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.[2] Additionally, children of mothers who gain more weight during pregnancy are at higher risk of being OV in early childhood.[3]

Based on the 2009 IOM guidelines, the recommended amount of GWG for underweight women (body mass index [BMI] <18.5 kg/m^2) is 12.5 to 18 kg (28–40 lb), normal weight (NW) women (BMI 18.5–24.9 kg/m^2) is 11.5 to 16 kg (25–35 lb), OV women (BMI 25.0–29.9 kg/m^2) is 7 to 11.5 kg (15–25 lb), and women who have OB (BMI >30.0 kg/m^2) is 5 to 9 kg (11–20 lb).[4] 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,[5–8] nutrition only for OV/OB women,[9–12] nutrition plus exercise,[5,13–21] nutrition plus exercise for OV/OB women,[10,22–26] exercise only,[17] and exercise only for OV/OB women.[10,27–29] The study expands on the 2015 Cochrane Review (Muktabhant et al [2015]) assessment of methods involving nutrition, exercise, and combination of nutrition-plus-exercise intervention studies to prevent excessive pregnancy weight gain based on studies published after the 2009 IOM recommendations. 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.[30] 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 search 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 (►**Fig. 1**). 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/m^2) 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[a]. 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.[51,56–61] Four were used twice because data of participants with NW, OV, and having OB were analyzed separately.[48,59–61] Two were used twice because they reported data of different interventions within studies.[51,52] One included interventions based on exercise only and nutrition plus exercise.[51] One included interventions based on low intensity (LI) and moderate intensity (MI) exercise.[52] 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.[36,61] One recruited at the 12th week of clinic.[47] One recruited at 6 to

[a] One-way ANOVA. 2010. Vassarstars.net. [accessed October 9, 2016, to June 30, 2017]. http://vassarstats.net/anova1u.html

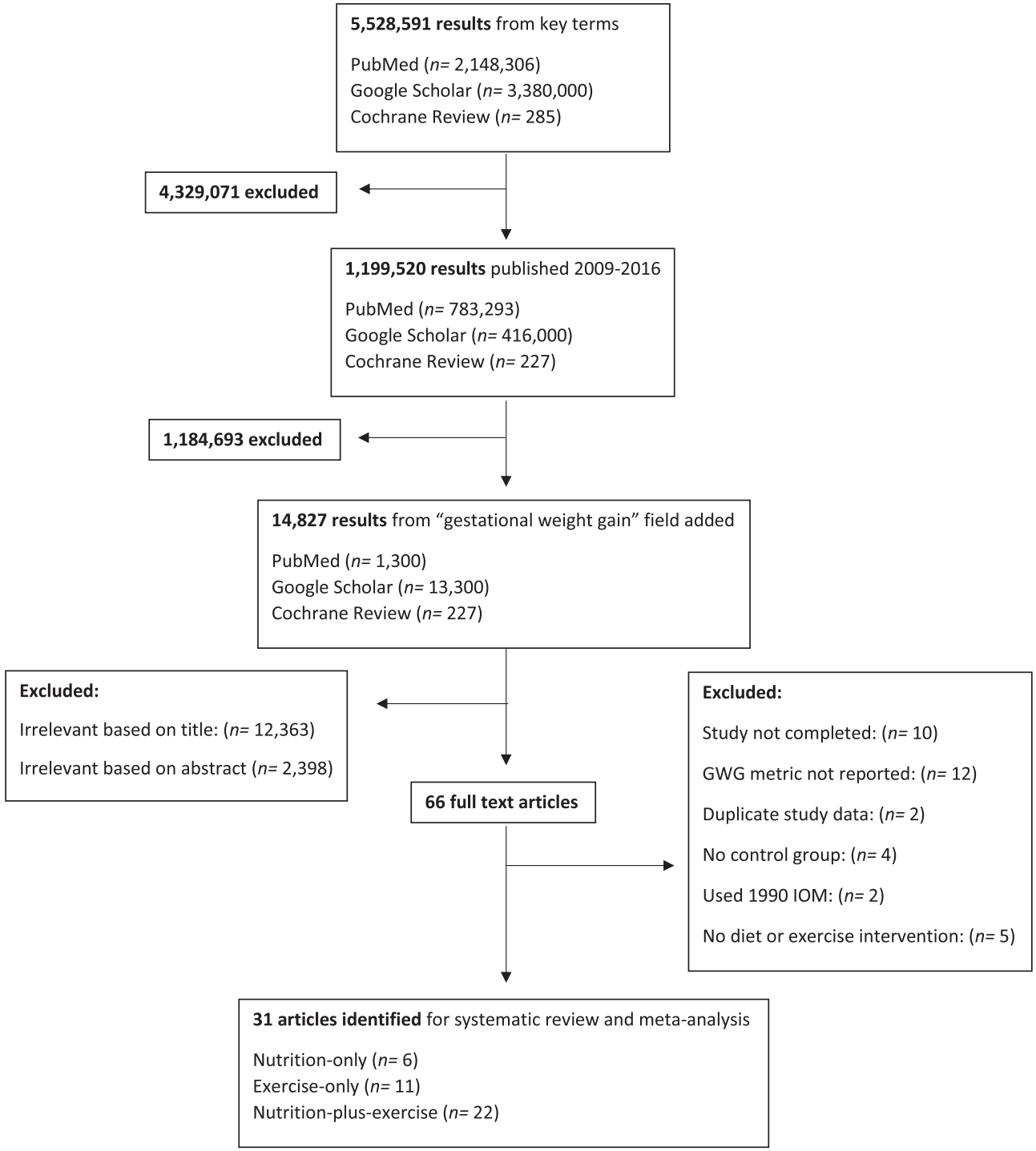

Fig. 1 Electronic search strategy and inclusion criteria for studies used in meta-analysis.

16 weeks.[38] One required 7 to 21 weeks.[55] One recruited at eight to nine weeks.[46] Two required 8 to 12 weeks.[44,45] One required 10 to 14 weeks.[54] One required 10 to 16 weeks.[48] One required 10 to 18 weeks.[34] One required 10 to 20 weeks.[53] Two required <12 weeks.[39,56] One required <13 weeks.[33] One required <14 weeks.[37] One required 14 to 24 weeks.[60] Two required < 15 weeks.[40,59] One required 15 to 18 weeks.[49] Two required <16 weeks.[41,51] One required 16 to 20 weeks.[52] Two required <18 weeks.[50,57] One required <20 weeks.[43] One required <24 weeks.[58] One required <26 weeks.[42] Three studies did not report the gestational age requirement for participants.[31,32,35]

Weight categories included NW (BMI 18.5–24.9 kg/m^2), OV (BMI 25.0–29.9 kg/m^2), and women with OB (BMI >30.0). Seventeen studies selected from general population without BMI specifications.[5,32–34,36–40,42,43,46,48,50,52,54,58] Three selected for OV participants.[31,47,53] Three selected for participants who are OV or have OB.[35,44,59] Eight selected for participants who have OB.[40,45,49,51,55–57,60] No significant differences in pre-pregnancy BMI.

Additional inclusion criteria include: nulliparous participants[32,37]; secundigravida women previously given birth to macrosomic newborn[32]; women expecting second pregnancy[36]; healthy Caucasian mothers[54]; no structured exercise program (>60 minutes once per week) 6 months before trial[58]; sedentary (exercising for <20 minutes on <3 days/week) before study[61]; not have engaged <3, 30-minute exercise per week for 6 months preceding enrollment,[60] nondiabetic[42]; have at least one of the following risk factors: BMI >25 kg/m^2; 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.[45]

Setting

Based on World Bank classifications from 2017 economy, 28 studies occurred in high-income countries.[31,32,34–36,40–59,61] Three studies occurred in upper middle-income countries.[33,39,60] No studies occurred in low-income countries.

Eleven studies specified treatment locations: university hospitals[33,47,51,54,57,59]; regular hospitals[32,55,56]; eight multiethnic hospitals[49]; obstetric clinic[38,60]; and six primary care maternity health clinics.[46] All other studies did not specify treatment locations.

Intervention Implementation

Of the six nutrition-only studies, three focused on low glycemic index (LGI) foods.[32,34,36] 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.[31–33] One provided focused nutritional advice based on the macronutrient composition of the participant's diet.[33] Three provided participants with lists of healthy foods based on local affordability[35] or LGI foods.[34,36] Three provided education in group settings.[34–36] 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,[57,60] one required participants to attend at least two sessions per week,[58] and one had one session per week.[60] Three supervised studies also had unsupervised exercise to be completed outside of the supervised sessions.[56,58,60] 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.[56] A heart rate monitor was provided to track exercise. One was based on a dance class and core exercises.[58] Two included aerobic and strength exercises.[57,60] One also included stretching.[60] One included aerobic, resistance, and core exercises.[61] One utilized pedometers[51] and one provided treadmills.[59] One registered daily steps on 7 consecutive days every 4 weeks and reminded participants of the recording period starting via text message.[51]

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.[42,43,49] Additional implementations included: weight goal setting by the mother,[43,49,53] extra-support for individuals not within IOM recommendations in which exercise and nutritional recommendations were revised,[38,39,48] food log,[39,40,43,48,50] pedometers,[48,51] text messages to remind participants when the daily steps recording period of 7 consecutive days every 4 weeks started,[51] profile-II nutritional program with six subscales to measure health behaviors,[39] exercises on reading food labels and shopping methods,[40] used Food Choice Map software,[42,43] free fitness membership,[54] heart rate monitors,[52] and calories calculated based on Dietary Approaches to Stop Hypertension (DASH) dietary pattern and reduced by 30% for participants without OB.[55] In addition to meeting the 2009 IOM recommendations, one study had the goal to keep weight within 3% of their weight at randomization.[55]

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

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 ($p = 0.013$). Nutrition-plus-exercise ($p = 0.056$) and exercise-only ($p = 0.069$) interventions trended toward statistical significance and show potential to control GWG (►**Tables 1** and **2**). ANOVA comparison of GWG between all intervention and control groups produced significant results ($p = 0.001$) (►**Table 1**).

Graphically, there is a visually noticeable difference between mean control and mean intervention GWG for all intervention groups; however, nutrition ($p = 0.013$) is the only statistically significant health system strategy (►**Fig. 3**). Exercise and nutrition plus exercise demonstrated some improvement; however, neither was statistically significant. When separated into supervised ($p = 0.61$) and unsupervised ($p = 0.494$) exercise programs, results were not significant.

►**Table 3** depicts upper and lower 95% confidence intervals for each study based on population (N) and standard deviation (SD). ►**Fig. 4** depicts the forest plot. Not all studies reported number of participants at, above, or below IOM recommendations, so odds ratio, risk ratio, nor 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.[37]

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.

Aşcı 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. 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. Control: (n= 63)

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)

Fig. 2 (*Continued*)

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

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*)

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	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

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-Hyövälti 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 4.8-5.5mmol/l and 2-hour OGTT plasma glucose <7.8mmol/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

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

Luoto et al. 2011

Methods	Cluster RCT Location: Finland

Fig. 2 (*Continued*)

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

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

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)

Fig. 2 (*Continued*)

Results	Intervention groups GWG: Overall: 10.3 ± 5.0 kg OW: 10.0 ± 1.7 kg OB: 10.4 ± 5.6 kg Control groups GWG: Overall: 11.5 ± 7.4 kg OV: 16.4 ± 3.9 kg OB: 10.9 ± 7.6 kg p-value Overall: 0.543 p-value OV: 0.001 p-value OB: 0.757

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

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)

Fig. 2 (*Continued*)

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)

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	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	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 ± 4.1kg 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*)

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

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

Vesco et al. 2015

Methods	parallel group RCT Location: Kaiser Permanente, Northwest Oregon

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 group GWG: 8.4 ± 4.7 kg p-value: <0.001

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 group GWG: 13.7 ± 4.9 kg p-value: 0.01

Fig. 2 (*Continued*)

Table 1 Comparison of GWG (kg)

Study or subgroup	Intervention		Control	
	Mean	SD	Mean	SD
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
	p-Value: 0.013			
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
Aşcı 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
	p-Value: 0.056			
Exercise				
Byrne et al (2011)	10.8	5.1	11.8	5.9
Garnæs et al (2016)	10.5	NR	9.2	NR
Haakstad and Bø (2011)	13.0	4.0	13.8	4.0
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
Nascimento et al (2011) (OV)	10.0	1.7	16.4	3.9
Nascimento et al (2011) (OB)	10.4	5.6	10.9	7.6
Renault et al (2014)	9.4	NR	10.9	NR
Ruiz et al (2013) (NW)	12.3	3.6	13.8	4.1
Ruiz et al (2013) (OV/OB)	11.1	4.3	11.6	4.2
	p-Value: 0.069			

(*Continued*)

Table 1 (*Continued*)

Study or subgroup	Intervention		Control	
	Mean	SD	Mean	SD
Supervised exercise				
Garnæs et al (2016)	10.5	10.5	9.2	NR
Haakstad and Bø (2011)	13.0	4.0	13.8	4.0
Nascimento et al (2011)	10.3	1.7	16.4	3.9
Nascimento et al (2011) (OV)	10.0	1.7	16.4	3.9
Nascimento et al (2011) (OB)	10.4	5.6	10.9	7.6
Ruiz et al (2013) (NW)	12.3	3.6	13.8	4.1
Ruiz et al (2013) (OV/OB)	11.1	4.3	11.6	4.2
	p-Value: 0.61			
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
	p-Value: 0.494			
	Total *p*-value: 0.0014			

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

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	
	Mean	SD	Mean	SD
Nutrition				
Di Carlo et al (2014)	8.2	4.0	13.4	4.2
Quinlivan et al (2011)	7.0	NR	13.8	NR
	p-Value: 0.011			
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
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
Renault et al (2014)	8.6	NR	10.9	NR
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: 0.129			

(*Continued*)

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
Garnæs 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
	Does not differentiate between OV and obese			
Renault et al (2014)	9.4	NR	10.9	NR
	p-Value: 0.308			
Supervised exercise				
Garnæs et al (2016)	10.5	NR	9.2	NR
Nascimento et al (2011)	10.3	1.7	16.4	3.9
	p-Value: 0.575			
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
	p-Value: 0.494			
	Total *p*-value: 0.0055			

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.

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[51,60,61] (►**Table 3**). Five of eight studies subjects selected for pre-pregnancy BMI as obese or OV.[51,56,57,59,60] These studies produced GWG greater than IOM recommendation for both control and intervention groups, except when Kong et al (2014) was divided into participants with OV and OB; OV individuals had mean GWG within IOM recommendations. Three studies did not have BMI specifications and were classified as NW with GWG within IOM.[52,58,61]

Studies were then divided into subgroups where exercise was either supervised or unsupervised. To be a supervised intervention, exercise must be performed under the supervision of a personal trainer or by attendance at an exercise class. Neither supervised ($p = 0.61$) nor unsupervised ($p = 0.494$) programs produced significant results. However, mean GWG for unsupervised intervention (10.7 kg) and control (11.275 kg) groups was lower than supervised (11.44 kg) intervention and control (12.96 kg) groups.

Nutrition Interventions

Five of six studies reported statistically significant differences in mean GWG[31,33–36,52] (►**Table 3**). Two studies selected subjects with OV or obese pre-pregnancy BMI.[31,35] The results of three studies demonstrated that the intervention group's average GWG was within IOM and the average GWG of control group exceed IOM.[31,34,35] All control groups' GWG exceeded IOM, except one that was within IOM recommendations.[34] One intervention group's GWG was below IOM recommendations.[33]

Combination of Exercise-Plus-Nutrition Interventions

Thirteen of 19 studies reported statistically significant differences in mean GWG[38–41,43,47,49–52,54,55] (►**Table 3**). Three underwent multiple analyses. When divided into subgroups, interventions 1 and 2,[40] NW participants[48] and both LI and MI exercise programs were significant.[52] Ten studies selected participants with OV or obese pre-pregnancy BMI.[40,44,45,47–49,51,53–55] Of these studies, six interventions and three control groups were within IOM recommendations. All NW subjects produced GWG within the IOM recommendations for the intervention group.[37,39,41–43,46,48,50]

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 produced 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.

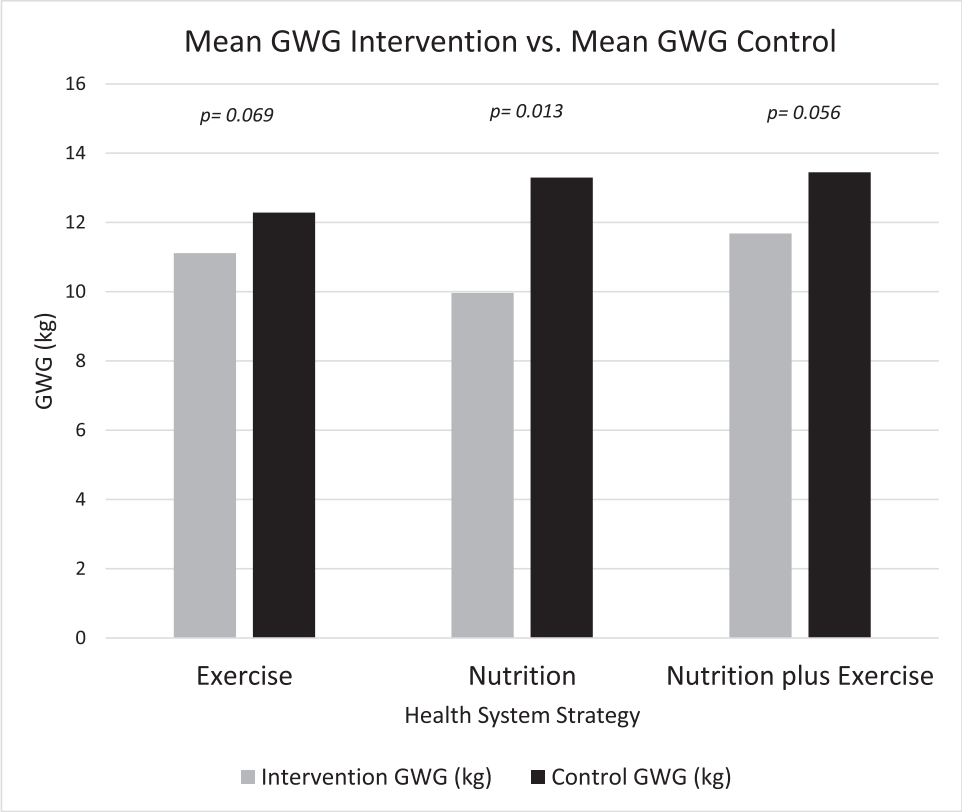

Fig. 3 Mean gestational weight gain (GWG) (kg) of health system strategies intervention groups versus mean GWG control groups.

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[a]	−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
Aşcı 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-Hyövälti 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*)

Table 3 (*Continued*)

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[a]	−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	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
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
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[a]	−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)								
Overall total events: 4,207 (intervention), 4,279 (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.
[a]Stated as insignificant.

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.[6–8] Walker et al's (2018) meta-analysis of general population concerning nutrition only, exercise only, and nutrition plus exercise claimed

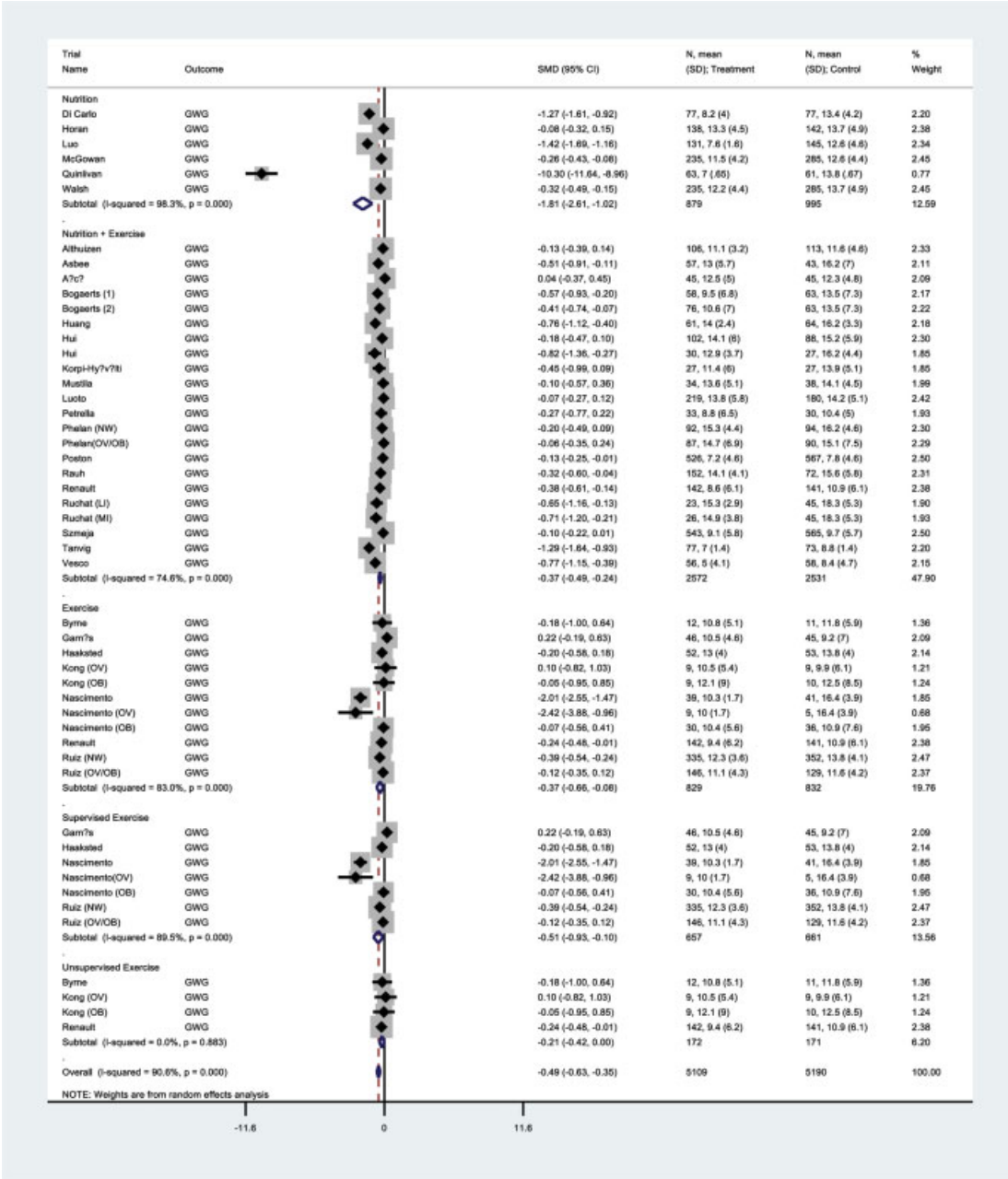

Fig. 4 Forest plot divided by subgroups.

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[10,17,27–29] and OV/OB except for one study.[10] Nutrition-plus-exercise interventions for general population were statistically significant.[14–21] Nutrition plus exercise for OV/OB were inconsistent, including a meta-analysis determining nutrition plus exercise as insignificant impact on GWG.[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.

Table 4 Per cent participants that exceed IOM recommendations

Study or subgroup	Intervention	Control
Nutrition		
Di Carlo et al (2014)	NR	NR
Horan et al (2016)	NR	NR
Luo et al (2014)	NR	NR
McGowan et al (2013)	33.2	44.7
Quinlivan et al (2011)	NR	NR
Walsh and McAuliffe (2015)	37.7	47.9
Nutrition plus exercise		
Althuizen et al (2013)	70.4	72.4
Asbee et al (2009)	61.4	48.8
Aşcı and Rathfisch (2016)	51.1	28.9
Bogaerts et al (2013) (1)	NR	NR
Bogaerts et al (2013) (2)	NR	NR
Huang et al (2011)	NR	NR
Hui et al (2012)	35.2	54.5
Hui et al (2014)	10	37
Korpi-Hyövälti et al (2011)	NR	NR
Luoto et al (2011)	NR	NR
Mustila et al (2012)	35.5	27.0
Petrella et al (2014)	33.3	60.8
Phelan et al (2011) (NW)	40.2	52.1
Phelan et al (2011) (OV/OB)	66.7	61.1
Poston et al (2015)	NR	NR
Rauh et al (2013)	38.2	59.5
Renault et al (2014)	NR	NR
Ruchat et al (2012) (LI)	35	53
Ruchat et al (2012) (MI)	31	53
Szmeja et al (2014)	NR	NR
Tanvig et al (2015)	NR	NR
Vesco et al (2014)	44	82
Exercise		
Byrne et al (2011)	NR	NR
Garnæs et al (2016)	58.3	44.4
Haakstad and Bø (2011)	33	38
Kong et al (2014) (OV)	44.4	50
Kong et al (2014) (OB)	77.8	77.8
Nascimento et al (2011)	47	57
Nascimento et al (2011) (OV)	NR	NR
Nascimento et al (2011) (OB)	NR	NR
Renault et al (2014)	NR	NR
Ruiz et al (2013) (NW)	23.8	32
Ruiz et al (2013) (OV/OB)	NR	NR
Supervised exercise		
Garnæs et al (2016)	58.3	44.4
Haakstad and Bø (2011)	33	38
Nascimento et al (2011)	47	57
Nascimento el al (2011) (OV)	NR	NR
Nascimento et al (2011) (OB)	NR	NR
Ruiz et al (2013) (NW)	23.8	32
Ruiz et al (2013) (OV/OB)	NR	NR
Unsupervised exercise		
Byrne et al (2011)	NR	NR
Kong et al (2014) (OV)	44.4	50
Kong et al (2014) (OB)	77.8	77.8
Renault et al (2014)	NR	NR

Abbreviations: IOM, Institute of Medicine; LI, low intensity; MI, moderate intensity; NR not reported; NW, normal weight; OB, obesity; OV, overweight.

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.

References

1 Ogden CL, Carroll MD, Fryar CD, Flegal KM. Prevalence of obesity among adults and youth: United States, 2011-2014. NCHS Data Brief 2015;219(219):1–8
2 Stang J, Huffman LG. Position of the academy of nutrition and dietetics: obesity, reproduction, and pregnancy outcomes. J Acad Nutr Diet 2016;116(04):677–691
3 Oken E, Taveras EM, Kleinman KP, Rich-Edwards JW, Gillman MW. Gestational weight gain and child adiposity at age 3 years. Am J Obstet Gynecol 2007;196(04):322.e1–322.e8
4 Rasmussen KM, Catalano PM, Yaktine AL. New guidelines for weight gain during pregnancy: what obstetrician/gynecologists should know. Curr Opin Obstet Gynecol 2009;21(06):521–526
5 Gardner B, Wardle J, Poston L, Croker H. Changing diet and physical activity to reduce gestational weight gain: a meta-analysis. Obes Rev 2011;12(07):e602–e620
6 Koutelidakis AE, Alexatou O, Kousaiti S, et al. Higher adherence to Mediterranean diet prior to pregnancy is associated with decreased risk for deviation from the maternal recommended gestational weight gain. Int J Food Sci Nutr 2018;69(01):84–92
7 Walker R, Bennett C, Blumfield M, et al. Attenuating pregnancy weight gain-what works and why: a systematic review and meta-analysis. Nutrients 2018;10(07):944
8 Abdel-Aziz SB, Hegazy IS, Mohamed DA, Abu El Kasem MMA, Hagag SS. Effect of dietary counseling on preventing excessive weight gain during pregnancy. Public Health 2018;154:172–181
9 Quinlivan JA, Julania S, Lam L. Antenatal dietary interventions in obese pregnant women to restrict gestational weight gain to Institute of Medicine recommendations: a meta-analysis. Obstet Gynecol 2011;118(06):1395–1401
10 Shieh C, Cullen DL, Pike C, Pressler SJ. Intervention strategies for preventing excessive gestational weight gain: systematic review and meta-analysis. Obes Rev 2018;19(08):1093–1109
11 Robertson N, Ladlow B. Effect of individual dietetic intervention on gestational weight gain and associated complications in obese pregnant women. Aust N Z J Obstet Gynaecol 2018;58(03):274–277
12 Dorise B, Byth K, McGee T, Wood A, Blumenthal C. A low intensity dietary intervention for reducing excessive gestational weight gain in an overweight and obese pregnant cohort. Eat Weight Disord 2018;•••;. Doi: 10.1007/s40519-018-0566-2
13 Streuling I, Beyerlein A, Rosenfeld E, Hofmann H, Schulz T, von Kries R. Physical activity and gestational weight gain: a meta-analysis of intervention trials. BJOG 2011;118(03):278–284
14 Shepherd E, Gomersall JC, Tieu J, Han S, Crowther CA, Middleton P. Combined diet and exercise interventions for preventing gestational diabetes mellitus. Cochrane Database Syst Rev 2017;11:CD010443
15 Liu YQ, Liu Y, Hua Y, Chen XL. Effect of diet and exercise intervention in Chinese pregnant women on gestational weight gain and perinatal outcomes: a quasi-experimental study. Appl Nurs Res 2017;36:50–56
16 Broekhuizen K, Simmons D, Devlieger R, et al. Cost-effectiveness of healthy eating and/or physical activity promotion in pregnant women at increased risk of gestational diabetes mellitus: economic evaluation alongside the DALI study, a European multicenter randomized controlled trial. Int J Behav Nutr Phys Act 2018;15(01):23
17 Nobles C, Marcus BH, Stanek EJ III, et al. The effect of an exercise intervention on gestational weight gain: the Behaviors Affecting Baby and You (B.A.B.Y.) study: a randomized controlled trial. Am J Health Promot 2018;32(03):736–744
18 Chan RS, Tam WH, Ho IC, et al. Randomized trial examining effectiveness of lifestyle intervention in reducing gestational diabetes in high risk Chinese pregnant women in Hong Kong. Sci Rep 2018;8(01):13849
19 Morison PN, Bacardi-Gascon M, Lopez-Corrales M, Jimenez-Cruz A. Combined dietary-exercise intervention for gestational weight gain and birthweight: a meta-analysis. Asia Pac J Clin Nutr 2018; 27(04):860–868
20 Rogozińska E, Marlin N, Betrán AP, et al. Effect of diet and physical activity based interventions in pregnancy on gestational weight gain and pregnancy outcomes: meta-analysis of individual participant data from randomised trials. BMJ 2017; 358:j3119
21 Sagedal LR, Øverby NC, Bere E, et al. Lifestyle intervention to limit gestational weight gain: the Norwegian Fit for Delivery randomised controlled trial. BJOG 2017;124(01):97–109
22 Cahill AG, Haire-Joshu D, Cade WT, et al. Weight control program and gestational weight gain in disadvantaged women with overweight or obesity: a randomized clinical trial. Obesity (Silver Spring) 2018;26(03):485–491
23 Yeo S, Walker JS, Caughey MC, Ferraro AM, Asafu-Adjei JK. What characteristics of nutrition and physical activity interventions are key to effectively reducing weight gain in obese or overweight pregnant women? A systematic review and meta-analysis. Obes Rev 2017;18(04):385–399
24 Van Horn L, Peaceman A, Kwasny M, et al. Dietary approaches to stop hypertension diet and activity to limit gestational weight: maternal offspring metabolics family intervention trial, a technology enhanced randomized trial. Am J Prev Med 2018;55(05): 603–614
25 Peaceman AM, Clifton RG, Phelan S, et al; LIFE-Moms Research Group. Lifestyle interventions limit gestational weight gain in women with overweight or obesity: LIFE-Moms prospective meta-analysis. Obesity (Silver Spring) 2018;26(09):1396–1404
26 Haby K, Berg M, Gyllensten H, Hanas R, Premberg Å. Mighty Mums - a lifestyle intervention at primary care level reduces gestational weight gain in women with obesity. BMC Obes 2018;5(01):16
27 Daly N, Farren M, McKeating A, O'Kelly R, Stapleton M, Turner MJ. A medically supervised pregnancy exercise intervention in obese women: a randomized controlled trial. Obstet Gynecol 2017;130 (05):1001–1010
28 Wang C, Wei Y, Zhang X, et al. A randomized clinical trial of exercise during pregnancy to prevent gestational diabetes mellitus and improve pregnancy outcome in overweight and obese pregnant women. Am J Obstet Gynecol 2017;216(04):340–351
29 Du MC, Ouyang YQ, Nie XF, Huang Y, Redding SR. Effects of physical exercise during pregnancy on maternal and infant outcomes in overweight and obese pregnant women: a meta-analysis. Birth 2018;•••;. Doi: 10.1111/birt.12396
30 Muktabhant B, Ta L, Lumbiganon P, Laopaiboon M. Diet or exercise, or both, for preventing excessive weight gain in pregnancy (review) summary of the findings for the main comparison. Cochrane Database Syst Rev 2015;(06):CD007145
31 Di Carlo C, Iannotti G, Sparice S, et al. The role of a personalized dietary intervention in managing gestational weight gain: a prospective, controlled study in a low-risk antenatal population. Arch Gynecol Obstet 2014;289(04):765–770
32 Horan MK, McGowan CA, Gibney ER, Byrne J, Donnelly JM, McAuliffe FM. Maternal nutrition and glycaemic index during pregnancy impacts on offspring adiposity at 6 months of age analysis from the ROLO randomised controlled trial. Nutrients 2016;8(01):13–15
33 Luo X-D, Dong X, Zhou J. Effects of nutritional management intervention on gestational weight gain and perinatal outcome. Saudi Med J 2014;35(10):1267–1270
34 McGowan CA, Walsh JM, Byrne J, Curran S, McAuliffe FM. The influence of a low glycemic index dietary intervention on maternal dietary intake, glycemic index and gestational weight gain during pregnancy: a randomized controlled trial. Nutr J 2013;12 (01):140
35 Quinlivan JA, Lam LT, Fisher J. A randomised trial of a four-step multidisciplinary approach to the antenatal care of obese pregnant women. Aust N Z J Obstet Gynaecol 2011;51(02):141–146
36 Walsh JM, McAuliffe FM. Impact of maternal nutrition on pregnancy outcome–does it matter what pregnant women eat? Best Pract Res Clin Obstet Gynaecol 2015;29(01):63–78

37 Althuizen E, van der Wijden CL, van Mechelen W, Seidell JC, van Poppel MNM. The effect of a counselling intervention on weight changes during and after pregnancy: a randomised trial. BJOG 2013;120(01):92–99

38 Asbee SM, Jenkins TR, Butler JR, White J, Elliot M, Rutledge A. Preventing excessive weight gain during pregnancy through dietary and lifestyle counseling: a randomized controlled trial. Obstet Gynecol 2009;113(2 Pt 1):305–312

39 Aşcı Ö, Rathfisch G. Effect of lifestyle interventions of pregnant women on their dietary habits, lifestyle behaviors, and weight gain: a randomized controlled trial. J Health Popul Nutr 2016; 35:7

40 Bogaerts AF, Devlieger R, Nuyts E, Witters I, Gyselaers W, Van den Bergh BRH. Effects of lifestyle intervention in obese pregnant women on gestational weight gain and mental health: a randomized controlled trial. Int J Obes 2013;37(06):814–821

41 Huang TT, Yeh CY, Tsai YC. A diet and physical activity intervention for preventing weight retention among Taiwanese childbearing women: a randomised controlled trial. Midwifery 2011; 27(02):257–264

42 Hui A, Back L, Ludwig S, et al. Lifestyle intervention on diet and exercise reduced excessive gestational weight gain in pregnant women under a randomised controlled trial. BJOG 2012;119(01): 70–77

43 Hui AL, Back L, Ludwig S, et al. Effects of lifestyle intervention on dietary intake, physical activity level, and gestational weight gain in pregnant women with different pre-pregnancy body mass index in a randomized control trial. BMC Pregnancy Childbirth 2014;14:331

44 Korpi-Hyövälti EA, Laaksonen DE, Schwab US, et al. Feasibility of a lifestyle intervention in early pregnancy to prevent deterioration of glucose tolerance. BMC Public Health 2011;11:179

45 Luoto R, Kinnunen TI, Aittasalo M, et al. Primary prevention of gestational diabetes mellitus and large-for-gestational-age newborns by lifestyle counseling: a cluster-randomized controlled trial. PLoS Med 2011;8(05):e1001036

46 Mustila T, Raitanen J, Keskinen P, Saari A, Luoto R. Lifestyle counseling during pregnancy and offspring weight development until four years of age: follow-up study of a controlled trial. J Negat Results Biomed 2012;11:11

47 Petrella E, Malavolti M, Bertarini V, et al. Gestational weight gain in overweight and obese women enrolled in a healthy lifestyle and eating habits program. J Matern Fetal Neonatal Med 2014;27 (13):1348–1352

48 Phelan S, Phipps MG, Abrams B, Darroch F, Schaffner A, Wing RR. Randomized trial of a behavioral intervention to prevent excessive gestational weight gain: the Fit for Delivery Study. Am J Clin Nutr 2011;93(04):772–779

49 Poston L, Bell R, Croker H, et al; UPBEAT Trial Consortium. Effect of a behavioural intervention in obese pregnant women (the UPBEAT study): a multicentre, randomised controlled trial. Lancet Diabetes Endocrinol 2015;3(10):767–777

50 Rauh K, Gabriel E, Kerschbaum E, et al. Safety and efficacy of a lifestyle intervention for pregnant women to prevent excessive maternal weight gain: a cluster-randomized controlled trial. BMC Pregnancy Childbirth 2013;13:151

51 Renault KM, Nørgaard K, Nilas L, et al. The Treatment of Obese Pregnant Women (TOP) study: a randomized controlled trial of the effect of physical activity intervention assessed by pedometer with or without dietary intervention in obese pregnant women. Am J Obstet Gynecol 2014;210(02):134.e1–134.e9

52 Ruchat SM, Davenport MH, Giroux I, et al. Nutrition and exercise reduce excessive weight gain in normal-weight pregnant women. Med Sci Sports Exerc 2012;44(08):1419–1426

53 Szmeja MA, Cramp C, Grivell RM, Deussen AR, Yelland LN, Dodd JM. Use of a DVD to provide dietary and lifestyle information to pregnant women who are overweight or obese: a nested randomised trial. BMC Pregnancy Childbirth 2014;14:409

54 Tanvig M, Vinter CA, Jørgensen JS, et al. Effects of lifestyle intervention in pregnancy and anthropometrics at birth on offspring metabolic profile at 2.8 years: results from the Lifestyle in Pregnancy and Offspring (LiPO) study. J Clin Endocrinol Metab 2015;100(01):175–183

55 Vesco KK, Karanja N, King JC, et al. Efficacy of a group-based dietary intervention for limiting gestational weight gain among obese women: a randomized trial. Obesity (Silver Spring) 2014;22 (09):1989–1996

56 Byrne NM, Groves AM, McIntyre HD, Callaway LK; BAMBINO group. Changes in resting and walking energy expenditure and walking speed during pregnancy in obese women. Am J Clin Nutr 2011;94(03):819–830

57 Garnæs KK, Mørkved S, Salvesen Ø, Moholdt T. Exercise training and weight gain in obese pregnant women: a randomized controlled trial (ETIP trial). PLoS Med 2016;13(07):e1002079

58 Haakstad LA, Bø K. Effect of regular exercise on prevention of excessive weight gain in pregnancy: a randomised controlled trial. Eur J Contracept Reprod Health Care 2011;16(02):116–125

59 Kong KL, Campbell CG, Foster RC, Peterson AD, Lanningham-Foster L. A pilot walking program promotes moderate-intensity physical activity during pregnancy. Med Sci Sports Exerc 2014;46 (03):462–471

60 Nascimento SL, Surita FG, Parpinelli MÂ, Siani S, Pinto e Silva JL. The effect of an antenatal physical exercise programme on maternal/perinatal outcomes and quality of life in overweight and obese pregnant women: a randomised clinical trial. BJOG 2011;118(12):1455–1463

61 Ruiz JR, Perales M, Pelaez M, Lopez C, Lucia A, Barakat R. Supervised exercise-based intervention to prevent excessive gestational weight gain: a randomized controlled trial. Mayo Clin Proc 2013;88(12):1388–1397