Nutrition and Exercise Strategies to Prevent Excessive Pregnancy Weight Gain: A Meta-analysis

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Abstract

Objective To evaluate nutrition-only, exercise-only, and nutrition-plus-exercise interventions for optimizing gestational weight gain (GWG) based on the 2009 Institute of Medicine (IOM) guidelines.

Study PubMed, Google Scholar, and 2015 Cochrane Review were searched. Analysis of variance was used to determine if significant GWG differences exist between strategies, with additional subanalyses on overweight (OV) or obese women based on 2009 IOM guidelines.

Results Of 66 identified studies, 31 contributed data (n = 8,558). Compared with routine prenatal care, nutrition-only interventions were significantly associated with reduced GWG and are most likely to produce weight gain within IOM recommendations (p = 0.013). Exercise-only (p = 0.069) and nutrition-plus-exercise (p = 0.056) interventions trended toward GWG within IOM guidelines, but did not reach statistical significance. Supervised (p = 0.61) and unsupervised (p = 0.494) exercise programs had similar effectiveness. Subanalyses on OV or obese women produced similar results to studies that did not differentiate results based on body mass index: nutrition only (p = 0.011), exercise only (p = 0.308), and nutrition plus exercise (p = 0.129).

Conclusion Preventing excessive GWG is crucial, especially for OV or obese women. In the current study, nutrition-based intervention is the health system strategy that showed significant impact on preventing excessive GWG compared with routine prenatal care. Among women who are OV or have obesity, nutrition-only interventions hold the most promise compared with routine prenatal care.

Keywords ► nutrition intervention ► exercise intervention ► pregnancy ► weight gain ► obesity

More women are entering pregnancy as overweight (OV) or having obesity (OB) than in the past, and many are gaining excessive weight during pregnancy. During 2011 to 2014, 34.4% of the U.S. women of childbearing age (aged 20–39 years) are OV or have OB.1 For women who gave birth in 2016, 21% aged 18 to 24 years, 23% aged 25 to 34 years, and 24% aged 35 to 44 years had OB.2 Weight gain exceeding the Institute of Medicine (IOM) recommendations, known as excessive gestational weight gain (GWG), increases the burden of chronic disease and can put the mother and her infant’s health at risk.

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These burdens include, but are not limited to, gestational hypertension, preeclampsia, gestational diabetes, cesarean section delivery, and preterm birth. Additionally, children of mothers who gain more weight during pregnancy are at higher risk of being OV in early childhood.

Based on the 2009 IOM guidelines, the recommended amount of GWG for underweight women (body mass index [BMI] <18.5 kg/m²) is 12.5 to 18 kg (28–40 lb), normal weight (NW) women (BMI 18.5–24.9 kg/m²) is 11.5 to 16 kg (25–35 lb), OV women (BMI 25.0–29.9 kg/m²) is 7 to 11.5 kg (15–25 lb), and women who have OB (BMI >30.0 kg/m²) is 5 to 9 kg (11–20 lb). Previous studies have addressed the ability to control GWG and prevent weight exceeding IOM recommendations where all forms of interventions were considered statistically significant: nutrition only, nutrition plus exercise, nutrition plus exercise for OV/OB women, exercise only, exercise only for OV/OB women, The study expands on the 2015 Cochrane Review (Muktahnt et al. [2015]) assessment of methods involving nutrition, exercise, and combination of nutrition-plusexercise intervention studies to prevent excessive pregnancy weight gain based on studies published after the 2009 IOM guidelines. The Cochrane Review found that whether women participated in nutrition, exercise, or both interventions, their risk of excessive GWG was reduced by an average of 20% and women of intervention groups were more likely to experience low GWG than those in control groups. The Cochrane Review and other previous reviews included studies prior to 2009, which could not have used the updated IOM guidelines. A review of interventions that only includes studies published after 2009 is necessary. This meta-analysis exclusively uses studies published after updated IOM guidelines were available. The objective of this study is to quantitatively assess the effect of three health system strategies on GWG: nutrition only, exercise only, and combination of nutrition plus-exercise interventions.

**Methods**

PubMed and Google Scholar databases were searched weekly from September 20, 2016, through October 29, 2016. All studies included in 2015 Cochrane Review were examined.

Initial key terms searched produced 5,528,591 results. Key terms include “pregnancy,” “body mass index (BMI),” “nutrition,” “exercise,” “counseling,” “obesity,” “overweight,” or “intervention.” Limiting publish dates from 2009 to 2016 produced 1,199,520 results. Studies published before 2009 were assumed to not have used the 2009 IOM recommendations for GWG, and therefore, ineligible for this meta-analysis. “Gestational weight gain” filters narrowed results to 14,827. All studies were assessed: 12,363 excluded based on irrelevant title; 2,398 excluded based on irrelevant abstract. Full articles for the remaining 66 studies were obtained. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was used for search and reporting of studies. Search was performed by primary author (K.A.C.). Not all aspects of PRISMA were addressed, including risk of bias across studies, due to single person data collection.

Reasons for exclusion include: mean GWG not reported, study published before 2009, and study in trial state. Inclusion criteria: randomized controlled parallel or cross-sectional study; at least 20 singleton pregnant women; women aged 18 years or older; control group with standard obstetric care; report means of GWG based on baseline BMI or pre-pregnancy BMI; and use 2009 IOM guidelines for GWG. For studies that did not use the 2009 IOM guidelines, additional analysis was made based on the reported mean GWG.

Data were collected for total GWG in kilogram based on the BMI (kg/m²) of women prior to pregnancy, age at the beginning of gestation, and pre-pregnancy BMI. Statistical analysis was done using Excel Version 2016 (Microsoft, Santa Rosa, CA, United States) and online Vassar Stats application. Due to strong evidence of heterogeneity between studies, using the random effect approach, we addressed the source of this heterogeneity using subgroup analyses. Analysis of variance (ANOVA) was performed using Vassar Stats to compare effect of intervention and control groups within each study and relative effectiveness of health system strategies. The summary measure in this meta-analysis was the standardized mean difference, defined as the ratio of the difference in mean outcome between the groups and the standard deviation of the outcome among participants. Additional analysis on supervised versus unsupervised exercise was completed. Furthermore, we provided the average GWG means for interventions and subgroups, mean differences, and 95% confidence intervals in the results section.

**Results**

**Study Search**

Using the search terms, 66 results were identified. Thirty-five were excluded for not meeting criteria. Thirty-one involving 8,558 participants met criteria and contributed data to these analyses. Of these 31 studies, 6 were nutrition only; 31–36 22 were nutrition plus exercise; 37–55 and 11 were exercise only. Four were used twice because data of participants with NW, OV, and having OB were analyzed separately. Two were used twice because they reported data of different interventions within studies. One included interventions based on exercise only and nutrition plus exercise. One included interventions based on low intensity (LI) and moderate intensity (MI) exercise. Results for all interventions reported separately were treated as separate studies. After separation of data, the 31 studies are analyzed as 39 studies.

**Participants**

These 39 studies involved 8,558 pregnant participants. Each study included 23 to 1,108 participants. No statistically significant differences in maternal age were reported. All studies required participants to be >18 years old and have singleton pregnancies. Studies recruited up to 26 weeks of gestation. Two recruited at the first prenatal visit. One recruited at the 12th week of clinic. One recruited at 6 to 36 weeks of gestation, and one recruited at the 21st week of gestation.
16 weeks. One required 7 to 21 weeks. One recruited at eight to nine weeks. Two required 8 to 12 weeks. One required 10 to 14 weeks. One required 10 to 18 weeks. One required 10 to 20 weeks. Two required <12 weeks. One required <13 weeks. One required 14 to 24 weeks. Two required <15 weeks. One required 15 to 18 weeks. Two required <16 weeks. One required 16 to 20 weeks. Two required <18 weeks. One required <20 weeks. One required <24 weeks. One required <26 weeks. Three studies did not report the gestational age requirement for participants.

Weight categories included NW (BMI 18.5–24.9 kg/m²), OV (BMI 25.0–29.9 kg/m²), and women with OB (BMI >30.0). Seventeen studies selected from general population without BMI specifications. Three selected for OV participants. Three selected for participants who are OV or have OB. Eight selected for participants who have OB. No significant differences in pre-pregnancy BMI.
Additional inclusion criteria include: nulliparous participants; secundigravida women previously given birth to macrosomic newborn; women expecting second pregnancy; healthy Caucasian mothers; no structured exercise program (>60 minutes once per week); 6 months before trial; sedentary (exercising for <20 minutes on <3 days/week) before study; not have engaged <3, 30-minute exercise per week for 6 months preceding enrollment; non-diabetic; have at least one of the following risk factors: BMI >25 kg/m²; gestational diabetes mellitus or any signs of glucose intolerance or newborn's macrosomia (>4,500 g) in early pregnancy; type 1 or 2 diabetes in first- or second-degree relatives; aged >40 years.

**Setting**

Based on World Bank classifications from 2017 economy, 28 studies occurred in high-income countries. Three studies occurred in upper-middle-income countries. No studies occurred in low-income countries.

Eleven studies specified treatment locations: university hospitals; regular hospitals; eight multiethnic hospitals; obstetric clinic; and six primary care maternity health clinics. All other studies did not specify treatment locations.

**Intervention Implementation**

Of the six nutrition-only studies, three focused on low glycemic index (LGI) foods. All studies used a food diary to document past eating habits for nutrition plans and to detail food consumption during the trial. Three provided individual nutrition plans. One provided focused nutritional advice based on the macronutrient composition of the participant’s diet. Three provided participants with lists of healthy foods based on local affordability or LGI foods. Three provided education in group settings. General advice on nutrition, such as a pamphlet, is standard prenatal care and was not considered a nutrition-only intervention.

Of the seven exercise-only studies, four were supervised and three were unsupervised. Two studies included three supervised sessions per week; one required participants to attend at least two sessions per week, and one had one session per week. Three supervised studies also had unsupervised exercise to be completed outside of the supervised sessions. Types of exercise differed based on the study. One advised exercise based on an expenditure goal of 900 kcal/wk by means of a walking protocol that took place in five stages of VO2 measured for oxygen cost. A heart rate monitor was provided to track exercise. One was based on a dance class and core exercises. Two included aerobic and strength exercises. One also included stretching. One included aerobic, resistance, and core exercises. One utilized pedometers and one provided treadmills. One registered daily steps on 7 consecutive days every 4 weeks and reminded participants of the recording period starting via text message.

Of the 19 nutrition-plus-exercise studies, 5 included group sessions and 14 provided one-on-one advice. Thirteen were unsupervised and six were supervised. Of the unsupervised interventions, three included DVD instructional videos for home exercise. Additional implementations included: weight goal setting by the mother, extra-support for individuals not within IOM recommendations in which exercise and nutritional recommendations were revised, among reading food labels and shopping methods, used Food Choice Map software, free fitness membership, heart rate monitors, and calories calculated based on Dietary Approaches to Stop Hypertension (DASH) dietary pattern and reduced by 30% for participants without OB. In addition to meeting the 2009 IOM recommendations, one study had the goal to keep weight within 3% of their weight at randomization.

**Effects of Interventions**

Among the total obstetric population studied, results of studies published after the 2009 IOM guidelines indicate that the nutrition-only intervention produced significant GWG differences between mean intervention and mean control groups 

- **Fig. 2** provides an overview of the study design and characteristics of included studies.

- **Table 1** depicts upper and lower 95% confidence intervals for each study based on population (N) and standard deviation (SD). **Fig. 3** depicts the forest plot. Not all studies reported number of participants at, above, or below IOM recommendations, so odds ratio, risk ratio, or weight could not be calculated.

- Eight studies categorized based on pre-pregnancy BMI and analyzed whether mean GWG, as adjusted for BMI, fell below, within, or above IOM recommendations. Three of 8 (37.5%) exercise-only, 3 of 6 (50%) nutrition-only, and 15 of 22 (68.18%) nutrition-plus-exercise interventions were within the IOM GWG recommendations. Compared with control groups within IOM, 3 of 8 (37.5%) exercise-only, 1 of 8 (12.5%) nutrition-only, and 6 of 22 (27.27%) nutrition-plus-exercise interventions produced GWG within IOM recommendation. For one of the nutrition-plus-exercise studies, the control GWG fell below the IOM recommendation. Of the studies that reported percentage of participants exceeding IOM, 2 of 2 (100%) nutrition only, 9 of 13 (69.23%) nutrition plus exercise, and 4 of 6 (66.67%) exercise only
reported that women in the intervention group exceeded the IOM recommendations less than control group. One exercise-only study on mothers with OB reported the same percentage exceeding IOM for intervention and control groups\(^{59}\) (Table 4).

Participants Who Are Overweight and/or Have Obesity
Additional analysis was completed on studies that selected for participants who are OV or have OB (Table 2). When examined individually, 2 of 2 nutrition only (100%), 7 of 10

### Althuizen et al. 2013

| Methods | RCT, February 2005-May 2006  
| Location: Netherlands |
| Participants | 219 randomized participants  
| Inclusion criteria: expecting first child; able to read, write and speak Dutch; within 14 weeks gestation  
| Exclusion criteria: NR |
| Intervention | Intervention: (n= 106) five face to face counseling sessions about how to control weight gain during and after pregnancy, diet, and exercise.  
| Control: (n= 113) |
| Results | Intervention group GWG: 11.6 kg  
| Control group GWG: 11.1 kg  
| p-value: NR (stated as insignificant) |

### Asbee et al. 2009

| Methods | RCT, Oct 2005-April 2007  
| Location: Resident Obstetrics Clinic, Charlotte, North Carolina |
| Participants | 100 randomized participants  
| Inclusion criteria: 6–16 weeks gestation; 18–49 years, prenatal care at Resident Obstetrics Clinic; English-speaking, Spanish-speaking, or both; singleton pregnancy  
| Exclusion criteria: >16 weeks gestation; non–English or non–Spanish-speaking; multiple pregnancy; BMI >40; preexisting diabetes; untreated thyroid disease, or hypertension requiring medication; medical conditions that might affect body weight; delivery at institution other than Carolinas Medical Center-Main; premature delivery (<37 weeks); limited prenatal care (<4 visits) |
| Intervention | Intervention: (n= 57) Recommendations for a patient-focused caloric value divided into 40% carbohydrate, 30% protein, and 30% fat fashion. Instructed to engage in moderate-intensity exercise ≥3 times per week and preferably 5 times per week. Received information on appropriate weight gain during pregnancy using the IOM guidelines. Each participant met with the dietician only at the time of enrollment. If weight gain not within the IOM guidelines, participant’s diet and exercise regimen was reviewed and changed.  
| Control: (n= 43) |
| Results | Intervention group GWG: 13.0 ± 5.7 kg  
| Control group GWG: 16.2 ± 7.0 kg  
| p-value: <0.01 |

**Fig. 2** Characteristics of included studies.
### Aşçı et al. 2016

| Methods | RCT  
| Location: Istanbul, Turkey |
| Participants | 102 randomized participants  
| Inclusion criteria: ≤12 weeks gestation; ≥18 years; gravidity ≤2; no health problems; did not intend to lose weight in pre-pregnancy; got pregnant in natural ways for 2 times at most  
| Exclusion criteria: NR |
| Intervention | Intervention: (n= 45) nutritional data on a 3-day log and healthy lifestyle behaviors measured using Profile-II with 6 subscales. Four meetings on healthy lifestyle, nutrition, exercise, and weight follow-up, given weight card. Women reaching their objectives were praised and encouraged. Women not meeting objectives were reviewed and regimens intensified. Low-level aerobic exercises recommended for pregnancy were shown and performed, recommended to do mild-moderate safe exercise types to increase heart rate to maximum 140 beats/min for 30 min every other day.  
| Control: (n= 45) |
| Results | Intervention group GWG: 12.5 ± 5.0 kg  
| Control group GWG: 12.3 ± 4.8 kg  
| p-value: 0.001 |

### Bogaerts et al. 2012

| Methods | RCT  
| Location: Flanders, Belgium |
| Participants | 205 randomized participants  
| Inclusion criteria: BMI >29; singleton  
| Exclusion criteria: moved out of region; >15 weeks gestation; pre-existing type 1 diabetes; multiple pregnancy, primary need for nutritional advice, insufficient knowledge of the Dutch language |
| Intervention | Intervention 1: (n= 58) purpose-designed brochure on nutritional advice and physical activity during pregnancy with information on how to limit excessive GWG.  
| Control: (n= 63) |
| Intervention 2: (n= 76) four small group information sessions of 2-3 women with midwife. 7-day food log with recommendations based on National Dietary Recommendations of 50–55% carbohydrate intake, 30–35% fat intake and 9–11% protein energy intake. Exercises in reading food labels and shopping methods. Discussed methods to increase exercise. Motivational interviewing. |

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**Fig. 2 (Continued)**
**Results**

- Intervention group 1 GWG: 9.5 ± 6.8 kg
- Intervention group 2 GWG: 10.6 ± 7.0 kg
- Control group GWG: 13.5 ± 7.3 kg
- p-value I1 vs C: 0.04
- p-value I1 vs C: 0.008

**Byrne et al. 2011**

**Methods**

RCT
Location: Royal Brisbane and Women's Hospital, Queensland, Australia

**Participants**

50 randomized participants
Inclusion criteria: 18–45 years; BMI ≥30; pregnancy care at the Royal Brisbane and Women’s Hospital; willing and able to do exercise intervention; able to provide informed consent
Exclusion criteria: non-English speaking; contradiction or inability to exercise; medical or obstetric contraindication to exercise; multiple gestation; severe anemia, chronic bronchitis; type 1 diabetes, orthopedic limitations; poorly controlled seizure disorder; poorly controlled hyperthyroidism; or heavy smoker

**Intervention**

- Intervention: (n= 12) whole group information session on general advice on exercise, diet based on the Australian Guide to Healthy Eating and weight gain based on IOM recommendations. Individual one-on-one session with midwife. Advised exercise energy expenditure goal of 900 kcal/week via walking protocol in 5 stages of speed with VO2 measure for oxygen cost. Provided with heart rate monitor to track work.
- Control: (n= 11)

**Results**

- Intervention group GWG: 10.8 ± 5.1 kg
- Control group GWG: 11.8 ± 5.9 kg
- p-value: NR (stated as insignificant)

**Di Carlo et al. 2014**

**Methods**

Retrospective, controlled study, January 2010-January 2011
Location: Italy

**Participants**

154 randomized participants
Inclusion criteria: NR
Exclusion criteria: significant maternal condition (excluding hypertension and thyroid diseases); multiple pregnancy; BMI ≤20 and ≥40 gestational diabetes; miscarriage or preterm delivery

**Intervention**

- Intervention: (n= 77) interviewed about diet, given personalized diet plan based on food frequency questionnaire (FFQ)
- Control: (n= 77)
### Results

- **Intervention group GWG:** 8.2 ± 4.0 kg
- **Control group GWG:** 13.4 ± 4.2 kg
- **p-value:** <0.001

### Garnæs et al. 2016

#### Methods
- **RCT**
- **Location:** Norwegian University of Science and Technology (NTNU) and St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway

#### Participants
- 91 randomized participants
- Inclusion criteria: BMI ≥28 kg/m², ≥18 years, <18 gestation, singleton live fetus at 11–14 week ultrasound scan; able to come to St. Olavs Hospital for assessments and exercise classes
- Exclusion criteria: high risk for preterm labor; diseases that could interfere with participation; habitual exercise training (twice or more weekly) before inclusion

#### Intervention
- Intervention: (n= 46) exercise program with supervised sessions 3 times per week and self-regulated at home once per week of 35 min moderate intensity endurance exercise and 25 min of strength training
- Control: (n= 45)

#### Results
- **Intervention group GWG:** 10.5 kg
- **Control group GWG:** 9.2 kg
- **p-value:** 0.35

### Haaksted et al. 2011

#### Methods
- **Parallel study**
- **Location:** Oslo, Norway

#### Participants
- 105 randomized participants
- Inclusion criteria: Nulliparous; pre-pregnancy exercise levels did not include participation in structured exercise program (>60 min once per week), with brisk walking (>120 min per week) for six months; able to read, understand and speak Norwegian; <24 weeks gestation
- Exclusion criteria: history of >2 miscarriages; severe heart disease (including symptoms of angina, myocardial infarction or arrhythmias); persistent bleeding after 12 weeks gestation; multiple pregnancy; poorly controlled thyroid disease; pregnancy-induced hypertension or pre-eclampsia; unable to attend weekly exercise classes
Nutrition and Exercise Strategies to Prevent Excessive GWG

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**Nutrition and Exercise Strategies to Prevent Excessive GWG**

**Fig. 2** (Continued)

| **Intervention** | Intervention: (n= 52) supervised sessions of aerobic dance exercises for 60 minutes with 35 minutes of dance and 15 minutes of core exercises, at least 2 times per week, for a minimum of 12 weeks. Asked to exercise 30 minutes/day outside of classes. Control: (n= 5) |
| **Results** | Intervention group GWG: 13.0 ± 4.0 kg  
  Control group GWG: 13.8 kg ± 4.0  
  p-value: 0.31 |

**Horan et al. 2016**

| **Methods** | RCT  
  Location: National Maternity Hospital, Ireland |
| **Participants** | 800 randomized participants  
  Inclusion criteria: secundigravida women previously given birth to macrosomic baby; sufficient literacy and English language fluency to understand the intervention and can complete questionnaires; healthy; singleton; no intrauterine growth abnormalities  
  Exclusion criteria: NR |
| **Intervention** | Intervention: (n= 138) received low glycemic index (GI) dietary advice based on 3-day food diary per trimester.  
  Control: (n= 142) |
| **Results** | Intervention group GWG: 13.3 ± 4.48 kg  
  Control group GWG: 13.7 ± 4.93 kg  
  p-value: 0.52 |

**Huang et al. 2011**

| **Methods** | 3-arm RCT, January-June 2006  
  Location: Norther Taiwan |
| **Participants** | 189 randomized participants  
  Inclusion criteria: ≥18 years; no cognitive impairment or psychiatric illness; ability to speak and read Chinese; not participating in another study; intention to give birth at the study site  
  Exclusion criteria: NR |

Fig. 2 (Continued)
**Nutrition and Exercise Strategies to Prevent Excessive GWG**

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### Intervention

- **Intervention:** (n= 61) personalized diet and exercise plan with 6 one-to-one counselling sessions of one primary session (about 30–40 minutes) at 16-week gestation visit, and five one-to-one booster sessions (28 gestational weeks, 36–38 gestational weeks, before hospital discharge after three–seven-day stay, six weeks post-partum and three months post-partum). Given chart of weight changes after each visit.
- **Control:** (n= 64)

### Results

- **Intervention group GWG:** 14.0 ± 2.4 kg
- **Control group GWG:** 16.2 ± 3.3 k
- **p-value:** <0.001

**Hui et al. 2011**

- **Methods:** RCT
- **Location:** Winnipeg

- **Participants:** 190 randomized participants
- **Inclusion criteria:** nondiabetic; <26 weeks gestation; living in Winnipeg
- **Exclusion criteria:** medical or obstetric contradictions to exercise; having diabetes

- **Intervention:** (n= 102) community-based group exercise sessions. Instructed exercise or mild-to-moderate exercise for 30–45 minutes/session at 3-5 times/week. Provided 1 group session/week and the rest at home with video. Dietary counselling 2 times using Food Choice Map.
- **Control:** (n= 88)

- **Results:**
  - **Intervention group GWG:** 14.1 ± 6.0 kg
  - **Control group GWG:** 15.2 ± 5.9 kg
  - **p-value:** 0.28

**Hui et al. 2014**

- **Methods:** RCT, May 2009-December 2011
- **Location:** Winnipeg, Manitoba

- **Participants:** 57 randomized participants
- **Inclusion criteria:** <20 weeks gestation; no existing diabetes during pregnancy; signed consent form
- **Exclusion criteria:** <3 times at group exercise; showed no interest to exercise at home; no record of exercise in logbook

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**Fig. 2 (Continued)**
| **Intervention** | Intervention: (n= 30) weekly community exercise program or unsupervised DVD at home. Mild-to-moderate aerobic exercise, stretching, and strength, encouraged to exercise for 3-5 times a week, 30-45 minutes/time. One-on-one private dietary consultation at baseline and at 2 months after using a Food Choice Map (FCM) software. Sticker board food log with portion sizes and frequency. Nutritional recommendation based on calorie intake and macronutrient analysis. Weight goal. Control: (n= 27) |
| **Results** | Intervention group GWG: 12.9 ± 3.7 kg Control group GWG: 16.2 ± 4.4 kg p-value: < 0.05 |

**Kong et al. 2014**

| **Methods** | RCT Location: Iowa State University, Des Moines, Iowa |
| **Participants** | 37 randomized participants Inclusion criteria: age 18-45 years; singleton; nonsmoker; self-reported BMI 26.0–29.9 kg/m2 or ≥30.0 kg/m2; no history of chronic diseases; no history of gestational diabetes; engaged in less than 3, 30-min bouts of leisure physical activity for 6 months preceding enrollment Exclusion criteria: NR |
| **Intervention** | Intervention: (n= 9 overweight; n= 9 obese) unsupervised walking program. Verbally given 2009 U.S. physical activity guidelines. Provided treadmills and asked to walk for 50 min (week 1), 100 minutes (week 2), 30 min most days of the week (week 3 to end) for an overall total of at least 150 minutes of weekly moderate physical activity Control: (n= 9 overweight; n= 10 obese) |
| **Results** | Intervention groups GWG: OV: 10.5 ± 5.4 kg OB: 12.1 ± 9.0 kg Control groups GWG: OV: 9.9 ± 6.1 kg OB: 12.5 ± 8.5 kg p-value: 0.859 |

**Korpi-Hyövärvi et al. 2011**

| **Methods** | RCT, April 2005 - May 2006 Location: Finland |

*Fig. 2 (Continued)*
### Participants

54 randomized participants
Inclusion criteria: ≥1 risk factors: BMI >25 kg/m², previous history of GDM or birth of child >4.5 kg, age >40 years, family history of diabetes, or the venous plasma glucose concentration after 12 hours fasting in the morning was 4.8-5.5 mmol/l and 2-hour OGTT plasma glucose <7.8 mmol/l
Exclusion criteria: NR

### Intervention

**Intervention:** (n= 27) women educated on how to eat based on Diabetes and Nutrition Study Group (DNSG) of European Association for the Study of Diabetes. Energy intake suggested 30 kcal/kg/day for normal weight women and 25 kcal/kg/day for overweight women. Given specific dietary advice 6 times by physiotherapist. Goal of exercise intervention was 30 minutes of daily physical activity for woman who previously exercised <2.5 hours per week, and 45 minutes if the woman already engaged in 2.5 hours or more per week of physical activity.

**Control:** (n= 27)

### Results

**Intervention group GWG:** 11.4 kg ± 6.0
**Control group GWG:** 13.9 kg ± 5.1
p-value: 0.062

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### Luo et al. 2014

**Methods**
Cross-sectional study, June 2010-Dec 2011
Location: Obstetrics and Gynecology Department of the Second Affiliate Hospital of the ChongQing University of Medical Sciences, Chongqing, China

**Participants**
276 randomized participants
Inclusion criteria: <13 weeks gestation; non-smoking; >18 years
Exclusion criteria: previous history of GDM or other concomitant disease

**Intervention**
(Intervention: (n= 131) individualized nutrition plan regarding the recommended macronutrient composition of their diet.
Control: (n= 145)

**Results**
**Intervention group GWG:** 7.6 ± 1.6 kg
**Control group GWG:** 12.6 ± 4.6 kg
p-value: <0.001

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### Luoto et al. 2011

**Methods**
Cluster RCT
Location: Finland
### Participants

399 randomized participants  
Inclusion criteria: ≥1 risk factors: body mass index (BMI) >25 kg/m² based on measured height and self-reported pre-pregnancy weight; GDM or any signs of glucose intolerance or newborn’s macrosomia in any earlier pregnancy; type 1 or 2 diabetes in first- or second-degree relatives; or age >40 years old  
Exclusion criteria: ≥1 of the three baseline (8–12 week gestation) oral glucose tolerance test abnormal measurements (fasting blood glucose >5.3 mmol/l, >10.0 mmol/l at 1 h, and >8.6 mmol/l at 2 h); prepregnant type 1 or 2 diabetes; inability to speak Finnish; <18 years old; multiple pregnancy; physical restriction preventing physical activity; substance abuse; treatment or clinical history for psychiatric illness

### Intervention

Intervention: (n= 219) individual intensified counseling on physical activity to increase amount of physical activity and diet and weight gain at five antenatal visits. Goal diet of <10% saturated fat, 5%–10% polyunsaturated fat, 25%–30% total fat, and 10% saccharide of total energy intake, and 25–35 g/d fiber. Participants made individual goals.  
Control: (n= 180)

### Results

- Intervention group GWG: 13.8 ± 5.8 kg  
- Control group GWG: 14.2 ± 5.1 kg  
- p-value: 0.52

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### McGowan et al. 2013

**Methods**  
RCT  
Location: Dublin, Ireland

**Participants**  
800 randomized participants  
Inclusion criteria: ≥18 years, singleton; 10–18 weeks gestation; adequate English to enable study participation  
Exclusion criteria: previous or current gestational diabetes (GDM); taking medication for a known medical condition; multiple pregnancy

**Intervention**  
Intervention: (n= 235) 1–2 hours GI-dietary education session in groups 2–6 with dietitian for at least 2 weeks based on Irish Nutrition and Dietetic Institute; not given specific information on their individual energy requirements or GWG goal for pregnancy; given list of foods that were high and low in GI; compliance questionnaire; 3-day food diary  
Control: (n= 285)

**Results**  
- Intervention group GWG: 11.5 ± 4.2 kg  
- Control group GWG: 12.6 ± 4.4 kg  
- p-value: 0.003

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*Fig. 2 (Continued)*
### Mustila et al. 2012

| Methods | RCT  
| Location: Tampere and Hämeenlinna, Finland |
| Participants | 72 randomized participants  
Inclusion criteria: no previous deliveries  
Exclusion criteria: <18 years, type 1 or type 2 diabetes mellitus (gestational diabetes mellitus excluded); twin pregnancy; physical disability preventing exercising; otherwise problematic pregnancy (determined by a physician); substance abuse, treatment or clinical history for any psychiatric illness; inadequate language skills in Finnish; intention to change residence within three months |
| Intervention | Intervention: (n= 35) individual counseling on physical activity and diet at five routine visits to a maternity health care nurse starting at 8–9 weeks of gestation. Option to attend supervised group exercise sessions once a week during pregnancy until 37 weeks’ gestation.  
Control: (n= 38) |
| Results | Intervention group GWG: 14.1 ± 4.5 kg  
Control group GWG: 13.6 ± 5.1 kg  
p-value: 0.69 |

### Nascimento et al. 2011

| Methods | RCT, clinical  
Location: Prenatal Outpatient Clinic of the Women’s Integral Healthcare Centre, University of Campinas, Campinas, Brazil |
| Participants | 82 randomized participants  
Inclusion criteria: BMI 26.0–29.9 kg/m2 or ≥30.0 kg/m2; ≥18 years, 14-24 weeks gestation  
Exclusion criteria: multiple gestations; exercising regularly and conditions that contraindicate exercise; risk of abortion |
| Intervention | Intervention: (n= 39) one supervised 40-minute exercise program of 10 minutes stretching, 22 minutes strength, 10 minutes relaxation. HR did no exceed 140 beats per minute. Home exercise counselling 5 times/week. Recorded exercise in journal.  
Control: (n= 41) |
### Petrella et al. 2014

**Methods**
- RCT
- Location: Obstetric Unit, Mother-Infant Dept. of Policlinico Hospital – University of Modena, Italy

**Participants**
- 63 randomized participants
- Inclusion criteria: pre-pregnancy BMI ≥25 kg/m², age >18 years, singleton
- Exclusion criteria: twin pregnancy; chronic diseases; gestational diabetes mellitus in previous pregnancies; smoking; previous bariatric surgery; regular physical activity; dietary supplements or herbal products known to affect body weight; medical conditions that might affect body weight; plans to deliver outside our Birth Center

**Intervention**
- Intervention: (n= 33) therapeutic life changes participants given diet based on BMI and recommended mild physical activity of 30 minutes per day, 3 times per week. Overweight participants with 1700 kcal/day, obese participants with 1800 kcal/day.
- Control: (n= 30)

**Results**
- Intervention group GWG: 8.8 ± 6.5 kg
- Control group GWG: 10.4 ± 5.0 kg
- p-value: 0.032

### Phelan et al. 2011

**Methods**
- RCT
- Location: Providence, Rhode Island

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Fig. 2 (Continued)
### Participants

338 randomized participants  
Inclusion criteria: gestational age 10 to 16 weeks, BMI 19.8 to 40, nonsmoking, adults (aged >18 years), fluency in English, access to a telephone, singleton  
Exclusion criteria: major health or psychiatric diseases, weight loss during pregnancy, or a history of >3 miscarriages

### Intervention

Intervention: (n= 179) behavior intervention with counseling to promote changes in eating and physical activity with one face-to-face visit. Recommended 30 min of walking most days of the week, and calorie goals (20 kcal/kg). Self-monitoring with provided body-weight scales, food records, and pedometers. Given personalized graphs of their weight gains with feedback at each appointment. Additional support for women not in IOM range.  
Control: (n= 184)

### Results

| Intervention groups GWG: | NW: 15.3 kg | OV/OB: 14.7 kg | Control groups GWG: | NW: 16.2 kg | OW/OB: 15.1 kg |
|--------------------------|-------------|----------------|---------------------|-------------|----------------|
| p-value NW: 0.003        |             |                | p-value OV/OB: 0.33 |             |                |

### Poston et al. 2015

#### Methods

RCT, March 31, 2009-June 2, 2014  
Location: Eight hospitals in multi-ethnic, inner-city UK

#### Participants

1555 randomized participants  
Inclusion criteria: 15-18 weeks gestation; >16 years, BMI ≥30 kg/m2  
Exclusion criteria: unwilling or unable to give informed consent; underlying disorders, including a pre-pregnancy diagnosis of essential hypertension, diabetes, renal disease, systemic lupus erythematosus, antiphospholipid syndrome, sickle cell disease, thalassemia, coeliac disease, thyroid disease, and current psychosis; or if currently being prescribed metformin

#### Intervention

Intervention: (n= 526) behavior intervention with 1 hour/once per week for 8 weeks with health trainer. Food frequency questionnaire before trial. Made SMART goals, given nutrition and exercise recommendations. Exercise based on International Physical Activity Questionnaire. Given exercise DVD and log book.  
Control: (n= 567)
### Results

- Intervention group GWG: 7.2 ± 4.6 kg
- Control group GWG: 7.8 ± 4.6 kg
- p-value: 0.041

### Quinlivan et al. 2011

| Methods         | RCT                      |
|-----------------|--------------------------|
| Location        | Melbourne, Australia     |

| Participants    | 126 randomized participants  |
|-----------------|-----------------------------|
| Inclusion criteria: | pregnant with a fetus with no known anomalies, spoke English, did not intend to relinquish their infant, singleton, able to attend hospital for antenatal care and were overweight (BMI 25–29.9) or obese (BMI >29.9) |
| Exclusion criteria: | NR                          |

| Intervention    | Intervention: (n = 63) participants weighed each visit, 5-minute intervention by food technologist, info on reading food labels, shopping lists of affordable foods available from local shops and healthy recipes, clinical psychology management. Control: (n = 61) |

| Results         | Intervention group GWG: 7.0 kg  |
|-----------------| Control group GWG: 13.8 kg  |
|                 | p-value: < 0.001               |

### Rauh et al. 2013

| Methods         | Cluster RCT                  |
|-----------------|-----------------------------|
| Location        | Munich, Germany             |

| Participants    | 224 randomized participants  |
|-----------------|-----------------------------|
| Inclusion criteria: | >18 years; singleton; <18 weeks; BMI ≥18.5 kg/m2, and “sufficient” German |
| Exclusion criteria: | any condition preventing physical activity; pre-pregnancy diabetes; uncontrolled chronic diseases that may affect weight development |

| Intervention    | Intervention: (n = 152) two individual counseling sessions on diet, physical activity, and weight monitoring with food log. Advised to exercise 30 minutes of moderate intensity activity most days of the week at appropriate heart-rate zone and do non-weight-bearing or low-impact endurance exercises using large muscle groups. Provided with local prenatal exercise programs list. Control: (n = 72) |

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Fig. 2 (Continued)
| Results | Intervention group GWG: 14.1 ± 4.1 kg  
Control group GWG: 15.6 ± 5.8 kg  
p-value: 0.035 |
|---------|--------------------------------------------------|

### Renault et al. 2014

| Methods | RCT  
Location: Hvidovre Hospital, University of Copenhagen |
|---------|--------------------------------------------------|
| Participants | 389 randomized participants  
Inclusion criteria: BMI >30; >18 years; singleton and normal scan at weeks 11-14; <16 weeks gestation; ability to read and speak Danish  
Exclusion criteria: multiple pregnancy; pre-gestational diabetes; other serious diseases limiting their level of physical activity; previous bariatric surgery, or alcohol or drug abuse |
| Intervention | Intervention 1: (n= 142) unsupervised exercise with goal of 11,000 steps per day using pedometer registered on 7 consecutive days every 4 weeks. Reminding text message when a recording period started. Met with dietitian every 2 weeks, alternating between outpatient visits and phone contacts.  
Intervention 2: (n= 142) unsupervised exercise with goal of 11,000 steps per day using pedometer registered on 7 consecutive days every 4 weeks. Reminding text message when a recording period started.  
Control: (n= 141) |
| Results | Intervention group 1 GWG: 8.6 kg  
Intervention group 2 GWG: 9.4 kg  
Control group GWG: 10.9 kg  
p-value I1 vs C: 0.008  
p-value I2 vs C: 0.042  
p-value I1 vs I2: 0.57 |

### Ruchat et al. 2012

| Methods | RCT  
Location: London, Ontario, Canada |
|---------|--------------------------------------------------|
| Participants | 73 randomized participants  
Inclusion criteria: not have participated in any structured exercise program during pregnancy; BMI 18.5-24.9; 16-20 weeks gestation  
Exclusion criteria: <18 years or >40 years; smoking; multiple pregnancy; presence of chronic disease, or other contraindications to exercise |

Fig. 2  (Continued)
Intervention 1: (n= 23) supervised low intensity exercise walking sessions 3-4 times per week, gradually increasing time 25 to 40 minutes. Wore HR monitor. Modified gestational diabetes meal plan.
Intervention 2: (n= 26) supervised moderate intensity exercise walking sessions 3-4 times per week, gradually increasing time 25 to 40 minutes. Wore HR monitor. Modified gestational diabetes meal plan.
Control: (n= 45)

Results
Intervention group 1 GWG: 15.3 ± 2.9 kg
Intervention group 2 GWG: 14.9 ± 3.8 kg
Control group GWG: 18.3 ± 5.3 kg
p-value C vs I1: 0.01
p-value C vs I2: 0.003
p-value I1 vs I2: 0.72

Ruiz et al. 2013

Methods
RCT, Sept 1, 2007-Jan 31, 2011
Location: Madrid, Spain

Participants
962 randomized participants
Inclusion criteria: sedentary (exercising for <20 minutes on <3 days/week); singleton; uncomplicated gestation; not at high risk of preterm delivery; not participating in any other trial
Exclusion: any obstetric contraindication to exercise

Intervention
(n= 481) supervised exercise program with light to moderate-intensity aerobic and resistance exercises 3 days/week (50-55 min/session). Heart rate was consistently less than 60% of their age-predicted maximum heart rate. Exercises included resistance, core and cardio.
Control: (n= 481)

Results
Intervention groups GWG:
NW: 12.3 ± 3.6 kg
OV/OB: 11.1 ± 4.3 kg
Control groups GWG:
NW: 13.8 ± 4.1 kg
OV/OB: 11.6 ± 4.2 kg
p-value Overall: <0.001
p-value NW: <0.001
p-value OV/OB: 0.51

Szmeja et al. 2014

Fig. 2 (Continued)
### Nutrition and Exercise Strategies to Prevent Excessive GWG

**Methods**  
Randomized parallel trial  
Location: Australia and New Zealand

**Participants**  
1108 randomized participants  
Inclusion criteria: singleton pregnancy; 10-20 weeks gestation; BMI ≥25 kg/m²  
Exclusion criteria: NR

**Intervention**  
Intervention: (n= 534) informational DVD on healthy eating, serving sizes, and exercise during pregnancy. Individualized advice for balance of carbohydrates, fat and protein, reduce intake of foods high in refined carbohydrates, saturated fats and increase intake of fiber and suggested two servings of fruit, five servings of vegetables, and three servings of dairy each day. Increase walking and incidental activity. Session with RD, set goals and self-monitor progress.  
Control: (n= 565)

**Results**  
Intervention group GWG: 9.1 ± 5.8 kg  
Control group GWG: 9.7 ± 5.7 kg  
p-value: 0.13

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**Tanvig et al. 2015**

**Methods**  
RCT  
Location: Odense and Aarhus University Hospitals, Denmark

**Participants**  
150 randomized participants  
Inclusion criteria: singleton; born at term in 2008 to 2009; BMI 18.5–24.9 kg/m²; healthy Caucasian  
Exclusion criteria: NR

**Intervention**  
Intervention: (n= 77) four counseling sessions on individual dietary advice, coaching, and exercise during pregnancy. Recommended moderately physical activity for 30 to 60 minutes daily. Offered free, full-time membership to a fitness center.  
Control: (n= 73))

**Results**  
Intervention group GWG: 7.0 kg  
Control group GWG: 8.8 kg  
p-value: 0.01

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**Vesco et al. 2015**

**Methods**  
parallel group RCT  
Location: Kaiser Permanente, Northwest Oregon

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*Fig. 2 (Continued)*
### Participants

|               | 114 randomized participants |
|---------------|-----------------------------|
| **Inclusion criteria** | English-speaking; BMI ≥30 kg/m²; ≥18 years; receiving prenatal care at Kaiser Permanente, Northwest |
| **Exclusion criteria** | diabetes mellitus or other medical conditions requiring specialized nutritional care; plans to leave area during follow-up period |

### Intervention

|               | Intervention: (n= 56) participants given dietary approaches to stop hypertension dietary pattern without sodium restriction, and weekly group meetings. Instructed to exercise 30 minutes per day. |
|---------------|------------------------------------------------------------------------------------------------------------------|
| **Control**   | (n= 58)                                                                                                          |

### Results

|               | Intervention group GWG: 5.0 ± 4.1 kg |
|---------------|-------------------------------------|
| **Control**   | Control group GWG: 8.4 ± 4.7 kg     |
| **p-value**   | <0.001                               |

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### Walsh et al. 2014

#### Methods

|               | RCT |
|---------------|-----|
| **Location**  | Dublin, Ireland |

### Participants

|               | 800 randomized participants |
|---------------|-----------------------------|
| **Inclusion criteria** | 2nd pregnancy |
| **Exclusion criteria** | any underlying medical disorders; history of gestational diabetes; using medications; unable to give full informed consent |

### Intervention

|               | Intervention: (n= 235) 2-hour dietary education session in groups of 2-6 women with dietician. 3-day food diary. First advised on general healthy eating guidelines, then focused on GI. Received resources on LGI foods. Advice not given for LGI recommendations for GWG. |
|---------------|------------------------------------------------------------------------------------------------------------------|
| **Control**   | (n= 285)                                                                                                          |

### Results

|               | Intervention group GWG: 12.2 ± 4.4 kg |
|---------------|-------------------------------------|
| **Control**   | Control group GWG: 13.7 ± 4.9 kg     |
| **p-value**   | 0.01                                |

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**Fig. 2 (Continued)**
### Table 1 Comparison of GWG (kg)

| Study or subgroup | Intervention | Control | Intervention | Control |
|-------------------|--------------|---------|--------------|---------|
| **Nutrition**     |              |         |              |         |
| Di Carlo et al (2014) | 8.2          | 4.0     | 13.4         | 4.2     |
| Horan et al (2016) | 13.3         | 4.5     | 13.7         | 4.9     |
| Luo et al (2014)   | 7.6          | 1.6     | 12.6         | 4.6     |
| McGowan et al (2013) | 11.5        | 4.2     | 12.6         | 4.4     |
| Quinlivan et al (2011) | 7.0        | NR      | 13.8         | NR      |
| Walsh and McAuliffe (2015) | 12.2       | 4.4     | 13.7         | 4.9     |
| **Nutrition plus exercise** |          |         |              |         |
| Althuizen et al (2013) | 11.1        | 3.2     | 11.6         | 4.6     |
| Asbee et al (2009) | 13.0         | 5.7     | 16.2         | 7.0     |
| Asci and Rathfisch (2016) | 12.5       | 5.0     | 12.3         | 4.8     |
| Bogaerts et al (2013) (1) | 9.5         | 6.8     | 13.5         | 7.3     |
| Bogaerts et al (2013) (2) | 10.6        | 7.0     | 13.5         | 7.3     |
| Huang et al (2011) | 14.0         | 2.4     | 16.2         | 3.3     |
| Hui et al (2012)   | 14.1         | 6.0     | 15.2         | 5.9     |
| Hui et al (2014)   | 12.9         | 3.7     | 16.2         | 4.4     |
| Korpi-Hyövälti et al (2011) | 11.4       | 6.0     | 13.9         | 5.1     |
| Luoto et al (2011) | 13.8         | 5.8     | 14.2         | 5.1     |
| Mustila et al (2012) | 13.6        | 5.1     | 14.1         | 4.5     |
| Petrella et al (2014) | 8.8         | 6.5     | 10.4         | 5.0     |
| Phelan et al (2011) (NW) | 15.3        | 4.4     | 16.2         | 4.6     |
| Phelan et al (2011) (OV/OB) | 14.7       | 6.9     | 15.1         | 7.5     |
| Poston et al (2015) | 7.2          | 4.6     | 7.8          | 4.6     |
| Rauh et al (2013)  | 14.1         | 4.1     | 15.6         | 5.8     |
| Renault et al (2014) | 8.6         | NR      | 10.9         | NR      |
| Ruchat et al (2012) (LI) | 15.3        | 2.9     | 18.3         | 5.3     |
| Ruchat et al (2012) (MI) | 14.9        | 3.8     | 18.3         | 5.3     |
| Szmeja et al (2014) | 9.1          | 5.8     | 9.7          | 5.7     |
| Tanvig et al (2015) | 7.0          | NR      | 8.8          | NR      |
| Vesco et al (2014) | 5.0          | 4.1     | 8.4          | 4.7     |

**Exercise**

| Study or subgroup | Intervention | Control |
|-------------------|--------------|---------|
| Byrne et al (2011) | 10.8         | 5.1     |
| Garnæs et al (2016) | 10.5         | NR      |
| Haakstad and Bø (2011) | 13.0        | 4.0     |
| Kong et al (2014) (OV) | 10.5        | 5.4     |
| Kong et al (2014) (OB) | 12.1        | 9.0     |
| Nascimento et al (2011) | 10.3        | 1.7     |
| Nascimento et al (2011) (OV) | 13.8       | 5.8     |
| Nascimento et al (2011) (OB) | 10.4        | 6.5     |
| Renault et al (2014) | 8.6          | NR      |
| Ruiz et al (2013) (NW) | 12.3        | 3.6     |
| Ruiz et al (2013) (OV/OB) | 11.1       | 4.3     |

*p-Value: 0.056*  
*p-Value: 0.61*

### Table 2 Comparison of GWG (kg) for studies that selected participants who are OV or have OB based on mean pre-pregnancy BMI

| Study or subgroup | Intervention | Control | Intervention | Control |
|-------------------|--------------|---------|--------------|---------|
| **Nutrition**     |              |         |              |         |
| Di Carlo et al (2014) | 8.2          | 4.0     | 13.4         | 4.2     |
| Quinlivan et al (2011) | 7.0         | NR      | 13.8         | NR      |
| **Nutrition plus exercise** |          |         |              |         |
| Bogaerts et al (2013) (1) | 9.5         | 6.8     | 13.5         | 7.3     |
| Bogaerts et al (2013) (2) | 10.6        | 7.0     | 13.5         | 7.3     |
| Korpi-Hyövälti et al (2011) | 11.4        | 6.0     | 13.9         | 5.1     |
| Luoto et al (2011) | 13.8         | 5.8     | 14.2         | 5.1     |
| Mustila et al (2012) | 13.6         | 5.1     | 14.1         | 4.5     |
| Petrella et al (2014) | 8.8          | 6.5     | 10.4         | 5.0     |
| Phelan et al (2011) (OV/OB) | 14.7        | 6.9     | 15.1         | 7.5     |
| Poston et al (2015) | 7.2          | 4.6     | 7.8          | 4.6     |
| Rauh et al (2013)  | 14.1         | 4.1     | 15.6         | 5.8     |
| Renault et al (2014) | 8.6          | NR      | 10.9         | NR      |
| Ruchat et al (2012) (LI) | 15.3        | 2.9     | 18.3         | 5.3     |
| Ruchat et al (2012) (MI) | 14.9        | 3.8     | 18.3         | 5.3     |
| Szmeja et al (2014) | 9.1          | 5.8     | 9.7          | 5.7     |
| Tanvig et al (2015) | 7.0          | NR      | 8.8          | NR      |
| Vesco et al (2014) | 5.0          | 4.1     | 8.4          | 4.7     |

*p-Value: 0.056*  
*p-Value: 0.011*  
*p-Value: 0.129*
nutrition plus exercise (70%), and 1 of 6 exercise only produced significant results (16.67%). One of two supervised and one of four unsupervised exercise produced significant results. Like the overall analyses, nutrition-only strategy was significant ($p = 0.011$). Overall, comparison between all interventions and controls was significant ($p = 0.004$) in this population.

**Exercise Interventions**

Three studies reported statistically significant differences in mean GWG ($p = 0.013$). Exercise-only ($p = 0.069$) and nutrition-plus-exercise ($p = 0.056$) interventions have potential to control GWG, but results did not reach statistical significance in the current study. In comparison to the Cochrane Review findings of studies published before the 2009 IOM guidelines which found all three intervention groups reduced GWG, the current meta-analysis study found that studies which utilized the 2009 IOM guidelines were more likely to produce reduced GWG with nutrition-only interventions. Nonsignificant findings from exercise and nutrition-plus-exercise health system strategies may be due to the inclusion of different exercise types. Exercise programs varied. Some included advice about exercise or discussed increased amount of physical activity, while others were more interventional, such as supervised dance programs or recommending a certain number of steps per day. The way in which these steps were achieved may and most likely differed between participants. Despite different nutritional advice, interventions universally recommend increased amounts of fruits and vegetables, and decreased consumption of food with high fat and sugar content. Additionally, retention to exercise programs may be more difficult than nutrition programs because one must eat to live, but exercise is not a fundamental need.

### Table 2 (Continued)

| Study or subgroup | Intervention | Control |
|------------------|--------------|---------|
|                  | Mean | SD | Mean | SD |
| **Exercise**     |      |    |      |    |
| Byrne et al (2011) | 10.8 | 5.1 | 11.8 | 5.9 |
| Garnäes et al (2016) | 10.5 | NR | 9.2 | NR |
| Kong et al (2014) (OV) | 10.5 | 5.4 | 9.9 | 6.1 |
| Kong et al (2014) (OB) | 12.1 | 9.0 | 12.5 | 8.5 |
| Nascimento et al (2011) | 10.3 | 1.7 | 16.4 | 3.9 |
|                  |      |    |      |    |
| **Supervised exercise** |      |    |      |    |
| Garnäes et al (2016) | 10.5 | NR | 9.2 | NR |
| Nascimento et al (2011) | 10.3 | 1.7 | 16.4 | 3.9 |
|                  |      |    |      |    |
| **Unsupervised exercise** |      |    |      |    |
| Byrne et al (2011) | 10.8 | 5.1 | 11.8 | 5.9 |
| Kong et al (2014) (OV) | 10.5 | 5.4 | 9.9 | 6.1 |
| Kong et al (2014) (OB) | 12.1 | 9.0 | 12.5 | 8.5 |
| Renault et al (2014) | 9.4 | NR | 10.9 | NR |

-Abbreviations: BMI, body mass index; GWG, gestational weight gain; LI, low intensity; MI, moderate intensity; NR not reported; NW, normal weight; OB, obesity; OV, overweight; SD, standard deviation.

### Discussion

Based on results of this meta-analysis, nutrition-only interventions were associated with statistically significant lower rates of excessive GWG and therefore have the highest probability of helping women achieve target IOM GWG guidelines ($p = 0.013$). Exercise-only ($p = 0.069$) and nutrition-plus-exercise ($p = 0.056$) interventions have potential to control GWG, but results did not reach statistical significance in the current study. In comparison to the Cochrane Review findings of studies published before the 2009 IOM guidelines which found all three intervention groups reduced GWG, the current meta-analysis study found that studies which utilized the 2009 IOM guidelines were more likely to produce reduced GWG with nutrition-only interventions. Nonsignificant findings from exercise and nutrition-plus-exercise health system strategies may be due to the inclusion of different exercise types. Exercise programs varied. Some included advice about exercise or discussed increased amount of physical activity, while others were more interventional, such as supervised dance programs or recommending a certain number of steps per day. The way in which these steps were achieved may and most likely differed between participants. Despite different nutritional advice, interventions universally recommend increased amounts of fruits and vegetables, and decreased consumption of food with high fat and sugar content. Additionally, retention to exercise programs may be more difficult than nutrition programs because one must eat to live, but exercise is not a fundamental need.
**Fig. 3** Mean gestational weight gain (GWG) (kg) of health system strategies intervention groups versus mean GWG control groups.

**Table 3** Comparison of mean intervention and control gestational weight gain (kg)

| Study or subgroup                  | Intervention | Control | p-Value | Mean difference | IV, random 95% CI |
|-----------------------------------|--------------|---------|---------|-----------------|------------------|
|                                   | N | Mean | SD | N | Mean | SD |                     |
| **Nutrition**                     |   |       |    |   |       |    |                     |
| Di Carlo et al (2014)             | 77 | 8.2  | 4.0 | 77 | 13.4 | 4.2 | <0.001 | -5.2 | -6.51, -3.89 |
| Horan et al (2016)                | 138 | 13.3 | 4.5 | 142 | 13.7 | 4.9 | 0.52  | -0.4 | -1.51, 0.71  |
| Luo et al (2014)                  | 131 | 7.6  | 1.6 | 145 | 12.6 | 4.6 | <0.001 | -5.0 | -5.83, -4.17 |
| McGowan et al (2013)              | 235 | 11.5 | 4.2 | 285 | 12.6 | 4.4 | 0.003 | -1.1 | -1.85, -0.35 |
| Quinlivan et al (2011)            | 63  | 7.0  | NR  | 61  | 13.8 | NR  | <0.001 | -6.8 | NR           |
| Walsh and McAuliffe (2015)        | 235 | 12.2 | 4.4 | 285 | 13.7 | 4.9 | 0.01  | -1.5 | -2.31, -0.69 |
| **Total events:** 879 (intervention), 995 (standard care) |   |       |    |   |       |    |                     |
| **Nutrition and exercise**        |   |       |    |   |       |    |                     |
| Althuizen et al (2013)            | 106 | 11.1 | 3.2 | 113 | 11.6 | 4.6 | NR* | -0.5 | -1.56, 0.56  |
| Asbee et al (2009)                | 57  | 13.0 | 5.7 | 43  | 16.2 | 7.0 | <0.01 | -3.2 | -5.72, -0.68 |
| Asçi and Rathfisch (2016)         | 45  | 12.5 | 5.0 | 45  | 12.3 | 4.8 | 0.001 | 0.2  | -1.85, 2.25  |
| Bogaerts et al (2013) (1)         | 58  | 9.5  | 6.8 | 63  | 13.5 | 7.3 | 0.04  | -4.0 | -6.55, -1.45 |
| Bogaerts et al (2013) (2)         | 76  | 10.6 | 7.0 | 63  | 13.5 | 7.3 | 0.008 | -2.9 | -5.30, -0.50 |
| Huang et al (2011)                | 61  | 14.0 | 2.4 | 64  | 16.2 | 3.3 | <0.001 | -2.2 | -3.23, -1.17 |
| Hui et al (2012)                  | 102 | 14.1 | 6.0 | 88  | 15.2 | 5.9 | 0.28  | -1.1 | -2.81, 0.61  |
| Hui et al (2014)                  | 30  | 12.9 | 3.7 | 27.0| 16.2 | 4.4 | <0.05 | -3.3 | -5.45, -1.15 |
| Korpi-Hyövättilä et al (2011)     | 27  | 11.4 | 6.0 | 27.0| 13.9 | 5.1 | 0.062 | -2.5 | -5.54, 0.54  |
| Luoto et al (2011)                | 219 | 13.8 | 5.8 | 180 | 14.2 | 5.1 | 0.52  | -0.4 | -1.49, 0.96  |
| Petrella et al (2014)             | 33  | 8.8  | 6.5 | 30  | 10.4 | 5.0 | 0.032 | -1.6 | -4.54, 1.34  |
| Phelan et al (2011) (NW)          | 92  | 15.3 | 4.4 | 94  | 16.2 | 4.6 | 0.003 | -0.9 | -2.20, 0.40  |

(Continued)
Previous studies have addressed the ability to control GWG and prevent weight exceeding IOM recommendations with mixed results. Since the study search for this article was completed, additional studies have been published with inconsistent results. Nutrition-only studies of the general population and of women who are OV/OB concur that nutrition-only interventions make significant differences for controlling GWG. Walker et al’s (2018) meta-analysis of general population concerning nutrition only, exercise only, and nutrition plus exercise claimed

| Study or subgroup | Intervention | Control | p-Value | Mean difference | IV, random 95% CI |
|------------------|-------------|---------|---------|-----------------|-----------------|
|                  | N  | Mean | SD | N  | Mean | SD |                   |                 |
| Phelan et al (2011) (OV/OB) | 87 | 14.7 | 6.9 | 90 | 15.1 | 7.5 | 0.33 | -0.4 | -2.54, 1.74 |
| Poston et al (2015) | 526 | 7.2 | 4.6 | 567 | 7.8 | 4.6 | 0.041 | -0.6 | -1.15, -0.05 |
| Rauh et al (2013) | 152 | 14.1 | 4.1 | 72 | 15.6 | 5.8 | 0.035 | -1.5 | -2.83, -0.17 |
| Renault et al (2014) | 142 | 8.6 | NR | 141 | 10.9 | NR | 0.008 | -2.3 | NR |
| Ruchat et al (2012) (LI) | 23 | 15.3 | 2.9 | 45 | 18.3 | 5.3 | 0.01 | -3.0 | -5.37, -0.63 |
| Ruchat et al (2012) (MI) | 26 | 14.9 | 3.8 | 45 | 18.3 | 5.3 | 0.003 | -3.4 | -5.76, -1.04 |
| Szmeja et al (2014) | 543 | 9.1 | 5.8 | 565 | 9.7 | 5.7 | 0.13 | -0.6 | -1.28, 0.08 |
| Tanvig et al (2015) | 77 | 7.0 | NR | 73 | 8.8 | NR | 0.01 | -1.8 | NR |
| Vesco et al (2014) | 56 | 5.0 | -4.1 | 58 | 8.4 | 4.7 | <0.001 | -3.4 | -5.04, -1.76 |
| Total events: 2,538 (intervention), 2,493 (standard care) | | | | | | | | | |
| Exercise | | | | | | | | | |
| Byrne et al (2011) | 12 | 10.8 | 5.1 | 11 | 11.8 | 5.9 | NR | -1.0 | -5.77, 3.77 |
| Garnæs et al (2016) | 46 | 10.5 | NR | 45 | 9.2 | NR | 0.35 | -1.3 | NR |
| Haakstad and Bø (2011) | 52 | 13.0 | 4.0 | 53 | 13.8 | 4.0 | 0.31 | -0.8 | -2.35, 0.75 |
| Kong et al (2014) (OV) | 9 | 10.5 | 5.4 | 9 | 9.9 | 6.1 | 0.859 | 0.6 | -5.16, 6.36 |
| Kong et al (2014) (OB) | 9 | 12.1 | 9.0 | 10 | 12.5 | 8.5 | 0.859 | -0.4 | -8.87, 8.07 |
| Nascimento et al (2011) | 39 | 10.3 | 1.7 | 41 | 16.4 | 3.9 | 0.543 | -6.1 | -7.45, -4.75 |
| Nascimento et al (2011) (OV) | 9 | 10.0 | 1.7 | 5 | 16.4 | 3.9 | 0.001 | -6.4 | -9.61, -3.19 |
| Nascimento et al (2011) (OB) | 30 | 10.4 | 5.6 | 36 | 10.9 | 7.6 | 0.757 | -0.5 | -3.84, 2.84 |
| Renault et al (2014) | 142 | 9.4 | NR | 141 | 10.9 | NR | 0.042 | -1.5 | NR |
| Ruiz et al (2013) (NW) | 335 | 12.3 | 3.6 | 352 | 13.8 | 4.1 | <0.001 | -1.5 | -2.08, -0.92 |
| Ruiz et al (2013) (OV/OB) | 146 | 11.1 | 4.3 | 129 | 11.6 | 4.2 | 0.51 | -0.5 | -1.51, 0.51 |
| Total events: 790 (intervention), 791 (standard care) | | | | | | | | | |
| Supervised exercise | | | | | | | | | |
| Garnæs et al (2016) | 46 | 10.5 | 10.5 | 45 | 9.2 | 9.2 | 0.987 | -0.3 | -6.75, 6.12 |
| Haakstad and Bø (2011) | 52 | 13.0 | 4.0 | 53 | 13.8 | 4.0 | 0.31 | -0.8 | -2.35, 0.75 |
| Nascimento et al (2011) | 39 | 10.3 | 1.7 | 41 | 16.4 | 3.9 | 0.543 | -6.1 | -7.45, -4.75 |
| Nascimento et al (2011) (OV) | 9 | 10.0 | 1.7 | 5 | 16.4 | 3.9 | 0.001 | -6.4 | -9.61, -3.19 |
| Nascimento et al (2011) (OB) | 30 | 10.4 | 5.6 | 36 | 10.9 | 7.6 | 0.757 | -0.5 | -3.84, 2.84 |
| Renault et al (2014) | 142 | 9.4 | 9.4 | 141 | 10.9 | 9.4 | 0.042 | -1.5 | NR |
| Ruiz et al (2013) (NW) | 335 | 12.3 | 3.6 | 352 | 13.8 | 4.1 | <0.001 | -1.5 | -2.08, -0.92 |
| Ruiz et al (2013) (OV/OB) | 146 | 11.1 | 4.3 | 129 | 11.6 | 4.2 | 0.51 | -0.5 | -1.51, 0.51 |
| Total events: 657 (intervention), 661 (standard care) | | | | | | | | | |
| Unsupervised exercise | | | | | | | | | |
| Byrne et al (2011) | 12 | 10.8 | 5.1 | 11 | 11.8 | 5.9 | NR | -1.0 | -5.77, 3.77 |
| Kong et al (2014) (OV) | 9 | 10.5 | 5.4 | 9 | 9.9 | 6.1 | 0.859 | 0.6 | -5.16, 6.36 |
| Kong et al (2014) (OB) | 9 | 12.1 | 9.0 | 10 | 12.5 | 8.5 | 0.859 | -0.4 | -8.87, 8.07 |
| Renault et al (2014) | 142 | 9.4 | NR | 141 | 10.9 | NR | 0.042 | -1.5 | NR |
| Total events: 172 (intervention), 171 (standard care) | | | | | | | | | |

**Abbreviations:** CI, confidence interval; LI, low intensity; MI, moderate intensity; NR not reported; NW, normal weight; OB, obesity; OV, overweight; SD, standard deviation.

*Stated as insignificant.
Nutrition-only interventions are the best method to control GWG. Lamminpää et al’s (2017) meta-analysis of OV/OB women only analyzed nutrition-only interventions because of previous reporting this as the best method. This meta-analysis found that nutrition-only results vary because of adherence inconsistency. Exercise-only interventions produced significant results for both general population\textsuperscript{10,17,27–29} and OV/OB except for one study.\textsuperscript{10} Nutrition-plus-exercise interventions for general population were statistically significant.\textsuperscript{14–21} Nutrition plus exercise for OV/OB were inconsistent, including a meta-analysis determining nutrition plus exercise as insignificant impact on GWG.\textsuperscript{20} Due to the variability of these findings, it is challenging to make a consensus regarding which intervention is best for clinical use. The results of this study confer with other studies that nutrition-only interventions are the best method to control GWG.

Limitations

Limitations include the inability to calculate risk ratio and weight. Based on heterogeneity of p-value greater than 0.10, 22 studies were determined to have excessive heterogeneity. Heterogeneity between subgroups was not significant; therefore, data were pooled between subgroups. Search did not explore worldwide databases such as EMBASE and LiLACS; therefore, some foreign studies may have been missed that would have otherwise met the inclusion criteria.

Fig. 4 Forest plot divided by subgroups.
Meta-analyses are generally limited due to selection bias and publication bias. No publication bias was detected.

Future Research

Evidence suggests that nutrition-only, exercise-only, and nutrition-plus-exercise interventions help control excessive GWG during pregnancy. Since the nutrition-only group was the only health system strategy to produce statistically significant results, this type of intervention should be favored as first line. Based on analysis, pre-pregnancy BMI is a better predictor of GWG than the type of intervention program studied. Pregnant individuals with a starting BMI categorized as OV or obese are more likely to exceed IOM recommendations regardless of intervention. Further research is needed on participants that are OV or have OB. Interventions on participants from middle-income or low-income countries should be analyzed because impact of interventions may differ based on several factors.

Conclusion

We found that nutrition-only interventions were more effective at decreasing rates of excessive GWG than exercise or nutrition-plus-exercise interventions. Time and resources are limited for all clinicians and clinics. Therefore, clinicians and clinical programs should focus efforts on nutrition education with health messages targeting increased consumption of fruits and vegetables and decreased consumption of foods with high fat or sugar content to maximize effectiveness. If additional resources are available, efforts may also be focused on exercise since such efforts are not harmful, but these efforts may be of lower yield.

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Conflict of Interest

The authors of this study declare no conflict of interest.
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