Can gestational weight gain be modified by increasing physical activity and diet counseling? A meta-analysis of interventional trials[1–3]

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ABSTRACT

Background: Excessive gestational weight gain (GWG) increases the risk of a number of adverse pregnancy outcomes and was recently identified as a potential risk factor for childhood obesity. It is therefore of interest whether GWG can be modified by an intervention combining dietary counseling and physical activity.

Objective: The objective was to review published data on interventions to reduce GWG by modulating diet and physical activity during pregnancy.

Design: We systematically reviewed 4 databases and bibliographies of various publications supplemented by a hand-search for relevant articles published in English or German and performed a meta-analysis to quantify the effect estimate by a random-effects model.

Results: Four randomized controlled trials and 5 nonrandomized trials with a total of 1549 women enrolled were identified as being relevant. Meta-analyses of all 9 trials indicated a lower GWG in the intervention groups, with a standardized mean difference of −0.22 units (95% CI: −0.38, −0.05 units). We observed no indication for publication bias.

Conclusions: Interventions based on physical activity and dietary counseling, usually combined with supplementary weight monitoring, appear to be successful in reducing GWG. The results are of particular interest with respect to the objective of preventing excessive GWG. *Am J Clin Nutr* 2010;92:678–87.

INTRODUCTION

Excessive gestational weight gain (GWG) is associated with maternal obesity postpartum and a number of adverse pregnancy outcomes, such as gestational diabetes mellitus, pregnancy-related hypertension, complications through labor and delivery, and macrosomia (1–4). Excessive GWG is also a potential prenatal risk factor for childhood obesity (5). A number of current reports showed a trend of increasing GWG in industrialized countries in recent years (4, 6, 7). Therefore, the avoidance of excessive GWG may constitute a particular opportunity for prevention and therapy.

There are a number of factors associated with GWG, such as maternal height, parity, and prepregnancy weight, that cannot be modified by prenatal interventions (6, 7). Excessive GWG, however, is likely to be a consequence of a persistently positive energy balance and might therefore be influenced by physical activity and diet modification.

Updated Cochrane reviews (8, 9) considered the effect of either modifications in diet or physical activity on GWG; whereas an energy or protein restriction alone may lower GWG (8), interventions to increase physical activity alone were not successful in reducing GWG (9). No Cochrane or other systematic review, however, addressed the effects of combined dietary and physical activity interventions. There are some reviews referring to the prevention of excessive GWG by physical activity and dietary counseling (10–16), but these articles were not based on a systematic literature search (15), did not attempt to quantify the effects of the combined intervention (10, 12), or both (11, 13, 14, 16).

We therefore performed a comprehensive literature search and meta-analysis on intervention trials regarding the association between physical activity in addition to diet counseling and GWG.

METHODS

Search strategy and study selection

We searched the databases MEDLINE (http://www.ncbi.nlm.nih.gov/pubmed/; 1950–2009), EMBASE (http://www.ovid.com/site/catalog/DataBase/903.jsp; 1974–2009), Cochrane CENTRAL Library Issue 4 (http://www.thecochranelibrary.com/view/0/index.html; 2009), and Web of Science (www.isiknowledge.com; 1900–2009) to identify relevant articles. The systematic computerized literature search of published studies was carried out from November 2009 to January 2010 with use of the following search terms: ("nutrition" or "diet" or "energy intake" or "protein intake" or "dietary protein") and ("exercise" or "physical activity" or "sports") and ("pregnancy" or "gestation" or "maternal") and ("weight gain" or "weight change" or "pregnancy outcome").

An additional hand-search of reference lists of relevant and related articles was done to ensure a complete collection. We included only intervention trials meeting the following a priori-

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defined inclusion criteria: written in English or German language; focusing on healthy women; singleton pregnancies; intervention comprised modification of diet and physical activity; subjects were compared with a control group receiving routine prenatal care; and GWG was documented for control and intervention groups separately.

Data collection and analysis

The articles were screened by their titles and inappropriate topics were excluded. Two researchers (IS, RvK) independently analyzed and selected the identified abstracts and full-text articles according to the inclusion criteria. Differences between reviewers were resolved by discussion.

We assessed the validity of the included trials by using the following criteria outlined in the Cochrane Handbook (17) and the CONSORT (Consolidated Standards of Reporting Trials) statement (18): randomization, allocation concealment, blinding, differences regarding potential confounders, intention-to-treat analysis, losses to follow-up, and other sources of bias.

Statistical analysis

For the meta-analysis, we calculated standardized mean difference (SMD) scores of GWG and corresponding 95% CIs to account for differences in GWG measurement between studies. This is a standard procedure in Cochrane meta-analyses to standardize outcome measures (17). The SMD for each study is calculated by dividing the difference of the sample means of the intervention and control groups by the pooled SD of outcome measurements in the intervention and control groups (19).

We calculated a random-effects model (DerSimonian and Laird) (17) for all trials. The individual studies were weighted by their inverse variances. Heterogeneity was tested by using Higgins I^2 [25% were considered as low, 50% as moderate, and 75% as high heterogeneity (19)], and potential publication bias was assessed in a funnel plot. To provide a rough estimate of the summary effect in terms of total GWG, we calculated a random-effects model based on raw mean differences (instead of SMDs) from the original studies in a supplementary analysis.

Because nonrandomized trials may be biased because of the choice of the control group (20), we performed additional analyses separately for both randomized controlled trials (RCTs) and nonrandomized trials. In addition, we performed a sensitivity analysis on those studies in which the intervention and control groups were comparable with respect to any potential confounders. A further analysis was based on studies without potential limitations in design or conduct. Another sensitivity analysis was performed on only those studies that included women with an average prepregnancy body mass index (BMI; in kg/m^2) >25 to examine potential effect modifications by maternal BMI. All analyses were performed with the use of Review Manager 5.0 for Windows (21).

RESULTS

Included studies

The electronic literature search revealed 2518 hits (**Figure 1**). We excluded 2457 articles with titles not related to physical activity, diet, or GWG. The remaining 61 abstracts were reviewed. Reviews and studies on a different topic were excluded.

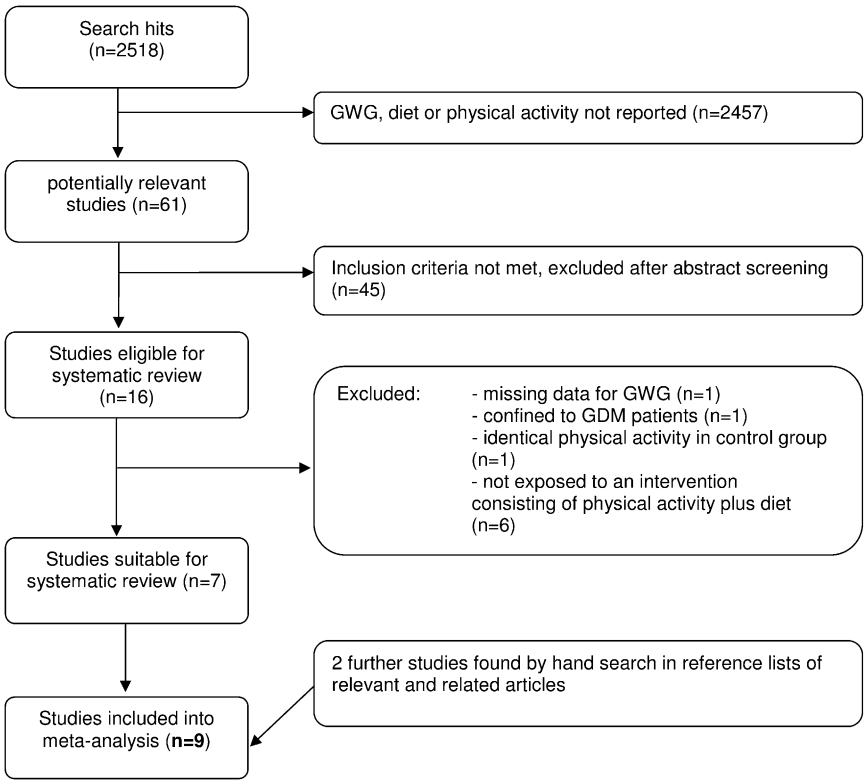

FIGURE 1. Identification of eligible studies. GWG, gestational weight gain; GDM, gestational diabetes mellitus.

TABLE 1
Description of studies analyzed[1]

First author, year, country (reference)	Method	Inclusion criteria	Exclusion criteria	Definition of GWG
Asbee, 2009, USA (30)	RCT	BMI (in kg/m^2) <40, English or Spanish language, prenatal care established at week 6–16 of gestation, age 18–49 y	Preexisting diabetes, untreated thyroid disease or hypertension, or other medical conditions that might affect body weight, premature delivery (less than week 37 of gestation), limited prenatal care	WD − PPW
Claesson, 2008, Sweden (37)	Prospective case-control intervention	Obese (BMI >30), Swedish language	Prepregnant diabetes, thyroid dysfunction or psychiatric disease treated with neuroleptic drugs, early miscarriage or legal abortion, moving away	WD − WEP
Gray-Donald, 2000, Canada (34)	Prospective intervention	All pregnant Cree women from 4 defined communities, less than week 26 of gestation	Pregestational diabetes	Not clearly defined
Guelinckx, 2010, Belgium (38)	RCT	Obese white women, Dutch language, less than week 15 of gestation	Preexisting diabetes or developing GDM, premature labor (less than week 37 of gestation), metabolic disorder, kidney problems, Crohn disease, allergic conditions	WD − PPW
Hui, 2006, Canada (35)	RCT	Less than week 26 of gestation	Preexisting diabetes, contraindications for exercise	Not defined
Kinnunen, 2007, Finland (36)	Controlled trial	Finnish language, age >18 y, no earlier deliveries	Type 1 or 2 diabetes (but not gestational diabetes), problematic pregnancy, contraindications for exercise, substance abuse, psychiatric illness, intention to move away	Not defined
Olson, 2004, USA (31)	Prospective cohort study	BMI of 19.8–29.0, age >18 y, entering prenatal care before third trimester, give birth to live term infant, mentally competent to give informed consent, plan to deliver locally and keep the infant	Medical condition that might affect body weight	WD − WEP
Polley, 2002, USA (32)	RCT	BMI >19.8, enrolled before week 20 of gestation, age >18 y	High-risk pregnancy, first prenatal visit less than week 12 of gestation	WD − PPW
Shirazian, 2010, USA (33)	Prospective matched controlled study	BMI >30, enrolled in first trimester, singleton pregnancy	Chronic medical conditions (diabetes, hypertension, lupus, thyroid disease, preterm delivery)	Not defined

[1] GWG, gestational weight gain; RCT, randomized controlled trial; GDM, gestational diabetes mellitus; WD, weight at delivery; PPW, prepregnancy weight; WEP, weight in early pregnancy.

The number of potentially relevant studies for full text investigation was 16.

We excluded one study because of missing data for GWG, even after contacting the author (22). One trial included only women with gestational diabetes mellitus and was therefore eliminated (23). Another study was excluded because the intervention comprised solely a modification in diet but not in physical activity (24). Six observational studies were excluded (7, 25–29). Finally, 7 studies from the electronic search plus 2 additional trials identified by the hand search were eligible for the meta-analysis.

Four trials were from the United States (30–33), 2 from Canada (34, 35), 1 from Finland (36), 1 from Sweden (37), and 1 from Belgium (38). In one of the Canadian trials (34) the study population consisted of women from Cree communities.

Overall, 1886 women were eligible for the studies and 1549 women completed the trials. Three trials included only overweight or obese women (33, 37, 38) (**Table 1**). The main target of all trials was to test interventions to prevent excessive GWG and adverse pregnancy outcomes.

Four studies were RCTs (30, 32, 35, 38). The remaining 5 nonrandomized trials used historical cohorts or contemporary data from a different institution (31, 33, 34, 36, 37).

Three authors defined GWG as the difference between prepregnancy weight and body weight at delivery (30, 32, 38) (Table 1). In 2 studies GWG was assessed as the difference between body weight in early pregnancy and body weight at delivery (31, 37). Four trials did not report how they defined GWG (33–36). We therefore expressed the difference of GWG in the individual studies as SMD. Characteristics of the study populations are shown in **Table 2**.

TABLE 2
Characteristics of participants of the included trials

First author, year (reference)	Maternal age	Prepregnancy BMI	
		Intervention	Control
	y	*kg/m²*	
Asbee, 2009 (30)	26.6 ± 5.6[1]	25.6 ± 6.0	25.6 ± 5.1
Claesson, 2008 (37)	30.0 ± 4.7	>30.0	>30.0
Gray-Donald, 2000 (34)	24.1 ± 6.1	30.8 ± 6.85	29.6 ± 6.45
Guelinckx, 2010 (38)	28.7 ± 4.0	34.1 ± 4.5	33.5 ± 3.9
Hui, 2006 (35)	26.2 ± 5.5	23.4 ± 3.9	25.7 ± 6.3
Kinnunen, 2007 (36)	28.5 ± 4.3	23.7 ± 3.9	22.3 ± 2.1
Olson, 2004 (31)	20–40[2]	24.2 (19.8–29.0)[3]	23.7 (20.0–29.0)
Polley, 2002 (32)	25.5 ± 4.8	26.9 ± 4.4	27.3 ± 4.9
Shirazian, 2010 (33)	26.7 ± 5.3	36.2 ± 5.2	34.2 ± 5.3

[1] Mean ± SD (all such values).
[2] More than 93% of participants.
[3] Range in parentheses (all such values).

Interventions

In 8 studies (30–34, 36–38) the intervention comprising modification of physical activity and diet was supplemented by regular weight monitoring, which occurred at each antenatal visit in most of the studies, and attempts to achieve GWG within the recommended Institute of Medicine (IOM) ranges of 1990 (with no upper bound for obese women) (39) (**Table 3**). Only 3 trials offered specific exercise programs for their subjects (34, 35, 37), whereas the others limited this part of the intervention to oral and written information and recommendations for exercise. Six studies provided individual nutrition counseling by professional nutritionists (30, 34–36, 38) or study coordinators (33). In one trial comprising obese pregnant women, weekly motivational talks were initiated with the aim of motivating the study subjects to change their behavior and obtain information relevant to their needs (37). Two other studies offered written and oral information about healthful eating during pregnancy (31, 32).

Methodologic quality

The validity of the trials was heterogeneous (**Table 4**). Only one study gave detailed information about their concealed randomization process (30). Three authors did not explain their method of randomization (32, 35, 38), whereas 4 others used historical cohorts (31, 34) or contemporary data from other clinics (31, 34, 36, 37). Matched patients from the same clinic were applied by another trial (33). Three of the nonrandomized trials reported differences between intervention and control groups regarding potential confounders for GWG, such as maternal age (33), prepregnancy BMI (36), and socioeconomic status (37). Blinding of participants or personnel with respect to the interventions was not possible in any study, because the intervention required the active participation of the subjects. Four authors reported losses to follow-up of >10% (34–36, 38). The remaining studies had lower losses to follow-up.

Summary results

A lower GWG in the intervention groups compared with the control groups (3 significant, $P < 0.05$; 3 nonsignificant) was observed in all but 3 of the studies. As depicted in **Figure 2**, the forest plot of the meta-analysis of all trials considered indicated a significant ($P = 0.01$) reduction of GWG in the intervention groups, resulting in an SMD of −0.22 units (95% CI: −0.38, −0.05 units), corresponding to an average reduction of GWG of 1.2 kg (data not shown). Moderate heterogeneity was suggested by Higgins I^2.

The study by Shirazian et al (33) showed by far the strongest effect estimate of all studies included. Exclusion of this trial resulted in an overall effect size of −0.18 (95% CI: −0.33, −0.03; data not shown).

The forest plot of the RCTs suggested only a nonsignificant reduction of GWG on average in the intervention groups (SMD = −0.13; 95% CI: −0.41, 0.15). There was moderate heterogeneity between the RCTs as indicated by Higgins I^2.

The forest plot of the nonrandomized trials showed a significantly ($P = 0.02$) lower GWG on average in the intervention groups (SMD = −0.27; 95% CI: −0.49, −0.04). Higgins I^2 denoted high heterogeneity between these studies.

The funnel plot was rather symmetric (**Figure 3**), indicating no evident publication bias.

Sensitivity analyses

The removal of those 3 studies with differences between intervention and control groups regarding potential confounders (33, 36, 37) resulted in an SMD of −0.15 (95% CI: −0.27, −0.02; $P = 0.02$) (data not shown). When we repeated our analyses without the studies with a potential risk of bias due to

TABLE 3
Definition of the different interventions in the individual studies[1]

			Intervention group treatment			Result: GWG[2]		
Author, year (reference)	Beginning of intervention	Control group treatment	PA	Nutrition	Additional treatment	Control	Intervention	*P* (reported)
						kg	*kg*	
Asbee, 2009 (30)	Week 6–16 of gestation	Routine prenatal care: initial physical examination and history, routine laboratory tests, routine visits per American College of Obstetricians and Gynecologists standard	Moderate exercising for 3–5 times/wk was recommended	Nutrition counseling by a dietitian at the first visit, diet should contain 40% carbohydrates, 30% protein, 30% fat	Information about IOM GWG guidelines were given; weight measurement at each visit, body weight was compared with guidelines and intervention was adapted	16.2 ± 7.0 [43]	13.0 ± 5.7 [57]	0.01
Claesson, 2008 (37)	Early pregnancy (approximately week 10–12 of gestation)	Routine antenatal program	Aqua aerobics especially designed for obese women, once or twice a week	Information about nutrition during pregnancy	Motivational talk/ interview; weekly weight control and supportive talk; if a woman lacked sufficient knowledge, she was offered information about diet, exercise, and GWG	11.3 ± 5.8 [161]	8.7 ± 5.5 [143]	<0.001
Gray-Donald, 2000 (34)	Before week 26 of gestation	Historical, not declared	Exercise/walking groups	Local radio broadcasts, booklets, supermarket tours, and cooking demonstrations; goal: improving intake of dairy products, fruit, and vegetables; decreasing intake of high-energy-dense food (soft drinks, French fries, etc)	Individual counseling; advice to stay within the IOM recommendations	13.2 ± 8.3 [96]	12.0 ± 6.4 [104]	0.29

(Continued)

TABLE 3 (*Continued*)

Author, year (reference)	Beginning of intervention	Control group treatment	Intervention group treatment			Result: GWG[2]		
			PA	Nutrition	Additional treatment	Control	Intervention	*P* (reported)
						kg	*kg*	
Guelinckx, 2010 (38)	Before week 15	Routine prenatal care	Information and discussion about PA during pregnancy	Active counseling by a nutritionist in 3 group sessions; goal: limiting intake of energy-dense foods by substituting them with healthier alternatives, increasing low-fat dairy products, increasing whole-wheat grains, reducing saturated fatty acids	Received brochure designed for the study, provides information on nutrition, PA and tips to limit GWG, discussion about energy balance, body composition, Nutrition Fact labels, and how to increase PA	10.6 ± 6.9 [43]	9.8 ± 7.6 [42]	>0.05
Hui, 2006 (35)	Week 20–30 of gestation	Standard care (physical activity only recommended, not instructed; information on nutrition)	Group session exercise (45 min, once a week, professional trainer), home-based exercise (self-monitoring heart rate, leading diary; 3–5 times/wk for 30–45 min, instructional video or DVD)	Individual nutrition counseling from a dietitian based on a "Food Choice Map"; actual food intake is recorded and a personalized plan is provided	None reported	14.2 ± 6.3 [21]	14.2 ± 5.3 [24]	1.00
Kinnunen, 2007 (36)	Week 8–9 of gestation	Standard maternity care (short-term counseling on diet, PA, and GWG)	PA counseling sessions (5 times), which included discussion about needs and opportunities to increase leisure-time PA and designing an individual activity plan, opportunity to join a group exercise session	Dietary counseling (4 sessions), main targets: *1*) regular meal pattern; *2*) 5 servings of fruit and vegetables/d; *3*) high fiber content; *4*) restrict intake of high-sugar snacks	Information on IOM recommendations	14.3 ± 4.1 [56]	14.6 ± 5.4 [48]	0.77

(*Continued*)

TABLE 3 (*Continued*)

Author, year (reference)	Beginning of intervention	Control group treatment	Intervention group treatment			Result: GWG[2]		
			PA	Nutrition	Additional treatment	Control	Intervention	*P* (reported)
						kg	*kg*	
Olson, 2004 (31)	Before third trimester	Historical (routine program?)	Tips and newsletters about PA in pregnancy	"Health checkbook" helps self-monitoring of diet, tips and newsletters for healthy eating	Self-monitoring GWG ("Health checkbook") and newsletters about GWG	14.8 ± 4.7 [381]	14.1 ± 4.5 [179]	0.09
Polley, 2002 (32)	Before week 20 of gestation	Standard care and standard nutrition counseling	Initially written and oral information on exercise during pregnancy; goal: developing a more active lifestyle	Initially written and oral information on healthful eating during pregnancy, goal: low fat, more fruit and vegetables	Initially written and oral information on appropriate GWG, personalized graph of GWG after each clinic visit, and adjustment of individual counseling	13.8 ± 5.4 [53]	14.5 ± 7.1 [57]	
Shirazian, 2010 (33)	First trimester of pregnancy	Historical cohort (matched for BMI, parity, socioeconomic status)	Written material, seminars and counseling sessions to encourage walking as exercise, received a pedometer to monitor	Written material, seminars and counseling sessions to promote healthy eating, identify dietary improvements, facilitate calorie counting, kept food diary	Written material, seminars and counseling sessions to educate the women on obesity and pregnancy and healthy living; goal: GWG <7 kg	15.4 ± 7.5 [20]	8.0 ± 7.4 [21]	0.003

[1] PA, physical activity; GWG, gestational weight gain; IOM, Institute of Medicine.
[2] Values are means ± SDs; numbers in brackets.

TABLE 4
Validity of the included trials

Author, year (reference)	Randomized controlled trial?	Allocation concealment?	Differences regarding potential confounders	Intention-to-treat analysis?	Losses to follow-up	Other sources of bias?
					%	
Asbee, 2009 (30)	Yes	Yes	None	No	8	No
Claesson, 2008 (37)	No	—	Socioeconomic group[1]	No	5	Yes
Gray-Donald, 2000 (34)	No	—	None	Yes	32	Yes[2]
Guelinckx, 2010 (38)	Yes	Unclear	None	No	37	No
Hui, 2006 (35)	Yes	Unclear	None	No	13	No
Kinnunen, 2007 (36)	No	—	Prepregnancy BMI, education, smoking status	No	20	Yes[3]
Olson, 2004 (31)	No	—	None	Unclear	0	Yes[2]
Polley, 2002 (32)	Yes	Unclear	None	Yes	8	Yes[4]
Shirazian, 2010 (33)	No[5]	—	Age	No	7	Yes[6]

[1] Gestational weight gain appeared to be independent of confounders when analyzed by ANCOVA (37).
[2] Historical control group.
[3] Control group from other clinics (3 intervention clinics compared with 3 control clinics).
[4] Lower-income clinic; participants had limited resources, which made intensive counseling difficult (32).
[5] Matched-control group.
[6] Control patients were determined through chart review (33).

limitations in design or conduct (32, 34, 36, 38), we obtained an SMD of −0.37 (95% CI: −0.61, −0.12; $P = 0.003$) (data not shown). The sensitivity analysis comprising only studies that included women with an average BMI >25 (30, 32–34, 37, 38) yielded an SMD of −0.30 (95% CI: −0.54, −0.06; $P = 0.01$) (data not shown).

DISCUSSION

This meta-analysis based on intervention trials on physical activity and diet to reduce GWG showed a significantly lower average GWG in the intervention groups compared with controls. If the analysis was confined to RCTs only, there was still a trend to lower GWG in the intervention groups. The observed effect

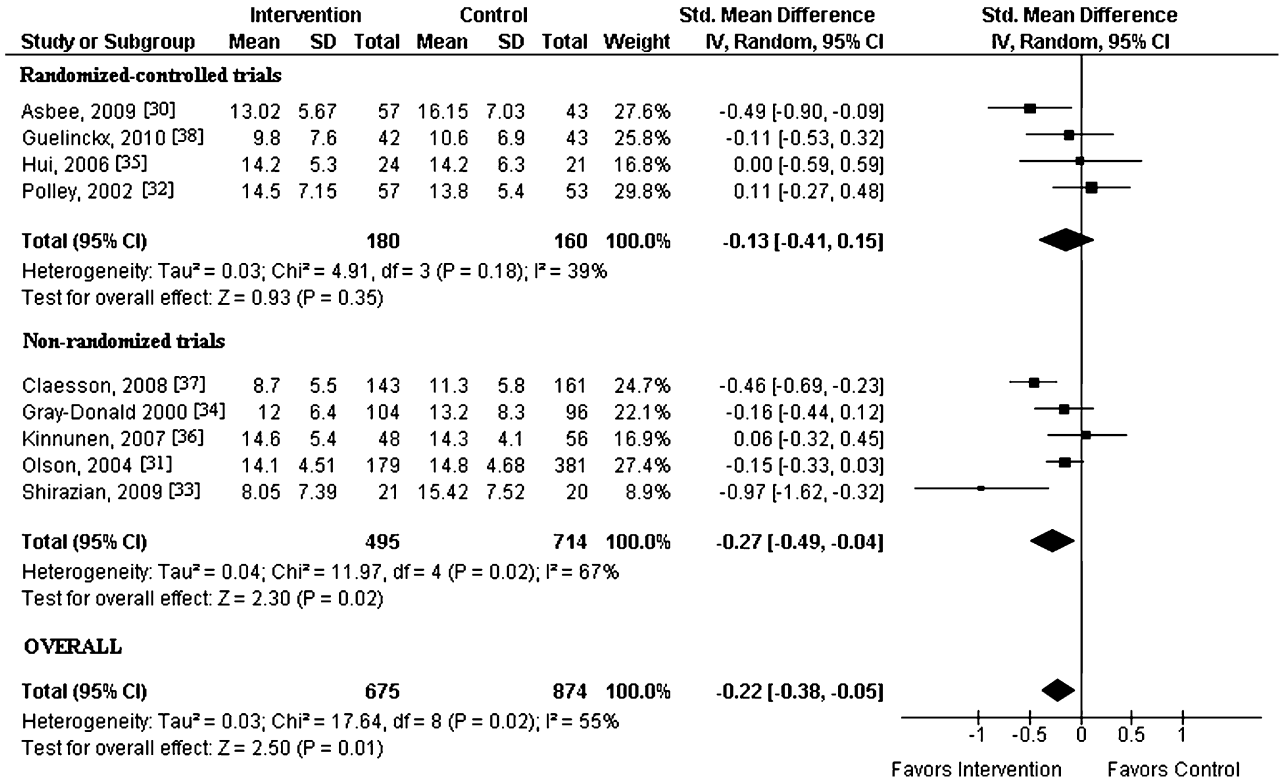

FIGURE 2. Standardized (Std.) mean difference between exercise and control groups of the included studies, divided into either randomized controlled trials only or nonrandomized trials only. The overall effect size comprises all included studies. Squares represent the point of estimate of each study; square size corresponds to the weight of the study in the meta-analysis. Horizontal lines denote the respective 95% CIs. Diamonds represent the overall pooled estimate of the treatment effect. IV, inverse variance.

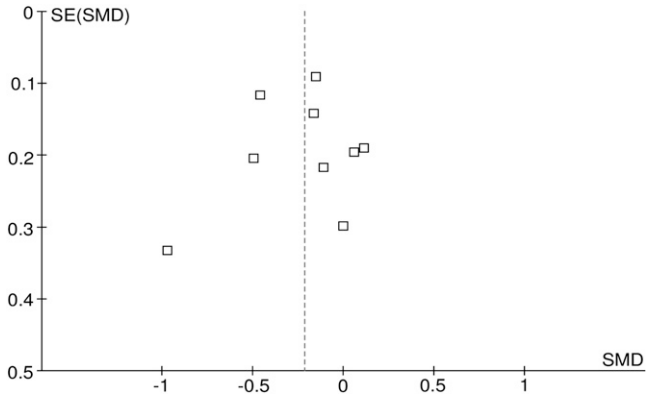

FIGURE 3. Funnel plot of the SE by standardized mean difference (SMD) for assessment of publication bias. Each square denotes a study included in the meta-analysis. The dashed vertical line represents the overall effect calculated with the random-effects model.

was robust to sensitivity analyses with respect to prepregnancy BMI, adjustment for potential confounders, and methodologic quality and is unlikely to be explained by publication bias, as indicated by a symmetrical funnel plot. Furthermore, the overall effect did not depend on the study with the strongest effect size (33), because the overall effect was still detectable after its exclusion.

We observed a reduction of the SMD in the intervention groups by −0.22 units. This corresponds to a reduction of GWG of 1.2 kg in relation to the mean GWG of 13.0 kg in the 1549 women who completed the included trials, indicating a clinically relevant reduction.

In all trials identified, oral or written recommendations regarding diet and physical activity were provided, mostly combined with personal counseling. Five interventions with additional weight monitoring (30–32, 37) or a predetermined goal of maximal GWG (33) appeared to be more effective than the 4 remaining ones (34–36, 38). No other specific intervention strategy, such as structured exercise programs (34, 35, 37) or individual nutrition counseling (30, 33–36, 38), appeared to be particularly effective. Unfortunately, it was not possible to quantify the intensity of different interventions on GWG, because the details given on the specific interventions in the individual studies were too imprecise to translate the intensity into common measures such as caloric intake or metabolic equivalents.

Comparison with other studies

There are some reviews referring to the effect of interventions combining physical activity and dietary counseling (10–16). The validity of these studies, however, is limited due to a selective literature search (11, 13–16). Further studies failed to quantify the results in a meta-analysis (10–14, 16). Three of these reviews concluded that the combined interventions may lower GWG (11, 14, 15), whereas the remaining reviews stated no clear conclusion and noted that further research is needed (10, 12, 13, 16). Our meta-analysis, based on a systematic review, therefore provides important new insight into the effects of a combined intervention to reduce GWG and allows quantifying the strength of the effect.

Strengths and limitations

In our meta-analysis, we included nonrandomized trials to increase the statistical power. The nonrandomized trials, however, with the use of either historical controls or contemporary data from a different site, may be biased due to structural disparities between the intervention and control groups. Potential confounding due to structural differences with regard to potential determinants of GWG was considered in all studies. Whereas there were no disparities with respect to age, prepregnancy weight or BMI, parity, smoking status, and education in the randomized trials, 3 of the 5 nonrandomized trials reported differences in age (33), socioeconomic group (37), prepregnancy BMI, education, and smoking status (36). Extremes of the maternal age distributions may affect GWG, but there is only limited evidence suggesting that socioeconomic status, education, and smoking status are related to GWG (4). Prepregnancy BMI, however, can definitely determine GWG (4, 7, 40). A sensitivity analysis excluding these 3 studies with structural heterogeneity yielded almost identical effect estimates.

Four studies were not of high methodologic quality because of high losses to follow-up (36, 38) or the choice of a specific subpopulation, such as women from a low-income clinic (32) or from Cree communities where physical activity during pregnancy is not desirable (34), which may have caused paltry compliance. Exclusion of these trials with limitations in design or conduct in a sensitivity analysis did not change the results considerably.

There is no accepted standard approach on how to measure GWG. This may explain why GWG was calculated based on weight before pregnancy in 3 studies and based on weight during early pregnancy in 2 studies and the approach to assess GWG in the other 4 studies was not reported. Although it might be argued that GWG in early pregnancy is usually low (41), therefore allowing the combination of different measurements of GWG to quantify the effect of the intervention, this approach is likely to account for some imprecision. Therefore, in accordance with standard Cochrane reviews (42, 43), we decided to calculate SMDs of GWG to estimate the effect size of the intervention irrespective of the GWG measurement method performed (even if it was not reported). The use of SMD is a standard procedure implemented in the Review Manager software.

Conclusions

Whereas interventions confined to either physical activity alone or diet do not appear to reduce GWG, our findings indicate that educational interventions comprising physical activity and dietary counseling, usually combined with supplementary weight monitoring, may be successful in lowering GWG. Our results are of particular interest with respect to the objective of preventing excessive GWG.

The authors' responsibilities were as follows—IS: literature review, meta-analysis, and principal authorship of the article; AB: statistical issues and contribution to the first and final draft of the manuscript; and RvK: conception of the research question, literature review, and contribution to the first and final draft of the manuscript. Parts of this work arose from the PhD thesis of IS at the medical department of the University of Munich (in preperation). The funding sources had no influence on any part of the study. None of the authors had a conflict of interest.

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