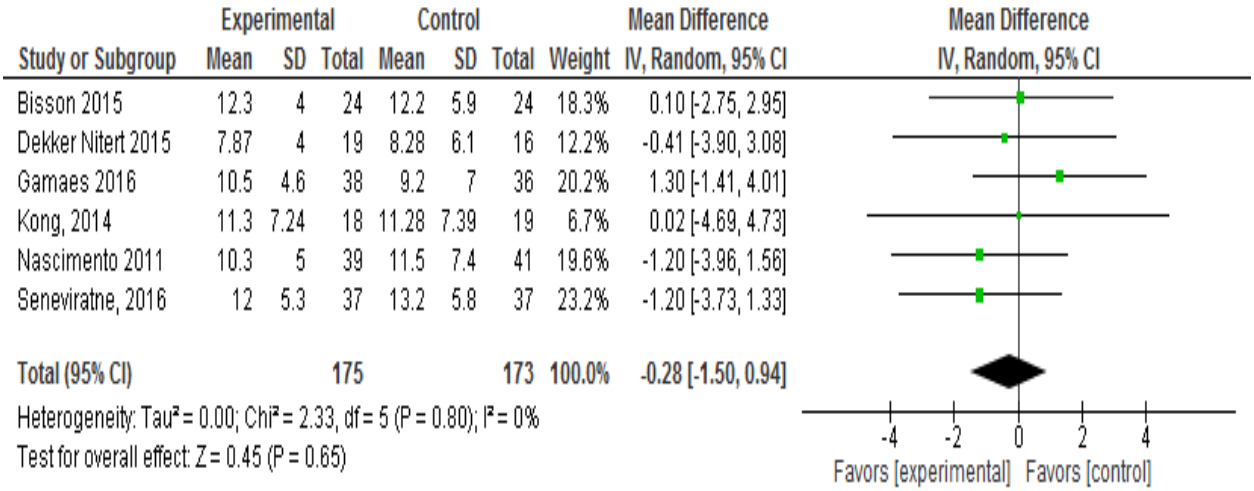


Table 6. Mean Difference in Gestational Weight Gain: Effect of Physical Activity (N = 6 studies)



Structured and supervised physical activity: Biston, Garnæs, and Nascimento
Structured but unsupervised physical activity: Kong and Seneviratne
Unsupervised and self-help physical activity: Decker-Nitert

Table 7. Mean Difference in Gestational Weight Gain: Effect of Combined Healthy Eating and Physical Activity (N = 11 studies)

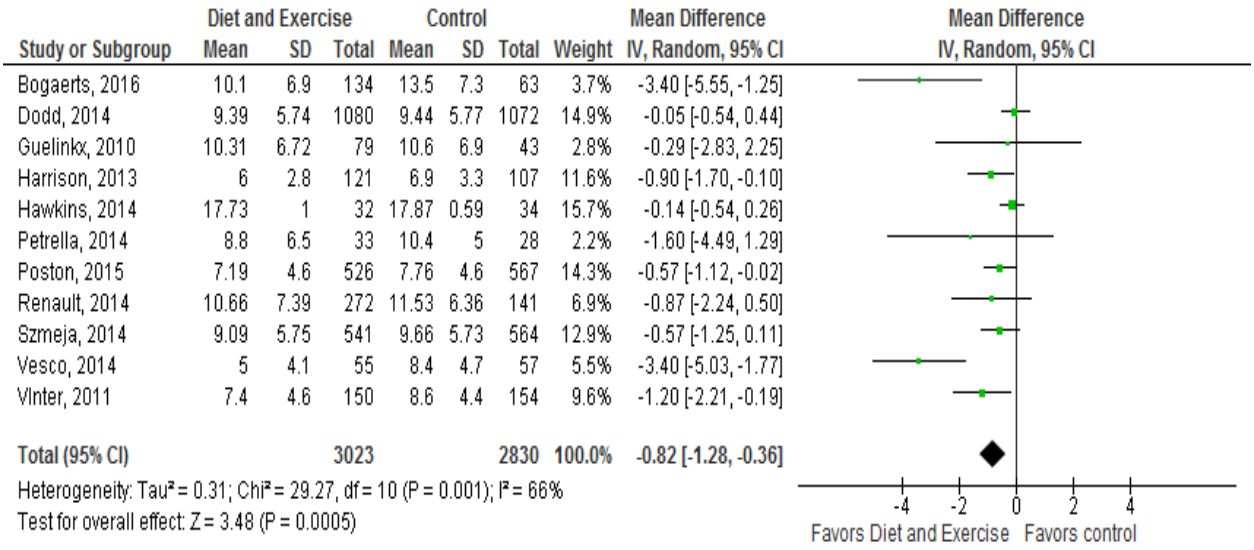
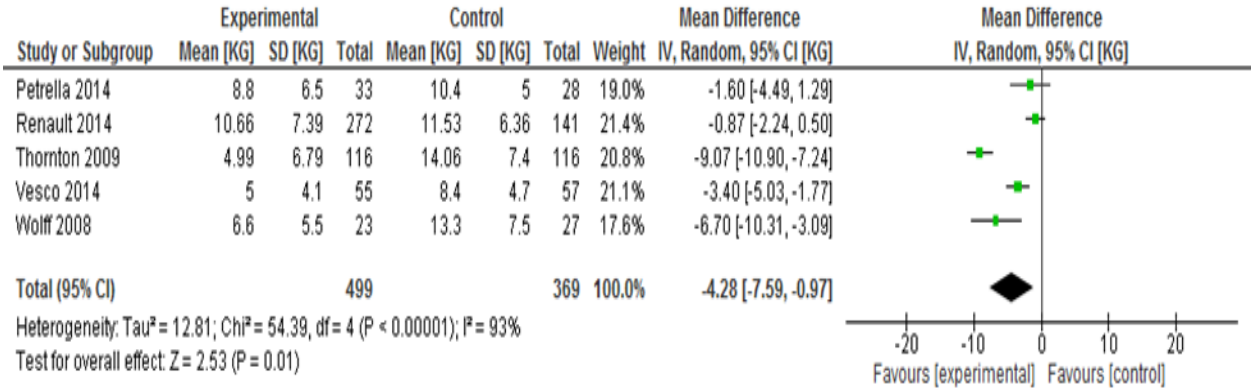
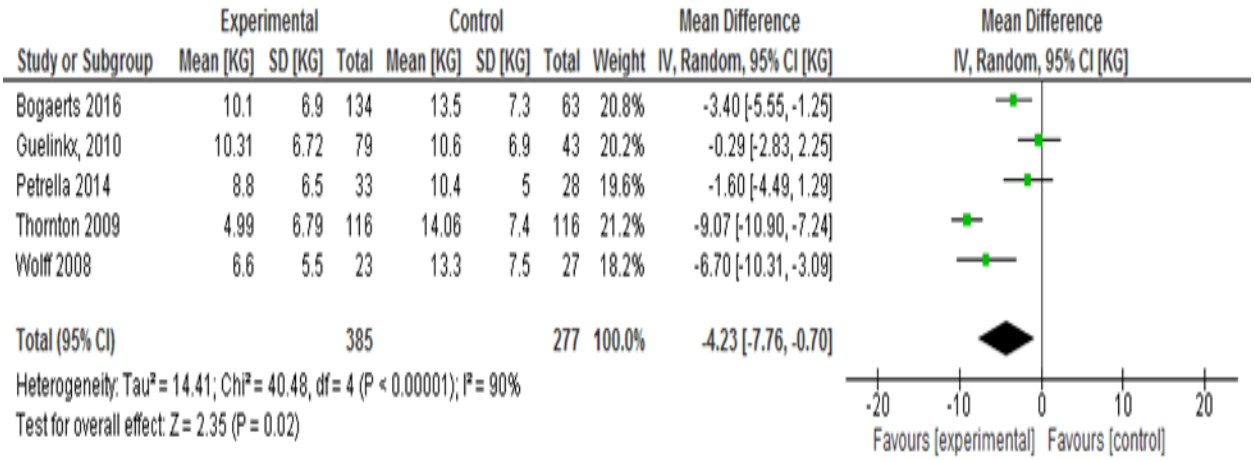


Table 8. Mean Difference in Gestational Weight Gain: Effect of Healthy Eating with Daily Calorie Goals (N = 5 studies)



Health eating intervention: Thornton and Wolff
Healthy eating and self-help physical activity intervention: Petrella, Renault, and Vesco

Table 9. Mean Difference in Gestational Weight Gain: Effect of Healthy Eating with Macronutrient Goals (N = 5 studies)



Health eating intervention: Thornton and Wolff
Healthy eating and self-help physical activity intervention: Bogaerts, Guelinkx, and Petrella