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RESEARCH

Effects of interventions in pregnancy on maternal weight and obstetric outcomes: meta-analysis of randomised evidence

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Abstract

Objective To evaluate the effects of dietary and lifestyle interventions in pregnancy on maternal and fetal weight and to quantify the effects of these interventions on obstetric outcomes.

Design Systematic review and meta-analysis.

Data sources Major databases from inception to January 2012 without language restrictions.

Study selection Randomised controlled trials that evaluated any dietary or lifestyle interventions with potential to influence maternal weight during pregnancy and outcomes of pregnancy.

Data synthesis Results summarised as relative risks for dichotomous data and mean differences for continuous data.

Results We identified 44 relevant randomised controlled trials (7278 women) evaluating three categories of interventions: diet, physical activity, and a mixed approach. Overall, there was 1.42 kg reduction (95% confidence interval 0.95 to 1.89 kg) in gestational weight gain with any intervention compared with control. With all interventions combined, there were no significant differences in birth weight (mean difference −50 g, −100 to 0 g) and the incidence of large for gestational age (relative risk 0.85, 0.66 to 1.09) or small for gestational age (1.00, 0.78 to 1.28) babies between the groups, though by itself physical activity was associated with reduced birth weight (mean difference −60 g, −120 to −10 g). Interventions were associated with a reduced the risk of pre-eclampsia (0.74, 0.60 to 0.92) and shoulder dystocia (0.39, 0.22 to 0.70), with no significant effect on other critically important outcomes. Dietary intervention resulted in the largest reduction in maternal gestational weight gain (3.84 kg, 2.45 to 5.22 kg), with improved pregnancy outcomes compared with other interventions. The overall evidence rating was low to very low for important outcomes such as pre-eclampsia, gestational diabetes, gestational hypertension, and preterm delivery.

Conclusions Dietary and lifestyle interventions in pregnancy can reduce maternal gestational weight gain and improve outcomes for both mother and baby. Among the interventions, those based on diet are the most effective and are associated with reductions in maternal gestational weight gain and improved obstetric outcomes.

Introduction

Obesity is a growing threat to women of childbearing age. Half the population is either overweight (body mass index (BMI) 25.0-29.9) or obese (BMI ≥30).[1] In Europe and the United States, 20-40% of women gain more than the recommended weight during pregnancy.[2] Increased maternal weight or excessive weight gain in pregnancy is associated with adverse pregnancy outcomes.[3] Half the women who die during pregnancy, childbirth, or puerperium in the United Kingdom are either obese or overweight.[4] For the offspring, maternal

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Extra material supplied by the author (see http://www.bmj.com/content/344/bmj.e2088?tab=related#webextra)

Appendix 1: Maternal and fetal clinical outcomes
Appendix 2: GRADE evidence profile
Appendix 3: Clinical characteristics of included studies
Appendix 4: Adverse outcomes

obesity is a major risk factor for childhood obesity, which persists into adulthood independent of other factors.[5] Obesity costs the UK National Health Service (NHS) around £0.5bn a year and the UK economy a further £2.3bn in indirect costs.[6]

The antenatal period, with opportunities for regular contact with health professionals, is considered an ideal time to intervene as mothers are motivated to make changes that could optimise their outcome and that of the baby.[7] There is a need to identify appropriate weight management interventions that are effective and safe in pregnancy. Existing reviews and guidelines are limited in their recommendations because of the small number of included studies.[8 9] They have not been able to identify the best intervention that optimises the outcomes for the mother and baby.[9 10] There is also a lack of consensus on what constitutes important outcomes. Guidelines from the Institute of Medicine (IOM) provide reference ranges for optimal weight gain in pregnancy for normal weight, overweight, and obese women based on observational evidence.[11] Given the potential importance of weight management interventions in pregnancy, we systematically reviewed the effects of dietary and lifestyle interventions on various outcomes ranked for their importance.

Methods

We carried out systematic reviews according to protocols developed using currently recommended review methods[12-14] and ranked outcomes for importance using a two round Delphi survey.[15]

Identification of studies

We searched Medline, Embase, BIOSIS, LILACS, Science Citation Index, Cochrane Database of Systematic Reviews (CDSR), Cochrane Central Register of Controlled Trials (CENTRAL), Database of Abstracts of Reviews of Effects (DARE), Health Technology Assessment Database (HTA), and PsychInfo from inception to January 2012 to identify relevant citations. We searched for relevant unpublished studies and those reported in the grey literature in databases such as Inside Conferences, Systems for Information in Grey Literature (SIGLE), Dissertation Abstracts, and Clinical Trials.gov. Internet searches were also carried out with specialist search gateways (such as OMNI: www.omni.ac.uk), general search engines (such as Google), and meta-search engines (such as Copernic: www.copernic.com). The search term combination captured the concept “pregnancy and weight” incorporating MeSH, free text, and word variants. Language restrictions were not applied.

Study selection

The electronic searches were scrutinised and full manuscripts of all citations likely to meet the predefined selection criteria were selected. Independent reviewers (ER and SG) examined these manuscripts and made the final decisions regarding inclusion or exclusion. When disagreements occurred, they were resolved by consensus or arbitration with a third reviewer (ST). In cases of duplicate publication, we selected the most recent and complete versions. Randomised controlled trials that evaluated any dietary or lifestyle interventions with potential to influence maternal and fetal outcomes related to weight were included. Two independent reviewers (ER, SG) classified interventions as mainly diet based, physical activity based, or mixed approach (with both diet and physical activity components that might or might not be underpinned by behavioural theory). Any disagreements were resolved by discussion with a third reviewer (ST). We excluded studies on pregnant women who were underweight (BMI <18.5).

Study quality assessment and data extraction

Quality, defined as the extent to which an estimate of effect was likely to be correct or unbiased, was evaluated with accepted contemporary standards.[16 17] The risk of bias in individual studies was assessed by considering six items: sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other potential sources of bias. This information provided data for one of the domains used in evidence rating (see below). Two independent reviewers (ER and SG) extracted data in duplicate using predesigned and piloted data extraction forms. We attempted to obtain missing information by contacting investigators.

Data synthesis

We calculated relative risks with 95% confidence intervals for dichotomous data. Continuous data were summarised as mean differences with standard deviations. We used the I^2 statistic to assess statistical heterogeneity between trials and explored possible causes if we detected substantial heterogeneity (I^2 >50%). Subgroup meta-analyses for the main outcomes were performed. For each outcome, the subgroups defined a priori were clinical characteristics such as BMI and diabetes in pregnancy; type of intervention; responders, defined as women with significant reduction in gestational weight gain with intervention; and study quality. A true subgroup effect was considered to be present when the difference in estimates between the subgroups was significant at $P<0.005$. When any heterogeneity was not explained by subgroup analyses, we performed meta-analysis using a random effects model. Birth weight was analysed in kilograms and is reported in grams. Funnel plots were used to display small study effects when the intervention effects in smaller studies differed from the effects displayed by larger studies. We used Egger’s test to test for funnel plot asymmetry.[18] All analyses were carried out with Revman[19] and Stata statistical software.[20]

Prioritisation and rating of evidence

Our primary outcomes were weight related changes in the mother and baby. We prioritised the other maternal and fetal outcomes related to pregnancy and ranked them for importance by a two round Delphi survey of clinicians with expertise in this specialty.[15] Nineteen clinicians (19/20, 95% response rate) participated in the first round and 16 (84%) in the second. The list of outcomes ranked as critically important to weight management in pregnancy is provided in appendix 1 on bmj.com.

We summarised the strength of evidence for key outcomes using the GRADE (grading of recommendations, assessment, development, and evaluation) methods.[21] This system rates the confidence in the observed estimate into one of four levels (high, moderate, low, and very low) evaluating five domains (risk of bias (see above), (in-)consistency of the results (heterogeneity), (in-)directness of the evidence, (im-)precision of the results, and publication bias). Initially we assigned evidence from randomised trials as high quality and readjusted the level on the basis of deficiencies in the above domains. This lowered the rating of evidence from high to moderate to low or even very low, depending on the severity of the deficiency. The footnotes in appendix 2 on bmj.com provide an explanation as to how we downgraded evidence in the light of various deficiencies.

Safety of the interventions in pregnancy

We undertook the review of safety of interventions based on recommended methods, including those of Cochrane adverse effects subgroup.[22 23] We designed a separate search strategy to evaluate safety by including text words and indexing terms for adverse effects. We limited the search by including search filters for "adverse events", "human studies", and "study type" (excluding editorials and letters). We searched Medline and Embase from inception to March 2011. We included any relevant randomised studies, observational studies, case series, or case reports without any language restrictions. The number of adverse events reported in pregnant women and children were obtained for each intervention to compute a percentage of the total number of women and children in whom the occurrence of that particular adverse event, or confirmation of its absence, was reported. The adverse events were quantified as relative risks and 95% confidence intervals.

Results

Study selection

From 19 593 citations, we selected 215 full papers for assessment (fig 1⇓). Forty four randomised trials (7278 women) reported the effects of dietary and lifestyle interventions in pregnancy. The interventions in the trials were broadly classified into three groups: those mainly based on diet (13 randomised trials)[24-36] or physical activity (18 randomised trials)[37-55] and a mixed approach with diet and physical activity components that might or might not be underpinned by behavioural counselling (13 randomised trials).[7 56-67]

Characteristics of the included studies and interventions

The included trials studied the effect of interventions on women with any BMI,[7 25-30 32 37-40 42-50 52 54-66] mostly obese and overweight women,[31 33 53] or only obese women[24 29 34-36 51 59 67] (clinical characteristics of all identified studies are in appendix 3 on bmj.com). Five randomised trials included pregnant women with a diagnosis of gestational diabetes mellitus[28 31 34 57 58] and one included women with pre-existing diabetes.[32] Typical dietary interventions included a balanced diet consisting of carbohydrates, proteins, and fat and maintenance of a food diary. Typical interventions based on physical activity included light intensity resistance training, weight bearing exercises, and walking for 30 minutes. The interventions in the mixed approach included counselling sessions, education concerning the potential benefit of diet and physical activity, and feedback on weight gain in pregnancy. The mixed approach used techniques of behavioural modification to give the women insight into controlling periods of emotional eating and preventing binge eating sessions. The quality of the studies varied (fig 2⇓). One study was available only as an abstract, and data were not included in the meta-analysis.[24]

Effect of intervention on maternal weight

Thirty four randomised trials (5481 women) evaluated the effect of interventions on maternal weight gain in pregnancy.[7 25-28 31-39 42 43 45-48 50-54 56 59-63 65-67] Compared with control women, there was a reduction in weight gain of 1.42 kg with interventions (95% confidence interval 0.95 to 1.89 kg; P<0.001, I^2=80%) (fig 3⇓). The largest reduction in weight gain was observed with dietary intervention (3.84 kg, 2.45 to 5.22 kg; P<0.001, I^2=92%) (table 1⇓, fig 3⇓). There was no significant difference between the two groups in their adherence to the Institute of Medicine (IOM) recommended gestational target weight gain (relative risk 0.85, 0.66 to 1.1).

Effect of intervention on fetal weight

Thirty one randomised trials (5278 newborns) evaluated the effect of the interventions on birth weight.[26-28 30-40 42 44-50 52 53 57 59 61-63 65 66] Compared with controls, there was minimal reduction in the birth weight that was not significant (mean difference −50 g, 95% confidence interval −100 to 0 g) for all interventions (table 1⇓, fig 4⇓). There was a trend towards reduction in the risk of large for gestational age babies (defined as birth weight above the 90th centile or 4000 g) (relative risk 0.85, 0.66 to 1.09) with interventions (fig 5⇓. The risk of small for gestational age babies (defined as birth weight below the 10th centile or 2500 g) was not altered (1.00, 0.78 to 1.28) with interventions (fig 5⇓).

Effect of intervention on obstetric maternal outcomes

Thirty six randomised trials (n=6543 women) studied the effect of interventions on obstetric maternal outcomes.[24 26 28-39 42 44-50 52-57 59 61-67] Fig 5⇓ shows the summary of the effect of weight management interventions on pregnancy outcomes. The overall effect of interventions led to a reduction in pre-eclampsia by 26% (relative risk 0.74, 0.60 to 0.92; P=0.006, I^2=31%). The summary estimate of interventions showed trends towards reduction in gestational diabetes (0.78, 0.57 to 1.08), gestational hypertension (0.89, 0.64 to 1.25), and preterm delivery (0.78, 0.60 to 1.02) that were not significant. Meta-analysis of the studies showed no difference between the groups in gestational age at delivery (mean difference 0.02 weeks, −0.08 to 0.11 weeks) and rates of caesarean section (0.93, 0.85 to 1.01), induction of labour (1.12, 1 to 1.26), and postpartum haemorrhage (0.90, 0.57 to 1.42).

Compared with the control, dietary interventions in pregnancy were associated with a 33% reduced risk of pre-eclampsia (0.67, 0.53 to 0.85; P<0.001, I^2=0%) and a 61% reduced risk of gestational diabetes (0.39, 0.23 to 0.69; P=0.001, I^2=21%) (fig 6⇓). They were also associated with a significant reduction in gestational hypertension (0.30, 0.10 to 0.88; P=0.03, I^2=0%) and preterm delivery (0.68, 0.48 to 0.96; P=0.03, I^2=35%) (table 2⇓). There were no differences in these outcomes with physical activity based and mixed approach interventions compared with the control. Visual analysis of the funnel plots showed no evidence of small study effects for weight related outcomes. There was some evidence for funnel asymmetry for pregnancy outcomes such as gestational diabetes (P=0.034) and caesarean section (P=0.002) and none for others.

Effect of interventions on fetal and neonatal outcomes

Fifteen randomised trials (n=3905 newborns) studied the effect of interventions on fetal and neonatal morbidity and mortality outcomes.[28-31 34 35 37-39 46 50 53 57 63 67] Meta-analysis of the effect of interventions showed trends towards reduction in intrauterine death (relative risk 0.15, 0.02 to 1.20, I^2=0%), birth trauma (0.36, 0.11 to 1.23, I^2=0%) (fig 7⇓), and hyperbilirubinaemia (0.84, 0.64 to 1.10; table 3⇓). The overall risk of shoulder dystocia was reduced by 61% with all interventions compared with the control group (0.39, 0.22 to 0.70; P=0.002, I^2=0%; table 3⇓). There were no differences between the groups for respiratory distress syndrome (1.05, 0.48 to 2.28), admission to neonatal intensive care (1.00, 0.75 to 1.33), or infant hypoglycaemia (1.07, 0.85 to 1.35) (fig 7⇓).

Subgroup and sensitivity analysis

Tables 4 and 5⇓⇓ provides estimates of subgroup analyses for clinical characteristics and quality of the included studies for maternal and fetal outcomes. There was a significant difference between the subgroups for gestational weight gain based on the type of intervention (P<0.001). The responders, defined as women with significantly reduced gestational weight gain with intervention, showed a difference in reduction in pre-eclampsia (P=0.009) and birth weight (P=0.002) compared with the non-responders. There were no significant differences between the subgroups based on the BMI, diabetic status in pregnancy, and risk of bias for allocation concealment.

When we excluded studies on women with diabetes in pregnancy[28 31 32 34 57 58] the sensitivity analysis consistently showed a overall reduction in gestational weight gain with interventions (mean difference −1.4 kg, 95% confidence interval −2.09 to −0.71 kg, P<0.001), including diet (−5.53 kg, −8.54 to −2.53 kg; P<0.001), physical activity (−0.72 kg, −1.2 to −0.25 kg, P=0.003), and mixed approach (−1.06 kg, −1.67 to −0.46 kg; P<0.001). There was no significant reduction in birth weight with intervention (−40 g, −100 to 10 g).[26 27 30 33 35-40 42 44-50 52 53 59 61-63 65 66] There were no differences between the groups in the incidence of babies who were small or large for gestational age or those with shoulder dystocia after we excluded women with diabetes. Dietary interventions in women without diabetes resulted in a significant reduction in preterm delivery (relative risk 0.26, 0.09 to 0.74) and gestational hypertension (0.30, 0.10 to 0.88). There was a trend towards a reduction in pre-eclampsia (0.82, 0.43 to 1.42) in these women with diet that was not significant.

Interventions in obese and overweight pregnant women showed a reduction in gestational weight gain (mean difference −2.1 kg, −3.46 to −0.75 kg; P<0.002, I^2=88%). There was no significant reduction in fetal weight or other clinical outcomes. Dietary intervention in obese and overweight women significantly reduced the risk of pre-eclampsia (relative risk 0.63, 0.42 to 0.96), gestational diabetes (0.39, 0.23 to 0.69), and gestational hypertension (0.30, 0.10 to 0.88). This benefit was not observed for other outcomes or with other interventions. After we excluded women with diabetes, the beneficial effect observed with diet persisted for gestational weight gain (mean difference −7.73 kg, −6.05 to −9.40 kg; P<0.001, I^2=41%) and gestational hypertension (relative risk 0.30, 0.10 to 0.88). There was no increase in the risk of small for gestational age babies, and there was no effect on any of the other maternal or fetal outcomes.

Rating the evidence

The Delphi survey of practicing clinicians determined the importance of the maternal and fetal outcomes.[15] The overall evidence rating was moderate for reduction in gestational weight gain (see appendix 2 on bmj.com). The rating was moderate for evidence of no effect observed with interventions on the risk of babies who were small for gestational age. The rating for clinical outcomes such as pre-eclampsia, gestational diabetes, preterm delivery, gestational hypertension, admission to neonatal unit, and neonatal hypoglycaemia was low to very low. The evidence rating for the beneficial effect of diet was high for gestational hypertension, moderate for gestational diabetes, low for pre-eclampsia, and very low for preterm birth. Although clinicians judged thromboembolism, maternal admission to high dependency or intensive care unit, and long term neurological sequelae to the fetus as critically important outcomes, we did not identify evidence for these outcomes.[15]

Safety of the interventions

We included 26 studies after reviewing 14 832 citations to assess the safety of the interventions in pregnancy. Of the included studies, two were randomised controlled trials (277 women)[40 64] and 24 were observational studies (19 cohort studies and five case-control studies, 468 581 women).[68-91] The studies evaluated the effects of dietary, physical activity, and other lifestyle interventions in pregnancy on maternal and fetal outcomes.

The two included randomised trials evaluated physical activity and did not show an increase in meconium staining of amniotic fluid (relative risk 0.62, 0.20 to 1.90), uterine atony (0.93, 0.22 to 3.89), or chorioamnionitis (3.69, 0.15 to 88.13). Eighteen studies observed the effect of diet on maternal and fetal outcomes. Most of the included studies evaluated the effect of severe reduction in energy intake in extreme conditions such as war or famine. There was an increase in the rate of neural tube defects and cleft lip and palate in babies of women with extreme forms of dieting and on diets with a high glycaemic index during pregnancy (see appendix 4 on bmj.com).[89] The risk of coronary artery disease, metabolic syndrome, breast cancer, and diabetes was increased in infants born to mothers whose diet had been severely restricted because of famine.[72] There were no significant maternal or fetal adverse effects such as cord abnormalities, threatened miscarriage, meconium stained liquor, abnormal fetal heart rate pattern, maternal sepsis, or chorioamnionitis observed with physical activity during pregnancy.

Discussion

Summary of the findings

Dietary and lifestyle interventions in pregnancy are effective in reducing gestational weight gain without any adverse effect on the risk of babies small for gestational age. Compared with physical activity and a mixed approach, dietary interventions were associated with the greatest reduction in weight gain in pregnancy. Interventions also resulted in significant reduction in the risk of pre-eclampsia. There was an overall trend towards reduction in gestational diabetes, gestational hypertension, preterm birth, and intrauterine death with intervention compared with control. Diet in particular, significantly reduced the risk of pre-eclampsia, gestational diabetes, gestational hypertension, and preterm births compared with any other intervention. The interventions had less effect on outcomes related to fetal weight and other morbidity and mortality. Furthermore, there was no evidence that the interventions reduced the rates of caesarean section or induction of labour. The rating of evidence quality was moderate (see appendix 2 on bmj.com) for the lack of effect observed with interventions on size for gestational age. The quality of evidence for the benefit observed with interventions on gestational weight gain was moderate but low for clinical outcomes.

Strengths and limitations

Our systematic review was comprehensive in its scope and search. We conducted the review in line with contemporary recommendations and complied with the PRISMA (preferred reporting items for systematic reviews and meta-analyses) statement.[92] Our search of literature aimed to minimise the risk of selection and publication bias. Most of the published reviews on effects of dietary and lifestyle interventions on maternal and fetal outcomes were limited to specific groups of women or types of intervention. There was no formal prioritisation of the importance of the clinical outcomes, and few assessed the quality of the evidence for the important outcomes. We undertook rigorous quality assessment and formally prioritised the outcomes for clinical importance. Reliable data were identified on clinically important outcomes related to weight and pregnancy by the Delphi survey. We explored for sources of heterogeneity when required.

Appropriate subgroup analyses and sensitivity analyses planned a priori were undertaken for important factors such as BMI, diabetic status, maternal weight change with intervention, and study quality that could influence outcomes. We formally rated strength of evidence for key outcomes identified through Delphi survey. This enabled our confidence in the estimates of the important effects observed. Our careful scrutiny and presentation of evidence profiles provides the much needed clarity necessary to make judgments about effects.

The validity of a meta-analysis depends on the quality of the component studies, heterogeneity observed, and the risk of publication bias. The quality across various outcomes assessed by GRADE was moderate for the benefit observed with gestational weight gain but low for other important obstetric outcomes such as pre-eclampsia, gestational diabetes, gestational hypertension, and preterm delivery. This weakens the inferences for these outcomes. The reasons for low evidence rating were the significant heterogeneity observed in the effect size, deficiencies in the quality of the individual studies, and risk of publication and related biases.

We observed heterogeneity for beneficial effects of interventions on maternal weight gain that persisted after accounting for the type of intervention, BMI, and diabetic status. Further information is needed on characteristics of included women—such as age, ethnicity, socioeconomic status, parity, and underlying medical conditions—and characteristics of the interventions—such as frequency, duration, and intensity—that could influence the outcomes. We were limited in our ability to identify the optimal weight change in pregnancy with interventions that would minimise maternal and fetal complications. Furthermore, constraints in the available data limited assessment of baseline prognostic factors on the effectiveness of outcomes. Such questions were difficult to answer with extracted results from trial publications because patient level information was not available and subgroup effects ("treatment-covariate interactions") were rarely reported in sufficient detail. Although the Delphi panel of clinicians identified long term neurological sequelae and metabolic syndrome of the fetuses exposed to the intervention, they were not reported in any of the studies.

Safety of the interventions

The beneficial effects observed in our review need balancing against potential adverse effects when evaluating clinical implications. The evidence of any adverse effects from diet in pregnancy was usually from observational studies on extremes of weight reduction diets or those on intake of food with a very high or low glycaemic index.[89] These findings do not apply to the interventions we reviewed. We also observed that reduction in weight gain in pregnancy was not associated with an increase in babies who were small for gestational age. Observational studies on physical activity in pregnancy did not show any significant adverse maternal or fetal outcome for activities of varying intensity.

Clinical and practical implications

Our findings suggest that interventions based on diet in pregnancy would reduce the gestational weight gain by 4 kg, on average, compared with 0.7 kg and 1.0 kg with physical activity and a mixed approach, respectively. Dietary interventions were most effective in reducing complications such as pre-eclampsia, gestational diabetes, gestational hypertension, and preterm delivery. One of the main concerns of the mothers is the effect of dietary and lifestyle interventions on the weight of the fetus. There is no evidence that the interventions evaluated in our review or recommended in current clinical practice are associated with adverse maternal or fetal outcomes.

The diet based interventions effective in reducing weight gain in pregnancy included a balanced diet of 18-24 kJ/kg, a low glycaemic diet with unprocessed whole grains, fruits, beans and vegetables, and a healthy diet with a maximum of 30% fat, 15-20% protein, and 50-55% carbohydrate, with energy intake individualised to the needs of the mother. Provision of regular input on planned nutritional intake from early pregnancy through dedicated dietetic teams in primary and secondary care has the potential to improve outcomes. Overweight and obese women benefit the most and could be targeted in clinical practice.

Current research focuses mainly on mixed interventions with both diet and physical activity components. But interventions predominantly based on diet seemed to be more effective for weight related and clinical outcomes. With lack of individual data on important factors such as age, ethnicity, socioeconomic status, compliance, and other risk factors, we are limited in our explanation for the benefit observed with diet compared with other methods. There could be various reasons for this finding. Firstly, in a complex intervention, the net benefit gained might be linked to the vigour with which the components of the intervention are delivered. In "mixed approaches" the individual components might not be delivered to the same standard as in studies that focus on diet alone. Secondly, compliance might have been better in trials with a diet only intervention than other methods because of its relative simplicity and perceived safety in contrast with physical activity in pregnancy.[93 94] Thirdly, specific components of the diet, such as fibre, might have benefits that are not evident with other interventions. Raised triglyceride concentrations in pregnancy are associated with the risk of pre-eclampsia.[95] There is a known reduction in the incidence of pre-eclampsia by up to 70% associated with a fall in the concentrations of triglycerides in women with the highest quarter of dietary fibre intake compared with the lowest quarter after adjustment for confounders.[96] The high fibre in the dietary intervention of the included studies could have influenced the beneficial effect observed with reduction in the rates of pre-eclampsia.

The economic evaluation undertaken by the National Institute for Health and Clinical Excellence on non-pharmacological interventions for weight management outside pregnancy reported that diet based interventions were cheaper than interventions based on physical activity.[97] With the clear benefit in gestational weight gain observed with dietary interventions in pregnancy, there is a potential for this strategy to be also cost effective compared with other methods.

Recommendations for future research

Synthesis of patient level data by individual patient data meta-analysis is needed to assess any differential effect of the benefits observed with interventions in various groups based on BMI, age, ethnicity, socioeconomic status, parity, and risk status in pregnancy. Availability of the raw data will substantially increase the power to detect baseline factors that truly modify the intervention effect[98] and will enable intervention effects to be quantified for clinically relevant groups.[99] In addition, individual patient data meta-analysis will be able to assess whether the improvement in clinical outcomes is related to reduction in gestational weight gain alone or if there is any added benefit from the type of intervention resulting in weight change. It will also allow the magnitude of benefit from weight change in pregnancy to be quantified for both the mother and baby. This will allow us to implement those weight management interventions that show clear benefit with specific weight gain targets in pregnancy. This approach will also provide adequate power to generate valid, reliable answers and to populate the model for decision analytic modelling for health economic evaluation.

The paucity of descriptive information on the intensity and duration of intervention, means of provision, and patient compliance are factors that could potentially facilitate or hinder implementation. These gaps identify issues for further research. There is a need for good quality large prospective studies for the important clinical outcomes identified including long term effects on the mother and fetus.

Conclusion

Until now, the recommendations for weight management in pregnancy have mainly focused on obese and overweight women without an emphasis on a particular type of intervention. Dietary intervention is effective, safe, and potentially cost effective and dominates physical activity based intervention. The case for its introduction with a service evaluation alongside is underpinned by our review. Ongoing effectiveness trials should focus on clinically relevant outcomes captured by our Delphi survey. They should generate data for determining the most efficient means for improving outcomes with weight management strategies in pregnancy.

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What is already known on this topic

Excessive weight gain in pregnancy is associated with adverse maternal and fetal outcomes

Interventions to manage weight in pregnancy have the potential to reduce adverse outcomes to mother and baby

Interventions based on diet or physical activity, or both, in pregnancy could influence maternal and fetal weight and obstetric outcomes

What this study adds

Diet and lifestyle interventions in pregnancy can reduce maternal weight gain in pregnancy

There is no significant overall effect on outcomes related to fetal weight

Diet based interventions are the most effective in reducing maternal gestational weight gain compared with other methods

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Tables

Table 1 | **Effect of dietary and lifestyle interventions in pregnancy on primary outcomes (weight gain in pregnancy and birth weight) and secondary weight related outcomes ranked as critically important by Delphi survey (except for exceeding IOM recommendations)**

	No of studies	No of participants	Summary estimate (95% CI)	P value	I^2 (%)
Dietary intervention					
Weight gain in pregnancy (kg)	10[25-28 31-36]	2560	−3.84* (−5.22 to −2.45)	<0.001	92
Birth weight (g)	10[26-28 30-36]	2861	−60* (−190 to 80)	0.41	84
Small for gestational age	3[28 30 31]	2252	1.02† (0.75 to 1.37)	0.91	0
Large for gestational age	5[28 29 31 34 35]	2378	0.78† (0.51 to 1.19)	0.26	63
Exceeds IOM recommendations	0	—	—	—	—
Physical activity					
Weight gain in pregnancy (kg)	14[37-39 42 43 45-48 50-54]	1057	−0.72* (−1.20 to −0.25)	0.003	30
Birth weight (g)	14[37-40 42 44-50 52 53]	1369	−60* (−120 to −10)	0.02	0
Small for gestational age	4[37 38 46 53]	409	1.28† (0.52 to 3.15)	0.60	0
Large for gestational age	4[38 39 46 52]	355	0.52† (0.25 to 1.09)	0.08	0
Exceeds IOM recommendations	1[46]	74	0.33† (0.11 to 0.98)	0.05	NA
Mixed approach					
Weight gain in pregnancy (kg)	10[7 56 59-63 65-67]	1864	−1.06* (−1.67 to −0.46)	<0.001	36
Birth weight (g)	7[57 59 61-63 65 66]	1048	10* (−50 to 70)	0.86	0
Small for gestational age	4[58 63 65 66]	891	0.88† (0.53 to 1.44)	0.60	0
Large for gestational age	9[57-59 61 62 63 65-67]	1500	1.05† (0.79 to 1.40)	0.72	0
Exceeds IOM recommendations	4[61 63 65 66]	899	0.89† (0.71 to 1.13)	0.33	56
All interventions					
Weight gain in pregnancy (kg)	34	5481	−1.42* (−1.89 to −0.95)	<0.001	80
Birth weight (g)	31	5278	−50* (−100 to 0)	0.08	57
Small for gestational age	11	3552	1.00† (0.78 to 1.28)	0.99	0
Large for gestational age	18	4233	0.85† (0.66 to 1.09)	0.21	38
Exceeds IOM recommendations	5	873	0.85† (0.66 to 1.11)	0.21	60

IOM=Institute of Medicine; NA=not applicable.

*Mean difference.

†Relative risk.

Table 2| **Effect of dietary and lifestyle interventions in pregnancy on secondary maternal outcomes (ranked as critically important by Delphi survey, except for vaginal delivery and gestational age at birth). Summary estimates are relative risks unless stated otherwise**

	No of studies	No of participants	Summary estimate (95% CI)	P value	I^2 (%)
Dietary intervention					
Gestational diabetes mellitus	3[33 35 36]	409	0.39 (0.23 to 0.69)	0.001	21
Pre-eclampsia	6[28 30 31 34-36]	2624	0.67 (0.53 to 0.85)	<0.001	0
Gestational hypertension	2[35 36]	282	0.30 (0.10 to 0.88)	0.03	0
Preterm delivery	4[26 30 31 35]	1474	0.68 (0.48 to 0.96)	0.03	35
Caesarean section	5[28 29 31 35 36]	2273	0.93 (0.84 to1.04)	0.19	49
Vaginal delivery	2[31 34]	472	0.97 0.89 to 1.07)	0.56	0
Induction of labour	4[28 31 34 35]	2277	1.12 (0.99 to 1.27)	0.07	60
Postpartum haemorrhage	2[28 35]	1232	0.90 (0.57 to 1.42)	0.64	0
Gestational age at delivery (weeks)	6[28 30-32 34 35]	2625	−0.05* (−0.18 to 0.08)	0.42	71
Physical activity					
Gestational diabetes mellitus	0	—	—	—	—
Pre-eclampsia	0	—	—	—	—
Gestational hypertension	0	—	—	—	—
Preterm delivery	5[37 38 46 52 53]	450	1.22 (0.51 to 2.90)	0.65	0
Caesarean section	5[37 39 48-50]	542	0.88 (0.66 to 1.17)	0.38	0
Vaginal delivery	3[37 39 49]	488	1.02 (0.93 to 1.11)	0.70	0
Induction of labour	0	—	—	—	—
Postpartum haemorrhage	0	—	—	—	—
Gestational age at delivery (weeks)	11[37-39 42 44-49 54]	1250	0.03* (−0.14 to 0.20)	0.74	0
Mixed approach					
Gestational diabetes mellitus	6[61 62 63 65-67]	1233	1.18 (0.78 to 1.77)	0.44	0
Pre-eclampsia	4[59 63 65 66]	718	1.16 (0.70 to 1.90)	0.57	39
Gestational hypertension	4[59 63 65 66]	779	1.08 (0.75 to 1.55)	0.69	42
Preterm delivery	4[57 63 65 66]	728	0.90 (0.55 to 1.47)	0.68	7
Caesarean section	8[56 57 59 61 63 65-67]	1407	0.94 (0.79 to 1.13)	0.53	10
Vaginal delivery	1[57]	34	1.25 (0.88 to 1.78)	0.21	NA
Induction of labour	1[59]	85	1.17 (0.78 to 1.75)	0.44	NA
Postpartum haemorrhage	0	—	—	—	—
Gestational age at delivery (weeks)	6[57 59 61 62 65 66]	813	0.20* (−0.02 to 0.42)	0.07	1
All interventions					
Gestational diabetes mellitus	9	1642	0.78 (0.57 to 1.08)	0.13	29
Pre-eclampsia	10	3342	0.74 (0.60 to 0.92)	0.006	31
Gestational hypertension	6	1061	0.89 (0.64 to 1.25)	0.51	50
Preterm delivery	13	2652	0.78 (0.60 to 1.02)	0.07	0
Caesarean section	18	4222	0.93 (0.85 to 1.01)	0.10	3
Vaginal delivery	6	994	1.00 (0.94 to 1.07)	0.91	0
Induction of labour	5	2362	1.12 (1.00 to 1.26)	0.05	47
Postpartum haemorrhage	2	1232	0.90 (0.57 to 1.42)	0.64	0
Gestational age at delivery (weeks)	23	4688	0.02* (−0.08 to 0.11)	0.72	33

NA=not applicable.

*Mean difference.

Table 3| Effect of dietary and lifestyle interventions in pregnancy* on secondary fetal and neonatal outcomes (ranked as critically important by Delphi survey, except for infant hyperbilirubinaemia). Summary estimates are relative risks unless stated otherwise

	No of studies	No of participants	Relative risk (95% CI)	P value	I^2 (%)
Dietary intervention					
Intrauterine death	2[28 30]	1320	0.15 (0.02 to 1.20)	0.07	0
Admission to neonatal intensive care unit	2[28 31]	1962	0.98 (0.66 to 1.47)	0.93	77
Shoulder dystocia	3[28 31 34]	2082	0.38 (0.21 to 0.69)	0.001	0
Birth trauma	2[28 31]	1961	0.36 (0.11 to 1.23)	0.10	0
Respiratory distress syndrome	2[28 31]	1962	1.05 (0.48 to 2.28)	0.91	58
Infant hypoglycaemia	3[28 31 34]	1877	1.05 (0.83 to 1.33)	0.69	41
Infant hyperbilirubinaemia	2[28 31]	1898	0.84 (0.64 to 1.10)	0.19	0
Mixed approach					
Intrauterine death	0	—	—	—	—
Admission to neonatal intensive care unit	1[67]	304	0.98 (0.56 to 1.71)	0.94	NA
Shoulder dystocia	1[63]	235	0.90 (0.06 to 14.14)	0.94	NA
Birth trauma	0	—	—	—	—
Respiratory distress syndrome	0	—	—	—	—
Infant hypoglycaemia	2[57 63]	269	2.35 (0.47 to 11.76)	0.3	0
Infant hyperbilirubinaemia	0	—	—	—	—
All interventions					
Intrauterine death	2	1320	0.15 (0.02 to 1.20)	0.07	0
Admission to neonatal intensive care unit	3	2266	1.00 (0.75 to 1.33)	1.00	58
Shoulder dystocia	4	2317	0.39 (0.22 to 0.70)	0.002	0
Birth trauma	2	1961	0.36 (0.11 to 1.23)	0.10	0
Respiratory distress syndrome	2	1962	1.05 (0.48 to 2.28)	0.91	58
Infant hypoglycaemia	5	2146	1.07 (0.85 to 1.35)	0.55	10
Infant hyperbilirubinaemia	2	1898	0.84 (0.64 to 1.10)	0.19	0

*No randomised studies evaluated effect of physical activity for above outcomes.
NA=not applicable.

Table 4| **Subgroup analyses for trial methods and clinical characteristics for maternal outcomes in evaluation of dietary and lifestyle interventions in pregnancy**

	Gestational weight gain (kg)			Pre-eclampsia		
Subgroup	**No of studies**	**Mean difference (95% CI)**	**P value for interaction**	**No of studies**	**Relative risk (95% CI)**	**P value for interaction**
Intervention type:						
Diet	10	−3.84 (−5.22 to −2.45)	<0.001	6	0.67 (0.53 to 0.85)	0.05
Physical activity	14	−0.72 (−1.20 to −0.25)		0	—	
Mixed	10	−1.06 (−1.67 to −0.46)		4	1.16 (0.70 to 1.90)	
Diabetic status:						
Women with diabetes	4	−1.85 (−2.44 to −1.26)	0.33	3	0.65 (0.50 to 0.84)	0.06
Normal women	30	−1.4 (−2.09 to −0.71)		7	1.01 (0.68 to 1.50)	
BMI:						
Obese and overweight	11*†	−2.41 (−4.04 to -0.77)	0.05	7†	0.81 (0.58 to 1.14)	0.49
Any weight	25*†	−0.63 (−1.24 to -0.02)		4†	0.70 (0.53 to 0.92)	
Maternal weight change with intervention:						
Significantly reduced	—	—	—	4	0.61 (0.47 to 0.79)	0.009
No significant change	—	—		6	1.12 (0.77 to 1.61)	
Risk of bias (allocation concealment):						
High risk	28	−0.89 (−1.61 to −0.17)	0.07	7	0.73 (0.56 to 0.93)	0.76
Low risk	6	−2.14 (−3.28 to −1.01)		3	0.78 (0.53 to 1.16)	

*Polley et al[66] data presented separately for normal weight women and overweight women.
†Phelan 2011 et al[65] data presented separately for normal weight women and overweight women.

Table 5| Subgroup analyses for trial methods and clinical characteristics for fetal outcomes in evaluation of dietary and lifestyle interventions in pregnancy

	Birth weight (g)			Large for gestational age			Small for gestational age		
Subgroup	No of studies	Mean difference (95% CI)	P value for interaction	No of studies	Relative risk (95% CI)	P value for interaction	No of studies	Relative risk (95% CI)	P value for interaction
Intervention type:									
Diet	10	−60 (−190 to 80)	0.22	5	0.78 (0.51 to 1.19)	0.16	3	1.02 (0.75 to 1.37)	0.76
Physical activity	14	−60 (−120 to −10)		4	0.52 (0.25 to 1.09)		4	1.28 (0.52 to 3.15)	
Mixed	7	10 (−50 to 70)		9	1.05 (0.79 to 1.40)		4	0.88 (0.53 to 1.44)	
Diabetic status:									
Women with diabetes	5	−60 (−170 to 50)	0.80	13	0.97(0.73 to 1.27)	0.34	3	1.03 (0.75 to 1.41)	0.77
Normal women	26	−40 (−100 to 10)		5	0.76 (0.50 to 1.15)		8	0.95 (0.64 to 1.42)	
BMI:									
Obese and overweight	9*	−20 (−90 to 50)	0.43	7†	1.05 (0.68 to 1.63)	0.13	4*†	1.17 (0.77 to 1.80)	0.35
Any weight	23*	−60 (−130 to 10)		12†	0.71 (0.55 to 0.91)		9*†	0.92 (0.68 to 1.24)	
Maternal weight change with intervention:									
Significantly reduced	7	−170 (−300 to −40)	0.002	5‡	0.79 (0.50 to 1.25)	0.70	2‡	1.03 (0.74 to 1.42)	0.78
No significant change	24	−10 (−50 to −30)		12‡	0.88 (0.66 to 1.17)		8‡	0.95 (0.64 to 1.42)	
Risk of bias (allocation concealment):									
High risk	26	−60 (−120 to 0)	0.33	15	0.82 (0.63 to 1.08)	0.66	7	0.89 (0.63 to 1.25)	0.35
Low risk	5	0 (−90 to 80)		3	0.96 (0.51 to 1.80)		4	1.13 (0.79 to 1.62)	

*Polley et al[66] data presented separately for normal weight women and overweight women.

†Phelan 2011 et al[65] data presented separately for normal weight women and overweight women.

‡Ferrara 2011 et al[58] did not provide data for gestational weight gain.

Figures

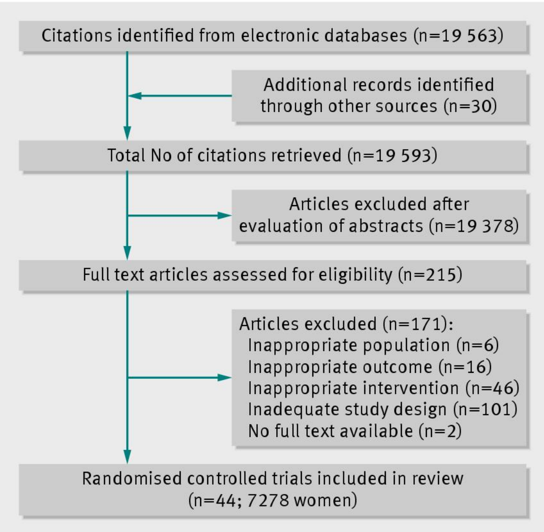

Fig 1 Identification of studies in systematic review of effects of dietary and lifestyle interventions in pregnancy on maternal and fetal outcomes

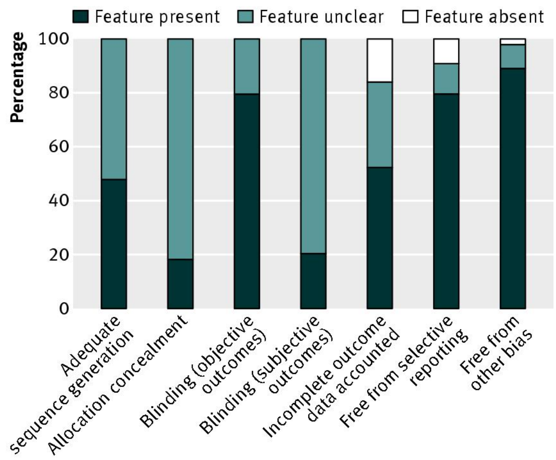

Fig 2 Quality of randomised controlled trials included in systematic review of dietary and lifestyle interventions in pregnancy on maternal and fetal outcomes

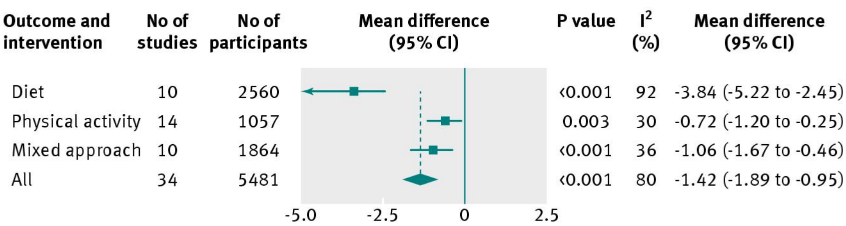

Fig 3 Mean difference in gestational weight gain (kg) with dietary and lifestyle interventions in pregnancy

Outcome and intervention	No of studies	No of participants	P value	I² (%)	Mean difference (95% CI)
Diet	10	2861	0.41	84	-60(-190 to 80)
Physical activity	14	1369	0.02	0	-60 (-120 to -10)
Mixed approach	7	1048	0.86	0	10 (-50 to 70)
All	31	5278	0.08	57	-50 (-100 to 0)

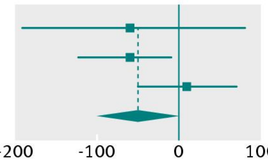

Fig 4 Mean difference in birth weight (g) with dietary and lifestyle interventions in pregnancy

Outcome and intervention	No of studies	No of participants	P value	I² (%)	Relative risk (95% CI)
Large for gestational age					
Diet	5	2378	0.26	63	0.78 (0.51 to 1.19)
Physical activity	4	355	0.08	0	0.52 (0.25 to 1.09)
Mixed approach	9	1500	0.72	0	1.05 (0.79 to 1.40)
All	18	4233	0.21	38	0.85 (0.66 to 1.09)
Small for gestational age					
Diet	3	2252	0.91	0	1.02 (0.75 to 1.37)
Physical activity	4	409	0.60	0	1.28 (0.52 to 3.15)
Mixed approach	4	891	0.60	0	0.88 (0.53 to 1.44)
All	11	3552	0.99	0	1.00 (0.78 to 1.28)

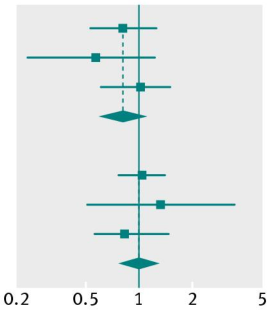

Fig 5 Relative risk of effect on size for gestational age with dietary and lifestyle interventions in pregnancy

Outcome and intervention	No of studies	No of participants	P value	I² (%)	Relative risk (95% CI)
Pre-eclampsia					
Diet	6	2624	<0.001	0	0.67 (0.53 to 0.85)
Mixed approach	4	718	0.57	39	1.16 (0.70 to 1.90)
All	10	3342	0.006	31	0.74 (0.60 to 0.92)
Gestational diabetes mellitus					
Diet	3	409	0.001	21	0.39 (0.23 to 0.69)
Mixed approach	6	1233	0.44	0	1.18 (0.78 to 1.77)
All	9	1642	0.13	29	0.78 (0.57 to 1.08)
Gestational hypertension					
Diet	2	282	0.03	0	0.30 (0.10 to 0.88)
Mixed approach	4	779	0.69	42	1.08 (0.75 to 1.55)
All	6	1061	0.51	50	0.89 (0.64 to 1.25)
Preterm delivery					
Diet	4	1474	0.03	35	0.68 (0.48 to 0.96)
Physical activity	5	450	0.65	0	1.22 (0.51 to 2.90)
Mixed approach	4	728	0.68	7	0.90 (0.55 to 1.47)
All	13	2652	0.07	0	0.78 (0.60 to 1.02)
Caesarean section					
Diet	5	2273	0.19	49	0.93 (0.84 to 1.04)
Physical activity	5	542	0.38	0	0.88 (0.66 to 1.17)
Mixed approach	8	1407	0.53	10	0.94 (0.79 to 1.13)
All	18	4222	0.10	3	0.93 (0.85 to 1.01)
Induction of labour					
Diet	4	2277	0.07	60	1.12 (0.99 to 1.27)
Mixed approach	1	85	0.44	NA	1.17 (0.78 to 1.75)
All	5	2362	0.05	47	1.12 (1.00 to 1.26)
Postpartum haemorrhage					
Diet	2	1232	0.64	0	0.90 (0.57 to 1.42)
All	2	1232	0.64	0	0.90 (0.57 to 1.42)

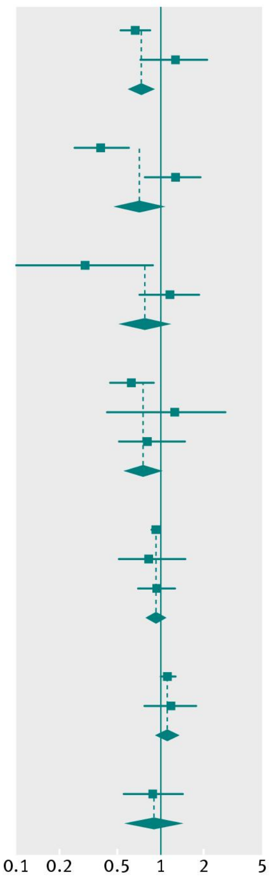

Fig 6 Relative risk of effects of weight management interventions in pregnancy on maternal outcomes

Outcome and intervention	No of studies	No of participants	P value	I^2 (%)	Relative risk (95% CI)
Intrauterine death					
Diet	2	1320	0.07	0	0.15 (0.02 to 1.20)
All	2	1320	0.07	0	0.15 (0.02 to 1.20)
Admission to neonatal intensive care unit					
Diet	2	1962	0.93	77	0.98 (0.66 to 1.47)
Mixed approach	1	304	0.94	NA	0.98 (0.56 to 1.71)
All	3	2266	1.00	58	1.00 (0.75 to 1.33)
Shoulder dystocia					
Diet	3	2082	0.001	0	0.38 (0.21 to 0.69)
Mixed approach	1	235	0.90	0.94	0.90 (0.06 to 14.14)
All	4	2317	0.002	0	0.39 (0.22 to 0.70)
Birth trauma					
Diet	2	1961	0.10	0	0.36 (0.11 to 1.23)
All	2	1961	0.10	0	0.36 (0.11 to 1.23)
Respiratory distress syndrome					
Diet	2	1962	0.91	58	1.05 (0.48 to 2.28)
All	2	1962	0.91	58	1.05 (0.48 to 2.28)
Infant hypoglycaemia					
Diet	3	1877	0.69	41	1.05 (0.83 to 1.33)
Mixed approach	2	269	0.30	0	2.35 (0.47 to 11.76)
All	5	2146	0.55	10	1.07 (0.85 to 1.35)

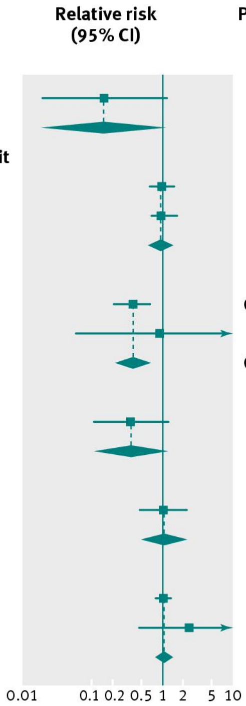

Fig 7 Relative risk of effects of weight management interventions in pregnancy on fetal and neonatal outcomes