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Review

Does dose matter in reducing gestational weight gain in exercise interventions? A systematic review of literature

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A B S T R A C T

Objectives: The purpose of this review was to examine the relationship between exercise dose and reductions in weight gain during pregnancy in exercise interventions.
Design: Systematic literature review.
Methods: Four electronic research databases (PubMed, Web of Science, CINAHL, and Academic Search Premiere) were used to identify exercise interventions conducted with pregnant women. Eligible articles must have satisfied the following criteria: inclusion of a control condition, exercise as a major intervention component, weight gain measured and reported for each experimental condition, description of exercise dose (frequency, intensity and duration), and utilized an adequate number of control conditions to assess independent effects of exercise on weight gain.
Results: The literature search identified 4837 articles. Of these, 174 abstracts were screened and 21 intervention studies (18 exercise-only, 3 exercise/diet) were eligible for review. Only 38% of the interventions achieved statistically significant reductions in gestational weight gain. Successful interventions possessed higher adherence and lower attrition rates and were predominantly conducted among normal weight populations. No clear patterns or consistencies of exercise dose and reductions in weight gain were evident.
Conclusions: An exercise dose associated with reductions in weight gain was unquantifiable among these interventions. Adherence and retention rates were strong contributors to the success of exercise interventions on gestational weight gain. It is strongly suggested that future researchers investigate methods to increase adherence and compliance, especially among overweight and obese women, and utilize objective measurement tools to accurately evaluate exercise dose performed by the participants and the impact on body composition and weight gain.

1. Introduction

Evidence suggests that maternal physical activity (PA) has decreased substantially over the past half century,[1,2] in concert with a significant increase in the prevalence of excessive gestational weight gain (GWG) during pregnancy.[3,4] Given that PA is an absolute requirement for metabolic control[5] and that the partitioning of nutrient-energy between the mother and fetus is a major determinant of birth outcomes,[6,7] any perturbation of maternal energy metabolism (e.g., increased adiposity, decrements in glycemic control) may induce significant pathologies.[7] Excessive weight gain during pregnancy is associated with several maternal-fetal complications.[7–11] Exercise, defined as planned, structured, and repetitive movements with the objective of increasing or maintaining physical fitness,[12] has been identified, in addition to diet,[13] as a potential contributing solution to excessive GWG due to its profound effects on energy metabolism (e.g., glycemic control[14,15]) and may be integral in weight management during pregnancy.[16]

In non-pregnant populations, there is fairly strong evidence that exercise is associated with weight maintenance among men and women.[17] To achieve weight maintenance, defined as a 1% to 3% change in weight, evidence suggests that individuals should engage in at least 150–300 min of moderate exercise per week.[18] However, during pregnancy the exercise dose for weight maintenance or reduced weight gain is largely unknown. Currently, the American College of Obstetricians and Gynecologists (ACOG) recommends that pregnant women engage in at least 30 min of

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moderate intensity exercise on 'most' days of the week.[19] These guidelines were largely based on evidence regarding the effect of exercise on maternal-fetal complications (e.g. adverse birth outcomes, metabolic conditions, preterm delivery) rather than on the potential impact on GWG and its associated outcomes.

The evidence from previous systematic reviews and meta-analyses assessing the effects of exercise interventions on weight gain during pregnancy appears weak as the findings are inconsistent.[16,20,21] The equivocal nature of the findings may be attributable to only a small number of reviews having assessed the *independent* effects of exercise on weight gain, potentially making it difficult to draw robust conclusions. Additionally, the inconsistency among the findings of these reviews may be in part due to the selection criteria utilized (e.g. restricting samples to overweight and obese women, requiring GWG to be a primary or secondary outcome), or that the prescription of an exercise dose may have been insufficient to reduce weight gain. The latter limitation has largely been ignored in the literature and considering the strong evidence regarding the relationship between exercise dose and weight stability among non-pregnant populations, it is essential to investigate whether this relationship exists among pregnant women. Therefore, the purpose of this study was to systematically review the current literature and examine the exercise dose prescribed in interventions during pregnancy and its influence on GWG. We hypothesized that exercise interventions that were successful at reducing weight gain during pregnancy assigned higher doses of exercise compared to unsuccessful exercise interventions, thereby potentially demonstrating a dose–response effect.

2. Methods

A systematic review of experimental exercise trials was conducted following the PRISMA (preferred reporting items for systematic review and meta-analysis) statement (Supplementary Table 1).[22] The primary author (SM) conducted an electronic search in four research databases, Pubmed, Web of Science, CINAHL and Academic Search Premiere, from inception to February 17th, 2014. We used the following keywords with various combinations to ascertain peer-reviewed articles: ('pregnancy' OR 'prenatal' OR 'antenatal') AND ('intervention' OR 'trial') AND ('physical activity' OR 'aerobic' OR 'exercise') AND ('weight' OR 'weight gain' OR 'gestational weight gain') AND ('overweight' OR 'obese' OR 'obesity') AND ('diet' OR 'nutrition'). In addition, references of obtained articles were scanned to ensure a complete collection of literature. Search strategies for all research databases used can be found in Supplementary Table 2. The inclusion criteria for this review were:

1. Inclusion of any control condition (e.g., concurrent, historical, wait-list),
2. GWG measured and reported for each condition,
3. Inclusion of any intervention with exercise as the primary focus (e.g., exercise training, PA counseling)
4. Complete description of the exercise dose (frequency, duration, and intensity), and
5. In the case of multiple intervention arms (i.e. exercise and diet), a sufficient number of experimental/control conditions (e.g. exercise-only, exercise plus diet, and/or control conditions) must have been utilized in order to examine the independent effect of exercise on GWG.

There were no restrictions placed on year of publication, country, pre-pregnancy body mass index (BMI) or gestational age at study entry. Additionally, we did not require that GWG be a primary or secondary outcome of the study as long as GWG was reported in the studies. Previous reviews have typically only included interventions with GWG as a primary or secondary outcome, which might have precluded the discovery of potentially effective interventions.[23,24] Moreover, studies following women into the postpartum period were also included.

We extracted the following data for each eligible study. Study characteristics consisted of information on study author, publication years, study design, sample size, and location. Participant characteristics included maternal age, gestational age at onset of the intervention, racial/ethnic composition, and anthropometrics (i.e. BMI, percent body fat, weight). Intervention characteristics consisted of whether the intervention sessions were supervised, intervention duration, type of intervention (exercise only or exercise and diet), type of control condition, adherence, attrition, intervention venue (e.g. laboratory, gym, home), and exercise-related injuries and/or maternal-fetal complications. Further, information on exercise dose (i.e. frequency, intensity and duration), PA and sedentary behaviors was extracted. Additionally, information regarding the statistical methods, measures of GWG, and the effect of the exercise intervention on GWG for each intervention condition was also extracted.

Prior to analyzing the extracted data, interventions were classified into two groups, 'successful' and 'unsuccessful', based on their effect on weight gain. A 'successful' intervention was defined as a statistically significant difference ($p < 0.05$) in weight gain at post-intervention between the exercise and control conditions. Characteristics of 'successful' interventions were then identified. Additionally, the difference in weight gain between the exercise and control conditions was calculated to examine the extent to which the exercise regimens may have prevented weight gain for both the 'successful' and 'unsuccessful' interventions (weight $\text{gain}_{\text{exercise}}$–weight $\text{gain}_{\text{control}}$). Negative differences indicated that women in the exercise condition had lower GWG compared to the control condition. Positive differences indicated that women in the control condition had lower GWG compared to the exercise condition.

3. Results

The identification of eligible intervention studies is summarized in Fig. 1. First, we identified 4837 potential articles from four databases (Pubmed [$n = 1720$], Web of Science [$n = 1671$], CINHAL [$n = 422$] and Academic Search Premiere [$n = 1024$]). Two additional articles were identified through reference tracking. All titles were screened for relevancy, of which 783 articles were selected for further screening. Of these, 609 articles were excluded due to irrelevancy ($n = 356$) and duplications ($n = 253$), resulting in 174 abstracts selected for the initial review. Second, of the 174 abstracts reviewed, 120 failed to meet the inclusion criteria and were excluded (see Fig. 1 for reasons for exclusion). The remaining 54 full-text articles were assessed for eligibility, of which 33 were excluded. Eighty-five percent of the 33 articles were deemed ineligible because these studies either did not provide a sufficient number of control conditions to adequately assess the independent effect of exercise on GWG ($n = 13$) or failed to provide a complete description of the dose of exercise ($n = 15$) implemented in the intervention. As a result, 21 studies were eligible for the final review: 18 were exercise only[25–42] and 3 were exercise and diet.[43–45]

Six studies were conducted in the United States,[25,29,32,37–39] two in Canada,[43,45] three in Brazil,[27,40,44] two in Norway,[33,35] three in Spain,[28,41,42] one in the Netherlands,[30] two in Iran,[26,36] one in Australia,[31] and one in New Zealand.[34] Eighty-six percent ($n = 18$) employed a randomized controlled study design[25–32,34–36,38–44] and three studies used a quasi-experimental study design.[33,37,45] Sample sizes varied considerably across the studies ($N = 12$ to 962).

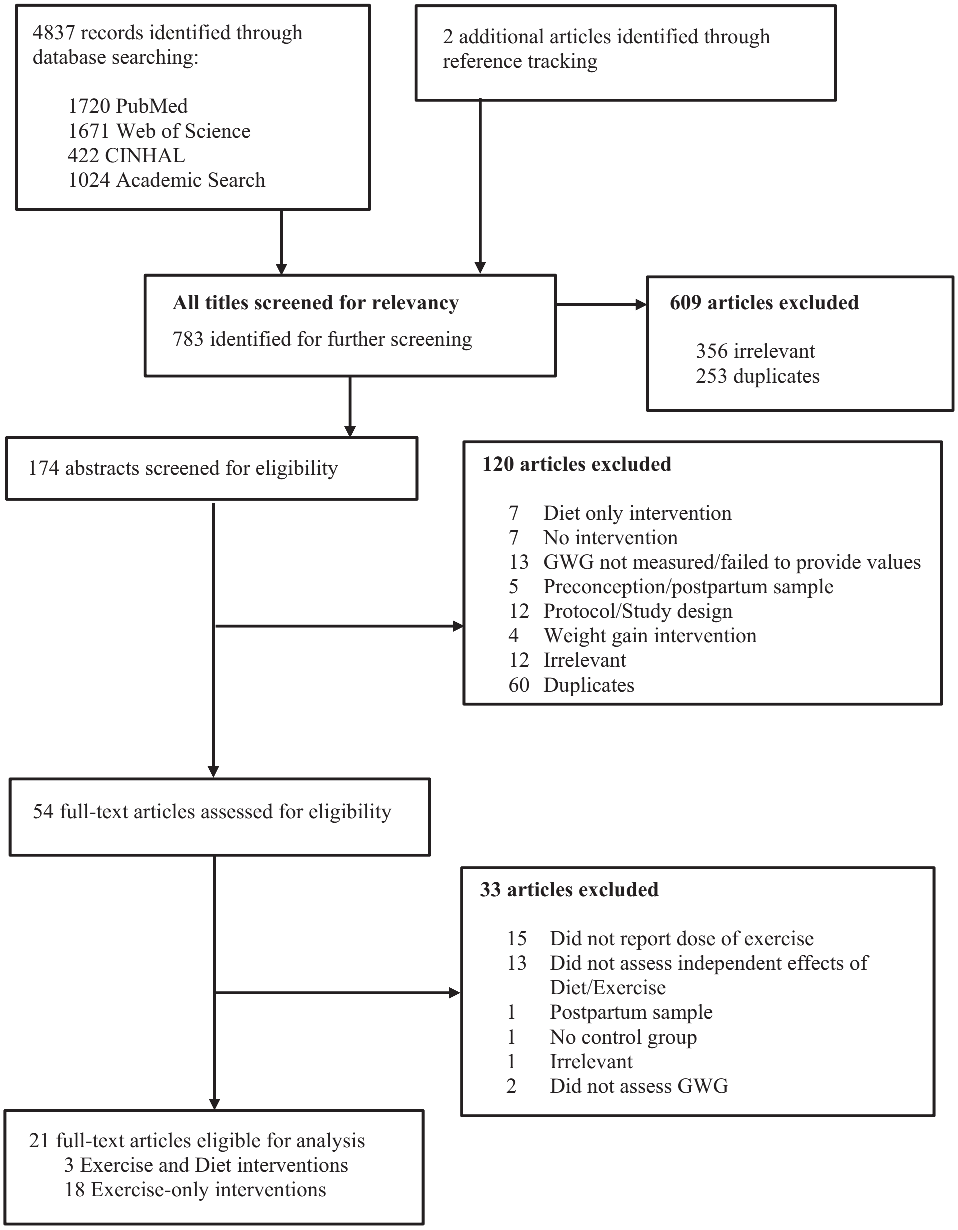

Fig. 1. Flow chart of study identification and ascertainment process.

The mean age of the pregnant women ranged from 23.2 to 33.4 years. These studies varied considerably in weeks of gestation at intervention onset, ranging from eight weeks[38,39] to 24–28 weeks of gestation.[45] Four studies implemented their intervention in the first trimester (8–12 weeks of gestation),[28,38,39,41] while the remaining 17 studies started their exercise programs in the second trimester (13–28 weeks of gestation).[25–27,29–37,40,42–45] The racial/ethnic composition of the study samples was only reported in four studies (19%)[25,29,30,34] of which three studies reported a predominantly White sample.[25,30,34] Moreover, ten of the 21 studies either restricted their sample to normal weight women or a majority of their sample was of normal weight.[26,28,32,35,38–43] Nine studies were conducted in overweight or obese populations,[25,27,29–31,34,36,44,45] of which five studies[27,30,31,44,45] restricted their enrollment to overweight/obese women and four studies[25,29,34,36] did not apply any BMI restrictions. The BMI or percent body fat of the participants were unknown in two studies as the authors only reported pre-pregnancy weight in kilograms.[33,37]

Eight studies enrolled an underactive sample population.[25,28,29,31,32,35,40,42] Definitions of 'underactive' varied across the studies and included: not exercising > 20 min more than once a week,[28,42] no aerobic exercise more than once per week in the past 6 months,[29] no participation in a structured program > 60 min once per week or brisk walking > 120 min per week,[35] not exercising on a regular basis at least one year prior to conception,[32] daily PA energy expenditure < 840 kcal per week,[25] or no definition provided.[31,40] Eight studies reported information on PA behaviors,[25,27,30,31,33,35,42,45] only three studies tested between-group differences in PA across pregnancy, of which one found a significant result[25] and two found no differences in PA.[30,31] Five studies assessed PA to provide additional participant information (e.g. baseline characteristics, confounding variable).[27,33,35,42,45]

A majority of the studies ($n = 17$) instructed participants in control condition to adhere to their current prenatal care routine.[26,28–32,34–37,39–45] Conversely, in two studies, the control condition consisted of a stretching routine[25,27] and in two other studies the control condition participated in a lower level of exercise intensity.[33,38] Duration of interventions differed considerably across the studies ranging from eight weeks[26] to 30 weeks.[28] Of the 21 intervention studies, 16 provided supervised exercise sessions throughout the intervention[26–32,35–39,41,42,44] and three interventions implemented unsupervised exercise sessions.[33,34,45] One study required participants to attend at least one supervised exercise session per week.[43] The remaining study decreased the number of supervised exercise sessions over the duration of the intervention.[25] Fifteen interventions were conducted at a designated facility (e.g. hospital, gym, exercise laboratory).[25–30,32,35–42] Three interventions consisted of solely home-based exercise programs,[31,33,34] and three others were partly home and facility-based (e.g. hospital, gym, exercise laboratory).[43–45] Adherence to the exercise programs ranged from 16%[30] to 97%.[28] Four studies did not report any detail regarding adherence to the exercise program.[32,33,37,45] Similarly, attrition varied considerably among the studies (0%[33,45] to 40%[32]). Three studies did not report on study attrition.[25,31,37] Moreover, the incidence of maternal-fetal complications was low, with only a few occurring in most studies. A majority of the studies (67%) reported maternal-fetal complications as reasons for discontinuation of the study or incidences that occurred after the intervention,[26,27,34,35,38,39,42] as an outcome and/or sample characteristic[30,40,44] or a combination of these reasons.[28,29,33,41] The remaining studies did not report any information on maternal-fetal complications.[25,31,32,36,37,43,45] Additionally, four studies reported that "no exercise-related injuries arose during the intervention period,"[30,35,42,44] while the remaining studies did not provide this information.[25–29,31–39,41,43,45]

Eleven of the 21 studies designed their programs aligning with the ACOG PA guidelines.[19,25–30,35,36,40,41,44] One study followed the American College of Sports Medicine (ACSM) PA guidelines for pregnant women.[37,46] Two studies used the Canadian guidelines for PA.[43,45,47] One of these two studies also utilized the ACSM guidelines in addition to the Canadian guidelines for PA during pregnancy.[43] One study modified their program to require more vigorous levels of intensity than ACOG guidelines.[32] Six studies did not mention which guidelines, if any, were used when developing their interventions.[31,33,34,38,39,42]

Exercise doses varied substantially across the studies. Frequency of the exercise programs ranged from one to six days per week, with three days as the most prescribed frequency ($n = 14$).[26–28,31,32,35–37,39–43,45] Likewise, duration varied from 15 min to 90 min per session. Intensity of the exercise program had the greatest variability of all the components. Exercise intensity was measured via four different methods: percent of age-predicted maximum heart rate (%APMHR/%HR_{max} [$n = 8$][25–28,31,40–42]), percent heart rate reserve (%HRR [$n = 2$][43,45]), percent of peak or maximal oxygen consumption (%$VO_{2\ peak/max}$ [$n = 4$][34,37–39]), or rating of perceived exertion (RPE/Borg Scale [$n = 6$][25–28–31,35]). Four studies did not describe their method used to determine the prescribed exercise intensity.[32,33,36,44] For studies using the APMHR method, intensities ranged from low (50%)[27,31] to moderate (<80%).[42] Studies using %HRR, intensity varied from low (30%)[43,45] to vigorous (70%).[43] Studies using %$VO_{2\ peak/max}$ ranged from moderate (55%)[38,39] to vigorous (70%).[37] Lastly, those studies utilizing the RPE/Borg scale, one study[28] used 10 on the scale which equated to light intensity while three studies used 12 to 14 on the scale which corresponded to moderate intensity.[25,29,35] Four studies reported target heart rates for the exercise program; however the method used to determine these values was not described.[32,33,36,44]

In order to determine whether participants were adhering to the prescribed exercise intensity, studies used several objective and subjective tools that measured physiological responses to exercise (e.g., heart rate, CO_2 production, fatigue). The tools used to determine the adherence to exercise intensities varied among the studies. Twelve of the 21 studies used only heart rate monitors during exercise sessions.[26,27,32–34,40,42,43,45] Two studies manually assessed heart rates during each exercise session.[36,37] Four studies used the RPE/Borg scale[29–31,35] and three used both heart rate monitors and the RPE/Borg scale.[25,28,41] Two studies used indirect calorimetry; however this was only done once every two weeks.[38,39] The remaining study did not specify any method used to monitor exercise intensity during the exercise sessions.[44] In addition, 17 of the 21 studies did not report mean intensity level[26–30,32–36,38–42,44,45] one study reported an average %HRR,[43] and one study reported an average value on the Borg Scale.[31] Two studies provided average heart rates but the relative exercise intensity (i.e. %HRR, %$VO_{2\ peak/max}$) was unclear.[25,37]

GWG was the primary outcome in seven studies,[26,28,35,40,42,43,45] the secondary outcome in four studies,[29,33,38,39] one of several outcomes in five studies[25,30,32,41,44] and simply a measurement for maternal characteristics in five studies.[27,31,34,36,37] The measurement of GWG varied across the studies. All 21 studies reported total weight gain; 13 of them used this measure as their sole outcome.[26,27,29–34,36,37,39,40,42] Weekly rate of GWG was reported in three studies.[43–45] GWG status (i.e. excessive, adequate and inadequate) as categorized by the 2009 Institute of Medicine (IOM) guidelines was reported in six studies.[25,28,35,41,43,45] Eight studies included at least two of the aforementioned measures of GWG.[25,28,35,38,41,43–45]

The characteristics of 'successful' and 'unsuccessful' interventions are depicted in Tables 1 and 2, respectively. Out of the 21 studies, eight interventions were 'successful'[26,28,33,35,38,41,43,44] and 13 were 'unsuccessful' [25,27,29–32,34,36,37,39,40,42,45] at reducing weight gained during pregnancy. Although the study characteristics were generally similar across the categories (e.g. sample size, study design, exercise dose etc.), there were several notable differences between the 'successful' and 'unsuccessful' interventions. Among the 'successful' interventions, 75% ($n = 6$) of the studies were conducted in women with normal pre-pregnancy BMI.[26,28,35,38,41,43] Conversely, 62% ($n = 8$) of the 'unsuccessful' interventions were implemented in overweight and obese populations.[25,27,29–31,34,36,45] The prescribed exercise doses did not greatly differ between the 'successful' and 'unsuccessful' interventions; however adherence and attrition rates were very different. Sixty-three percent ($n = 5$) of the 'successful' interventions had an adherence rate of ≥70%,[26,28,35,38,41] whereas only 46% of the 'unsuccessful' studies reached this level of adherence.[29,31,34,36,39,42] Moreover, the proportion of 'successful' studies achieving ≤20% attrition was 63%[26,28,33,38,44] vs 23%[39,42,45] in the 'unsuccessful' studies. Furthermore, 63%[28,33,38,41,43] of the 'successful' studies implemented interventions ≥20 weeks in duration, vs only 31%[25,29,39,42] in the 'unsuccessful' interventions. Seventy-five percent of 'successful' interventions[28,35,38,41,43,44] used at least two methods of measuring GWG vs only 15%[25,45] of the 'unsuccessful' interventions. Among the 'successful' interventions, the difference in weight gain between the exercise and control conditions ranged from −1.3 kg to −6.0 kg whereas the difference in weight gain for the 'unsuccessful' interventions ranged from −1.9 kg to +1.8 kg.

Similar to the comparison between 'successful' and 'unsuccessful' interventions, the doses of exercises among only 'successful' interventions also varied considerably. As such, there were no discernible patterns of exercise dose and the calculated reductions in weight gain within the 'successful' exercise interventions.

4. Discussion

The purpose of this review was to examine the relationship between exercise dose and weight gain during pregnancy in exercise interventions. No clear patterns or consistencies among the

Table 1
Study characteristics of 'successful' exercise interventions[†].

Author (year)	Study characteristics	Participant characteristics	Intervention characteristics	Exercise dose	GWG measure[‡]	Stat analysis	Results
Barakat[41] (2014)	RCT $N = 251$ Spain	**Age:** 31.57 y (EX) 31.51 y (CON) **Gestation:** 9–13 weeks **BMI:** 68.9% (NW) 23.6% (OW) 6.6% (OB) **Underactive sample?** NR	Supervised Duration: 27–30 weeks Exercise only **Adherence:** >95% **Attrition:** **EX:** 22% **CON:** 18%	**Frequency:** 3×/week **Duration:** 55–60 min **Intensity:** 55–60% HR_{max} **Progressive:** NR	Total GWG (4) %IOM Guidelines	Unpaired *t*-test χ^2 test	**Total GWG:** **EX:** 11.72 kg $p = 0.06$ **CON:** 13.66 kg **IOM Guidelines - Excessive** **EX:** 21.2% $p = 0.026$ **CON:** 35.6%
Clapp[38] (2002)	RCT $N = 80$ US	**Age:** 31 y (Lo-Hi) 30 y (Mod-Mod) 32 y (Hi-Lo) **Gestation:** 8 weeks **%Body Fat:** 19% (Lo-Hi) 18% (Mod-Mod) 19% (Hi-Lo) **Underactive sample?** NR	Supervised Duration: 29 weeks Exercise Only **Adherence:** >90% **Attrition:** 6% (combined)	**Lo-Hi:** **Frequency:** 5×/week **Duration:** 20 to 60 min (progressed up to week 24) **Intensity:** 55–60% $VO_{2\ max}$ **Mod-Mod:** **Frequency:** 5×/week **Duration:** 40 min **Intensity:** 55–60% $VO_{2\ max}$ **Hi-Lo:** **Frequency:** 5×/week **Duration:** 60 to 20 min (decreased until week 24) **Intensity:** 55–60% $VO_{2\ max}$ **Progressive:** Yes	Total GWG (4) % change in BF	ANOVA	**Total GWG:** **Lo-Hi:** 12 kg $p < 0.02$ (Lo-Hi vs Mod) **Mod-Mod:** 14.6 kg **Hi-Lo:** 15.5 kg $p < 0.02$ (Lo-Hi vs Hi-Lo) **Body Fat%** **Lo-Hi:** 2.8% $p < 0.02$ (Lo-Hi vs Mod) **Mod-Mod:** 4.2% **Hi-Lo:** 5.5% $p < 0.02$ (Lo-Hi vs Hi-Lo)
Haakstad[35] (2011)	RCT $N = 205$ Norway	**Age:** 31.2 y (EX) 30.3 y (CON) **Gestation:** 17.3 weeks (EX) 18.0 weeks (CON) **BMI:** 23.8 kg/m^2 (EX) 23.9 kg/m^2 (CON) **Underactive sample?** Yes	Supervised Duration: 12 weeks Exercise Only **Adherence:** 71% **Attrition:** **EX:** 19.2% **CON:** 20.8%	**Frequency:** 2–3/week **Duration:** 60 min **Intensity:** Moderate Borg Scale 12–14 **Progressive:** NR	Total GWG (1) %IOM Guidelines Excessive	ITT analysis Independent *t*-test χ^2 test	**Total GWG:** *ITT Analysis*: **EX:** 13.0 kg $p = 0.31$ **CON:** 13.8 kg *Per Protocol:* **EX:** 12.5 kg $p = 0.23$ **CON:** 13.8 kg *Attendance-24 sessions:* **EX:** 11.0 kg $p = 0.01$ **CON:** 13.8 kg **IOM Guidelines- Excessive:** *ITT Analysis:* **EX:** 33% $p = 0.59$ **CON:** 38% *Per Protocol:* **EX:** 19% $p = 0.12$ **CON:** 38% *Attendance-24 sessions:* **EX:** 0% $p = 0.006$ **CON:** 38%

Table 1 (*Continued*)

Author (year)	Study characteristics	Participant characteristics	Intervention characteristics	Exercise dose	GWG measure‡	Stat analysis	Results
Kardel[33] (1998)	Quasi *N* = 42 Norway	**Age:** 26.7 y (Moderate EX) 28.8 y (High EX) **Gestation:** 17 weeks **Weight:** 63.0 kg (Moderate EX) 59.4 kg (High EX) **Underactive sample?** NR	Not Supervised Duration: 20 weeks Exercise Only **Adherence:** NR **Attrition:** 0% (combined)	**Moderate EX:** *Interval Training:* **Frequency:** 2×/week **Duration:** 25 min **Intensity:** 170–180 bpm HR monitors *Endurance Training:* **Frequency:** 2×/week **Duration:** 1.5 h **Intensity:** 120–140 bpm *Strength Training:* **Frequency:** 2×/week **Duration:** 1 h 12 min **Intensity:** N/A **High EX:** *Interval Training:* **Frequency:** 2×/week **Duration:** 35 min **Intensity**: 170–180 bpm HR monitors *Endurance Training:* **Frequency:** 2×/week **Duration:** 2.5 h **Intensity:** 120–140 bpm *Strength Training:* **Frequency:** 2×/week **Duration:** 1 h 12 min **Intensity:** N/A **Progressive:** NR	Total GWG (1) by sex of child	One-way ANOVA	**Total GWG:** *GIRL* **Moderate EX:** 10.3 kg $p = 0.021$ **High EX:** 14.4 kg *BOY:* **Moderate EX:** 12.6 kg $p \geq 0.05$ **High EX:** 12.6 kg
Nascimento[44] (2009)	RCT *N* = 82 Brazil	**Age:** 29.7 y (EX) 30.9 y (CON) **Gestation:** 17.6 weeks (EX) 17.8 weeks (CON) **BMI:** 34.8 kg/m^2 (EX) 36.4 kg/m^2 (CON) **Underactive sample?** NR	Supervised Duration: 16 weeks Exercise and Diet–Both the EX and CON conditions received diet counselling **Adherence:** 62.5% **Attrition:** **EX:** 2.5% **CON:** 2.4%	**Frequency:** 1×/week **Duration:** 40 min **Intensity:** HR < 140 bpm **Home Counselling:** In addition to the prescribed exercise sessions, women received home exercise counselling 5x per week. Consisted of protocol exercises or walking **Progressive:** NR	Total GWG (1) Weekly GWG	Student's *t*-test Mann–Whitney *U* statistic	**Total GWG:** *Overweight* **EX:** 10.0 kg $p = 0.001$ **CON:** 16.4 kg *Obese* **EX:** 10.4 kg $p = 0.757$ **CON:** 10.9 kg **Weekly GWG:** *Overweight* **EX:** 0.28 kg $p = 0.038$ **CON:** 0.57 kg *Obese* **EX:** 0.39 kg $p = 0.577$ **CON:** 0.36 kg
Ruchat[43] (2012)	RCT *N* = 73 Canada	**Age:** 31 y Light Intensity (LI) 30.4 y Moderate Intensity (MI) **Gestation:** 17.5 weeks (LI) 17.0 weeks (MI) **BMI:** 22.1 kg/m^2 (LI) 21.7 kg/m^2 (MI) **Underactive sample?** NR	Supervised: 1 session required Duration: 21.5 week Exercise and Diet: LI and MI received diet program **Adherence:** **LI:** 55% **MI:** 67% **Attrition:** **EX:** 21.2% **CON:** 30.3%	**Frequency:** 3–4×/week **Duration:** 15 min Increased weekly by 2 min until 30 min reached **Intensity:** LI: 30% HRR MI: 70% HRR **Progressive:** Yes	Total GWG (4) Weekly GWG %IOM Guidelines	ANCOVA Covariates: pre-pregnancy body weight χ^2 test	**Total GWG:** **LI:** 15.3 kg $p = 0.72$ (LI vs MI) **MI:** 14.9 kg $p = 0.01$ (LI vs CON) **CON:** 18.3 kg $p = 0.003$ (MI vs CON) **Weekly GWG:** **LI:** 0.49 kg $p > 0.05$ **MI:** 0.47 kg **CON:** N/A* **IOM Guidelines–Excessive Prevented** **LI:** 70% $p = 0.32$ **MI:** 77% N/A in CON*

Ruiz[28] (2013)	RCT $N = 962$ Spain	**Age:** 31.9 y (EX) 31.6 y (CON) **Gestation:** 9 weeks **BMI:** 23.7 kg/m^2 (EX) 23.5 kg/m^2 (CON) **Underactive sample?** Yes	Supervised Duration: 30 weeks Exercise Only **Adherence:** 97% **Attrition:** **EX:** 14.1% **CON:** 14.5%	**Frequency:** 3×/week **Duration:** 50–55 min **Intensity:** <60% HR_{max} Borg Scale 10 **Progressive:** NR	Total GWG (1) %IOM Guidelines	ITT analysis One-way ANCOVA Covariates: age, gestational age, pre-gravid weight, education Logistic regression	**Total GWG** *Total Group* **EX:** 11.9 kg $p < 0.001$ **CON:** 13.2 kg *NW* **EX:** 12.3 kg $p < 0.001$ **CON:** 13.8 kg *OW/OB* **EX:** 11.1 kg $p = 0.51$ **CON:** 11.6 kg **IOM Guidelines - Excessive** *Total Group* **EX:** 23.8% (OR:0.625; $p = 0.002$) **CON:** 32.0% *NW* **EX:** 12.6% (OR: 0.508; $p = 0.001$) **CON:** 22.1% *OW/OB* **EX:** 49.3% (OR: 0.649; $p = 0.14$) **CON:** 58.9%
Sedaghati[26] (2007)	RCT $N = 100$ Iran	**Age:** 23.28 y (EX) 23.26 y (CON) **Gestation:** 20–22 weeks **BMI:** 24.10 kg/m^2 (EX) 24.30 kg/m^2 (CON) **Underactive sample?** NR	Supervised Duration: 8 weeks Exercise Only **Adherence:** >88% **Attrition:** **EX:** 20% **CON:** 0%	**Frequency:** 3×/week **Duration:** 45 min **Intensity:** 55–65% APMHR **Progressive:** NR	Total GWG (4)	*t*-test	**Total GWG:** **EX:** 13.55 kg $p < 0.000$ **CON:** 15.10 kg

Note: † A successful intervention was defined as a statistically significant difference in gestational weight gain and/or percent body fat between the exercise and control conditions. PA = physical activity; EX = exercise condition; CON = control condition; NW = normal weight; OW/OB = overweight and obese; GWG = gestational weight gain; NR = not reported. IOM Guidelines: 2009 Institute of Medicine (IOM) Gestational Weight Gain Guidelines. APMHR = Age-predicted maximum heart rate; HR = heart rate; RCT = randomized controlled trial; quasi = quasi-experimental study design, %BF = percent body fat. * Ruchat[43] utilized a sample of postpartum (2 months) women ($n = 45$) as a control group, data were available on total GWG but not for weekly rate GWG or IOM excessive weight gain. ‡ Denotes the calculation used for total weight gain of the following four definitions: (1) Weight prior to delivery (or last prenatal or lab visit) minus pre-pregnancy weight; (2) weight at the end of the intervention minus weight at the start of the intervention; (3) weight prior to delivery (or last prenatal or lab visit) minus weight at study entry; (4) calculation for total weight gain was not specified. For studies not reporting exact *p*-values, $p < 0.05$ was used for significant and $p \geq 0.05$ for non-significant findings, unless specified otherwise.

Table 2
Study characteristics of 'unsuccessful' interventions†.

Author (year)	Study characteristics	Participant characteristics	Intervention characteristics	Exercise dose	GWG–measure‡	Stat analysis	Results
Barakat[42] (2009)	RCT *N* = 142 Spain	**Age:** 30.4 y (EX) 29.5 y (CON) **Gestation:** 12–13 weeks **BMI:** **EX:** 0% (UW) 68.1% (NW) 19.4% (OW) 12.5% (OB) **CON:** 3.1% (UW) 70.3% (NW) 21.9% (OW) 4.7% (OB) **Underactive sample?** Yes	Supervised Duration: 26 weeks Exercise Only **Adherence:** >90% **Attrition:** **EX:** 12.5% **CON:** 10%	**Frequency** 3×/week **Duration:** 35–40 min **Intensity:** ≤80% APMHR **Progression:** NR	Total GWG (1)	ITT analysis Unpaired *t*-tests	**Total GWG:** *Total Group* **EX:** 11.5 kg $p > 0.1$ **CON:** 12.4 kg *NW* **EX:** 12.2 kg $p > 0.1$ **CON:** 12.6 kg *OW* **EX:** 10.9 kg $p > 0.1$ **CON:** 12.3 kg *OB* **EX:** 8.4 kg $p > 0.1$ **CON:** 9.7 kg
Cavalcante[40] (2009)	RCT *N* = 71 Brazil	**Age:** 25.8 y (EX) 24.4 (CON) **Gestation:** 18–20 weeks **BMI:** 24.1 kg/m^2 (EX) 23.4 kg/m^2 (CON) **%Body Fat:** 29.7% (EX) 28.2% (CON) **Underactive sample?** Yes	Supervised Duration: 16–18 weeks Exercise Only **Adherence:** 51% **Attrition:** **EX:** 38.2% **CON:** 27.0%	**Frequency** 3×/week **Duration:** 50 min **Intensity:** 70% APMHR **Progression:** NR	Total GWG (1) % change in BF	ITT analysis Student's *t*-test MANOVA	**Total GWG:** **EX:** 14.1 kg $p = 0.38$ **CON:** 15.1 kg **Body Fat%:** **EX:** 6.0% $p = 0.07$ **CON:** 3.9%
Clapp[39] (2000)	RCT *N* = 50 US	**Age:** 31 y (Total Group) **Gestation:** 8 weeks **Weight:** 62.1 kg (EX) 61.7 kg (CON) **%Body Fat:** 21.9% (EX) 21.3% (CON) **Underactive sample?** NR	Supervised Duration: 27–30 weeks Exercise Only **Adherence:** >95% **Attrition:** 8% (combined)	**Frequency:** 3–5×/week **Duration:** 20 min **Intensity:** 55–60% $VO_{2\ max}$ **Progression:** Indirect calorimetry every two weeks	Total GWG (4)	Unpaired *t*-tests	**Total GWG:** **EX:** 15.7 kg $p \geq 0.05$ **CON:** 16.3 kg
Collings[37] (1983)	Quasi *N* = 20 US	**Age:** 26.9 y (EX) 28.0 y (CON) **Gestation:** 22.5 weeks **Weight:** 60.3 kg (EX) 64.4 kg (CON) **Underactive sample?** NR	Supervised Duration: 13.4 weeks Exercise Only **Adherence:** NR **Attrition:** NR	**Frequency:** 3×/week **Duration:** 50 min **Intensity:** 65–70% Vo_{2max} **Progression:** workload adjusted to maintain intensity	Total GWG (4)	Not described for the sample characteristics	**Total GWG:** **EX:** 15.8 kg $p \geq 0.05$ **CON:** 14.0 kg

Davenport[45] (2008)	Quasi N = 40 Canada	**Age:** 33.3 y (EX) 33.4 y (CON) **Gestation:** 24–48 weeks **BMI:** 32.9 kg/m^2 (EX) 32.8 kg/m^2 (CON) **Underactive sample?** NR <ENUN>**Cases** <ENUN- *p* > GDM	Not Supervised Duration: NR Exercise and Diet **Adherence:** NR **Attrition:** 0% (combined)	**Frequency:** 3–4×/week **Duration:** 25–40 min–not to exceed 40 min **Intensity:** 30% HRR **Progression:** NR	Total GWG (4) GWG per week %IOM Guidelines: Excessive by BMI	Mann–Whitney U statistic χ^2 test	**Total GWG:** **EX:** 12.0 kg p≥0.05 **CON:** 12.7 kg **GWG per Week:** **EX:** 0.35 kg p≥0.05 **CON:** 0.35 kg **IOM Guidelines - Excessive** *NW* **EX:** 100% p≥0.05 **CON:** 100% *OW* **EX:** 60% p≥0.05 **CON:** 50% *OB* **EX:** 38% p≥0.05 **CON:** 43%
Garshasbi[36] (2005)	RCT N = 266 Iran	**Age:** 26.3 y (EX) 26.5 y (CON) **Gestation:** 17–22 weeks **BMI:** 25.98 kg/m^2 (EX) 25.58 kg/m^2 (CON) **Underactive sample?** NR	Supervised Duration: 12 weeks Exercise Only **Adherence:** >92% **Attrition:** **EX:** 33.5% **CON:** 0%	**Frequency:** 3×/week **Duration:** 60 min **Intensity:** ≤140 bpm **Progression:** NR	Total GWG (4)	Student's t-test	**Total GWG:** **EX:** 14.1 kg p = 0.63 **CON:** 13.8 kg
Hopkins[34] (2010)	RCT N = 98 New Zealand	**Age:** 31 y (EX) 29 y (CON) **Gestation:** 19 weeks **BMI:** 26.7 kg/m^2 (EX) 25.5 kg/m^2 (CON) **Underactive sample?** NR	Not Supervised Duration: 15 weeks Exercise Only **Adherence:** 75% **Attrition:** **EX:** 4% **CON:** 24%	**Frequency:** at most 5×/week **Duration:** 40 min **Intensity:** 65% $VO_{2\ max}$ **Progression:** Yes	Total GWG (3)	ITT analysis Repeated measures ANOVA	**Total GWG:** **EX:** 8.0 kg p = 0.76 **CON:** 8.2 kg
Marquez-Sterling[32] (2000)	RCT N = 20 US	**Age:** 31.3 y (EX) 27.8 y (CON) **Gestation:** 18.2 weeks (EX) 20.0 weeks (CON) **BMI:** 22.8 kg/m^2 (EX) 24.5 kg/m^2 (CON) **Underactive sample?** Yes	Supervised Duration: 15 weeks Exercise Only **Adherence:** NR **Attrition:** **EX:** 10% **CON:** 40%	**Frequency** 3×/week **Duration:** 60 min **Intensity:** HR at 120–130 bpm (first two weeks), then increased to 140–150 bpm and then increased to 150–156 bpm **Progression:** Yes	Total GWG (1)	Independent Student's t-test	**Total GWG:** **EX:** 16.2 kg p = 0.649 **CON:** 15.7 kg
Ong[31] (2009)	RCT N = 12 Australia	**Age:** 30 y (Total Group) **Gestation:** 18 weeks **BMI:** 35.1 kg/m^2 **Underactive sample?** Yes	Supervised Duration: 10 weeks Exercise Only **Adherence:** 94% **Attrition:** NR	**Frequency** 3×/week **Duration:** 15–30 min then progressed to 40–45 min **Intensity:** 50–60% HR_{max} **Progression:** Increase intensity to 60–70%	Total GWG (4)	Repeated measures ANOVA Independent and paired t-tests	**Total GWG:** **EX:** 3.7 kg p = 0.155 **CON:** 5.2 kg
Oostdam[30] (2012)	RCT N = 121 Amsterdam	**Age:** 30.8 y (EX) 30.1 y (CON) **Gestation:** 15 weeks **BMI:** 33.0 kg/m^2 (EX) 33.9 kg/m^2 (CON) **Underactive sample?** NR	Supervised Duration: 17 weeks Exercise Only **Adherence:** 16.3% **Attrition:** 29.8% (combined)	**Frequency** 2×/week **Duration:** 60 min **Intensity:** Strength (30–60% of 1 RM) Aerobic (60–80%) Borg Scale of 12 **Progression:** The program will progress when intensity reaches 12.	Total GWG (4)	ITT analysis Linear regression Covariates: Baseline values, group allocation	**Total GWG at 32 weeks:** **EX:** 6.2 kg **CON:** 5.6 kg (β = 0.65 kg; 95% CI: -1.23, 2.52)

Table 2 (*Continued*)

Author (year)	Study characteristics	Participant characteristics	Intervention characteristics	Exercise dose	GWG–measure‡	Stat analysis	Results
Price[29] (2012)	RCT *N* = 91 US	**Age:** 30.5 y (EX) 27.6 y (CON) **Gestation:** 12–14 weeks **BMI:** 26.6 kg/m^2 (EX) 28.7 kg/m^2 (CON) **Underactive sample?** Yes	Supervised Duration: 22–24 weeks Exercise Only **Adherence:** 77% **Attrition:** **EX:** 27.9% **CON:** 35.4%	**Frequency** 4×/week **Duration:** 45–60 min **Intensity:** Moderate 12–14 on Borg Scale Walk on own for 30–60 min **Progression:** NR	Total GWG (3)	Repeated measures ANOVA	**<u>Total GWG:</u>** **EX:** 12.4 kg $p = 0.15$ **CON:** 10.5 kg
Santos[27] (2005)	RCT *N* = 92 Brazil	**Age:** 26.0 y (EX) 28.6 y (CON) **Gestation:** 17.5 weeks (EX) 18.4 weeks (CON) **BMI:** 28.0 kg/m^2 (EX) 27.5 kg/m^2 (CON) **Underactive sample?** NR	Supervised Duration: 12 weeks Exercise Only **Adherence:** 40% **EX:** 40% **CON:** 50% **Attrition:** **EX:** 19.6% **CON:** 23.9%	**Frequency** 3×/week **Duration:** 60 min **Intensity:** 50–60% HR_{max} <140 bpm **Progression:** NR	Total GWG (4)	ITT analysis Repeated measures ANCOVA Covariates: baseline values of age, gestational age, maternal weight	**<u>Total GWG:</u>** **EX:** 5.7 kg $p = 0.605$ **CON:** 6.3 kg
Yeo[25] (2009)	RCT *N* = 124 US	**Age:** 20–34 y: 66.7% (EX) 20–34 y: 66.7% (CON) ≥35 y: 31.8% (EX) ≥35 y: 33.3% (CON) **Gestation:** 18 weeks **BMI ≥ 29 kg/m^2:** 80.9% (EX) 81.6% (CON) **Underactive sample?** Yes	Supervised: Yes, but decreased over time Duration: 20 weeks Exercise Only **Adherence:** 65% **Attrition:** NR	**<u>Walkers</u>Frequency** 5×/week **Duration:** 40 min **Intensity:** 55–69% APMHR RPE/Borg Scale: 12–13 **<u>Stretchers</u> Frequency** 5×/week **Duration:** 40 min **Intensity:** None **Progression:** NR	Total GWG (1) % IOM Guidelines Excessive	One-sample *t*-test Fisher's exact test	**<u>Total GWG:</u>** **EX:** 15.4 kg $p \geq 0.05$ **CON:** 15.9 kg **<u>IOM Guidelines</u> - Excessive** **EX:** 100.0% $p = 0.041$ **CON:** 88.6%

Note: †A successful intervention was defined as a statistically significant difference in gestational weight gain and/or percent body fat between the exercise and control conditions. PA = physical activity; EX = exercise condition; CON = control condition; UW = underweight; NW = normal weight; OW/OB = overweight and obese; GWG = gestational weight gain; NR = not reported. IOM Guidelines: 2009 Gestational Weight Gain Guidelines set forth by the Institute of Medicine. APMHR = Age-predicted maximum heart rate; HR = heart rate; RCT = randomized controlled trial; quasi = quasi-experimental study design, %BF = percent body fat. ‡ Denotes the calculation used for total weight gain of the following four definitions: (1) Weight prior to delivery (or last prenatal or lab visit) minus pre-pregnancy weight; (2) weight at the end of the intervention minus weight at the start of the intervention; (3) weight prior to delivery (or last prenatal or lab visit) minus weight at study entry; (4) calculation for total weight gain was not specified. For studies not reporting exact *p*-values, $p < 0.05$ was used for significant and $p \geq 0.05$ for non-significant findings, unless specified otherwise.

prescribed dose and its impact on GWG emerged from the literature reviewed likely due to the high level of heterogeneity across the studies. It was anticipated that 'successful' interventions would have had a higher prescribed dose of exercise compared to the 'unsuccessful' interventions, thereby demonstrating a dose-response effect; however this finding was not confirmed.

It is plausible that a dose-response effect may have been present; however, given the high variability of the exercise dose components (i.e. frequency, intensity and duration) and varying participant and intervention characteristics (including adherence), it was difficult to confirm its existence. Nevertheless, one study among the 'successful' interventions potentially illustrated this effect by comparing three conditions of varying patterns of exercise doses across pregnancy (low-to-high dose, moderate-to-moderate dose and high-to-low dose).[38] This study found that women in the low-to-high dose exercise condition gained significantly less body fat and weight during pregnancy compared to the other conditions. This finding demonstrated that a progressive dose of exercise from early to late pregnancy may be predictive of weight gain, suggesting that higher dose of exercise may be necessary in the latter trimester of pregnancy to elicit greater reductions in body fat and weight gain. This pattern was demonstrated in both the moderate-to-moderate and high-to-low conditions where the dose of exercise was either maintained or decreased during the time period (20th to 30th weeks of gestation) when the rate of adipose tissue deposition was accelerating[48] and as such may have been insufficient to reduce body fat or weight gain. Importantly, these findings also suggest that high levels of exercise at the start of pregnancy may not be protective of weight gain as demonstrated by the high-to-low dose condition. In this group, women started with a high dose of exercise followed by a low dose. These women gained significantly more weight compared to the low-to-high condition.

Aside from the unexpected results regarding exercise dose, other patterns emerged between the 'successful' and 'unsuccessful' interventions. A majority (75%) of 'successful' interventions were implemented in normal weight pregnant women. One possible reason for the significant reduction in weight gain among these women may be the decreased energy cost with movement. Previous literature has established a positive relationship between body weight and energy expenditure.[49,50] That is, the energy expenditure and therefore physical effort during any given weight-bearing activity is far greater in an individual with a high body weight compared to a lighter individual. This may result in increased difficulty during energy-demanding tasks (i.e. exercise).[50] Additionally, 83% of the 'successful' and 62% of 'unsuccessful' interventions implemented among normal weight and overweight/obese women, respectively, were prescribed weight-bearing exercise. This form of exercise is far more energy-costly for overweight and obese women compared to non-weight bearing exercise.[51] Because of this, normal weight women may be more receptive and compliant to PA interventions compared to overweight or obese women. Moreover, it is possible that normal weight women may have been more active during the preconception period compared to overweight and obese women and as a result, maintaining PA during pregnancy may have been easier than initiating this health behavior at the onset of pregnancy.

Greater adherence and lower attrition rates were likely to be strong contributors to the significant reduction in weight gain in the 'successful' interventions compared to the 'unsuccessful' interventions. Haakstad et al.[35] demonstrated the influence of adherence and attrition rates in their study as the intention-to-treat analysis revealed no significant differences between the exercise and control conditions; however women attending 100% of the exercise sessions gained significantly less weight and 0% exceeded the IOM guidelines compared to less compliant women.

Another substantial difference between the 'successful' and 'unsuccessful' interventions was the measure of GWG used across the studies. The most common measurement used was total weight gained during pregnancy, which is simple to use and calculate. However, this aggregate measure provides little detail (e.g., patterns, rates, accumulating tissues) about weight gain compared to other measures. All studies utilized this measure to quantify GWG; however, 75% of 'successful' interventions used at least two measures of GWG vs only 15% of 'unsuccessful' interventions. It is possible that studies employing multiple measures of GWG placed more emphasis on weight gain, as weight gain was the primary outcome in 88% of the studies utilizing at least two measures of GWG. Other measures of weight gain included weekly rate of weight gain, percent body fat and the 2009 IOM guidelines. While it is acknowledged that using multiple measures of weight gain may increase the likelihood of finding positive results, each of these measures may provide a different piece of information (e.g. mean weight gain, % excessive, early vs late weight gain, % body fat) thus, potentially providing a more complete evaluation of the effect of an exercise intervention on weight gain. Additionally, multiple measures of weight gain may overcome the potential bias of total weight gain, however the other measures are not without limitations (e.g. assumption of constant rate of weight gain in the 1st trimester of pregnancy [0.5–2 kg], misclassification).[52]

An additional limitation regarding the weight gain measurements methods used was the inability to distinguish between the different types of tissues that may accumulate during pregnancy (i.e. adipose, muscle, etc.). While it is established that weight gain during pregnancy can be partly attributed to maternal fat stores, weight of the fetus, supportive tissues (i.e. placenta, uterus, and amniotic fluid) and tissue for lactation processes, the composition of the remaining accumulating tissues is unknown. Differentiating between fat mass and fat-free mass is critical especially when the exposure is exercise. Previous literature suggests that exercise of moderate-to-vigorous intensity can induce increases in muscle mass and reductions in body fat tissue, providing significant metabolic benefits (e.g., glycemic and lipidemic control) to both the mother and fetus.[53–56] However, the weight gain measures used as opposed to measures of body composition, especially among women engaging in resistance training,[27–30,35,41,42,44,57] may have resulted in the reporting of null findings, when in fact, significant and beneficial changes in body composition occurred.

This review has a number of significant strengths despite being unable to adequately determine the role of exercise dose and GWG. To the best of our knowledge, this was the first study to attempt to assess the impact of exercise dose on weight gain during pregnancy. In addition, the less-restrictive inclusion criteria utilized in this review resulted in the most comprehensive collection of exercise interventions allowing for a more thorough evaluation of the current evidence. Moreover, this was the first review to evaluate the characteristics of 'successful' and 'unsuccessful' exercise interventions and reductions GWG which may provide useful information for the development and implementation of future interventions. However, as with any study, this review has limitations. First, it is possible that while conducting the literature search that some eligible interventions were missed, potentially limiting a complete evaluation of the current evidence. Second, due to the heterogeneity of the exercise doses prescribed and insufficient reporting of the dose received, we were unable to assess the impact on GWG as intended. Because of this, the exercise dose associated with reductions in GWG among 'successful' interventions is 'unquantifiable.' Third, given the large number of 'unsuccessful' interventions, inclusion of quasi-experimental studies, and homogeneous samples (i.e. normal weight women) utilized in the 'successful' interventions, it is difficult to conclude any causal inferences that are generalizable to all pregnant women.

In light of these findings and given the importance of GWG and the potential intergenerational effects of excessive weight gain,[7,58] it is strongly recommended that future researchers allocate their resources to designing a large randomized controlled trial consisting of varying exercise doses in an anthropometrically (i.e. body fat) diverse sample of pregnant women to identify an effective exercise dose. Importantly, it is critical to consider identifying strategies to increase adherence and compliance (e.g. incentives, decrease participant burden) to exercise interventions. As indicated by the finding of this review, these factors likely had a strong influence on the success of these interventions, and as such may make the identification of an effective dose more achievable. Moreover, it is recommended that researchers investigate the role of a diet intervention independent of exercise, as the one successful intervention among overweight and obese pregnant women in this review[44] included diet, which may explain their significant finding. It is acknowledged that several diet interventions have incorporated exercise;[20] however few of these studies provided a sufficient number of control conditions to assess the impact of diet and exercise independently. Further, it is strongly suggested that future researchers utilize appropriate measures of changes in body composition (i.e. body fat and lean body mass) in addition to weight gain. Moreover, it is imperative that investigators validate that the exercise dose prescribed is the exercise dose received and to accomplish this, the utilization of objective measures of exercise dose (i.e. heart rate monitors, indirect calorimetry, accelerometers etc.) are required. Additionally, examining the effects of exercise dose on weight gain across pregnancy (early vs late) and the potential impact on the neonate is encouraged. Lastly, it is recommended that researchers objectively measure daily PA to assess if interventions lead to compensatory changes across the day.

5. Conclusion

Despite the unclear evidence of the effect of exercise dose on GWG, we did find successful interventions that suggest exercise during pregnancy may reduce excessive GWG. In addition, adherence and retention rates were likely strong contributors to the success of exercise interventions on GWG. No injuries and/or maternal or fetal complications related to exercise occurred during these interventions, suggesting that exercise is a relatively safe behavior for women without a high-risk pregnancy to perform during pregnancy. In addition to GWG, exercise during pregnancy possesses a myriad of other health benefits for both mother and child[59,60] and therefore should be encouraged in all women during pre and postnatal periods.

6. Practical implications

- An exercise dose that enables women to control their weight during pregnancy is still unknown; this is likely due to the absence of appropriate measurement methods of the exercise dose received during interventions.
- Adherence and compliance are likely to be strong contributors to the success of exercise interventions in pregnant women.
- The continuous use of poor measurements of gestational weight gain, changes in body composition and exercise dose will likely perpetuate the production of null findings found in exercise interventions among pregnant women.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2015.03.004.

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