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Systematic review

Antenatal interventions for overweight or obese pregnant women: a systematic review of randomised trials

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Background Overweight and obesity during pregnancy is an increasing health problem.

Objective A systematic review to assess the benefits and harms of antenatal dietary or lifestyle interventions for pregnant women who are overweight or obese.

Search strategy The Cochrane Controlled Trials Register (CENTRAL) was searched (last search January 2010). Reference lists of retrieved studies were searched by hand. No date or language restrictions were used.

Selection criteria Randomised controlled trials comparing antenatal dietary and/or lifestyle or other interventions with no treatment for overweight or obese women were considered. Studies were evaluated independently for appropriateness for inclusion and methodological quality. The primary outcome was large-for-gestational-age infants.

Data collection and analysis Nine randomised controlled trials were included involving 743 women who were overweight or obese during pregnancy. Seven trials compared a dietary intervention with standard antenatal care.

Main results There were no statistically significant differences identified between women who received an antenatal intervention and those who did not for the large-for-gestational-age infant outcome (three studies; 366 women; risk ratio 2.02; 95% CI 0.84, 4.86) or mean gestational weight gain [four studies; 416 women; weighted mean difference −3.10 kg; 95% CI −8.32, 2.13 (random-effects model)]. There were no statistically significant differences identified for other reported outcomes.

Author's conclusions The effect of providing an antenatal dietary intervention for overweight or obese pregnant women on maternal and infant health outcomes remains unclear.

Keywords Infant health outcomes, maternal health outcomes, overweight or obesity, randomised controlled trial, systematic review.

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Introduction

Obesity is listed as the sixth most important risk factor contributing to the overall burden of disease worldwide,[1] contributing to a significant reduction in adult life expectancy through an increased risk of cardiovascular disease and type-II diabetes.[1] Overweight and obese women represent a significant and increasing problem encountered in obstetric practice, with estimates suggesting that approximately 35% of pregnant women in Australia have a body mass index (BMI) >25 kg/m^2.[2] There are well-documented risks associated with obesity in pregnancy, including hypertension and pre-eclampsia,[3–7] gestational diabetes,[3,5] infection,[3] thromboembolic disease,[7] a need for the induction of labour,[8] Caesarean birth,[3–6,8] and stillbirth.[4,9]

Similarly, infants born to women who are obese are more likely to be large for gestational age,[3,4] require neonatal intensive care,[10] or be diagnosed with a congenital anomaly.[10] There are a number of factors that have been identified as increasing an individual's risk of obesity during childhood, the most consistent and independent of other factors being high infant birthweight and high maternal BMI.[11–14] Obesity in childhood has reached alarming proportions, with estimates suggesting that over 20% of children aged 6–11 years are overweight or obese.[15,16] Of

greater concern, over 20% of 2- to 3-year-old Australian children are considered to be overweight or obese.[17]

There is considerable information available in the literature describing the effects of obesity during pregnancy and childbirth, and its associated risk of ongoing health problems for the woman's offspring. It is unclear whether antenatal intervention for women who are overweight or obese is effective in limiting gestational weight gain, whether there are additional benefits in terms of improved maternal and infant health outcomes, and whether there are any sustained benefits for the infant, such as reducing the risk of child obesity. We conducted a systematic review and meta-analysis to evaluate the benefits and harms associated with the provision of antenatal dietary and/or lifestyle intervention for pregnant women who are overweight or obese.

Methods

We searched PUBMED, the Cochrane Controlled Trials Register (CENTRAL), and the Australian and International Clinical Trials registers using the following free-text search terms: pregnancy, obesity, overweight, dietary intervention, lifestyle intervention, and randomis(z)ed controlled trial. The reference lists of the retrieved studies were searched by hand, and no date or language restrictions were placed on the search (date of last search January 2010). Our review followed the methods detailed in the Cochrane Handbook.[18]

Study inclusion and exclusion criteria

All published randomised controlled trials in which antenatal dietary and/or lifestyle advice or intervention was provided to pregnant women who were overweight or obese were considered for inclusion. Trials were excluded where information was available in abstract form only. Women were defined as overweight if their BMI was ≥25 kg/m^2, and were defined as obese if their BMI was ≥30 kg/m^2.

Outcomes of the review

The primary outcome was a large-for-gestational-age infant (defined as a birthweight of greater than the 90th centile for gestation and infant sex or a birthweight >4000 g, as defined by the trial authors). The secondary outcomes included mean gestational weight gain, hypertension, pre-eclampsia or eclampsia, gestational diabetes, preterm birth before 37 weeks of gestation, infection, need for induction of labour, Caesarean section, postpartum haemorrhage requiring blood transfusion, perinatal death (stillbirth and neonatal death), congenital anomalies, infant birthweight of >4500 g, infant birthweight of <2500 g, Apgar score of <7 at 5 minutes of age, hypoglycaemia requiring intravenous treatment, hyperbilirubinaemia requiring treatment, admission to neonatal intensive care unit, and birth trauma. Childhood outcomes of relevance relate to body size (including height, weight, and BMI) and body composition. The outcome definitions were those used by the individual trial authors.

Evaluation of studies for inclusion

Studies under consideration were evaluated independently for appropriateness for inclusion and methodological quality without consideration of their results by two authors (JD and RG), according to the PRISMA guidelines for systematic reviews of randomised trials.[19] There was no blinding of authorship.

Assessment of studies

The assessment of quality considered the generation of the randomisation sequence (with a random-number table or computer-generated sequence judged as adequate), concealment of allocation (with central telephone randomisation or sealed opaque envelopes judged as adequate), blinding (including participants, caregivers, and outcome assessors), and completeness of follow up (with <20% loss to follow up for primary outcomes judged as adequate). This was conducted by two authors independently (JD and RG).

Data synthesis

We carried out statistical analysis using Review Manager.[20] We used fixed-effect inverse variance meta-analysis for combining data where trials were examining the same intervention, and where the populations and methods of the trials were judged to be sufficiently similar. If substantial heterogeneity was identified in a fixed-effect meta-analysis (as indicated by an I^2 statistic of >50%), this was noted, the analysis was repeated using a random-effects model, and the reasons for the heterogeneity were explored. For dichotomous data, risk ratios (RRs) and 95% confidence intervals (CIs) were calculated; for continuous data, weighted mean differences (WMDs) and 95% CIs were calculated. Primary analyses were based on intention-to-treat principles.

Results

Our search strategy identified 254 abstracts or reports, of which 36 full-text manuscripts or reports were reviewed. Ten published randomised trials were identified:[21–30] one study was presented only in abstract form,[31] and nine were ongoing randomised trials for consideration.[32–40] Of the ten published randomised trials, nine were included in the analysis (Figure 1).

Description of the studies included

Nine randomised controlled trials were included,[21,22,24–30] involving 743 women who were overweight or obese during

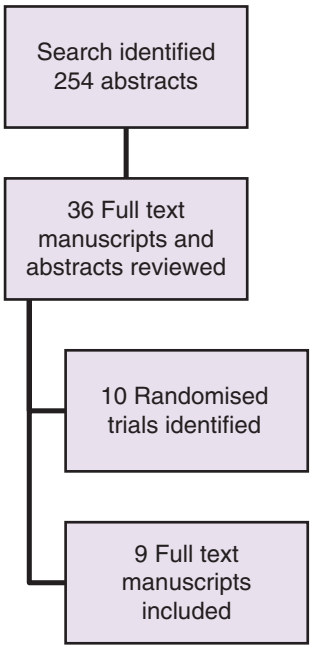

Figure 1. Flow chart of study selection.

pregnancy. Seven trials compared a dietary intervention with standard antenatal care (involving no intervention),[21,24–26,28–30] whereas two trials evaluated the effect of a lifestyle intervention focussing on aerobic and/or resistance exercise.[22,27] The trials by Polley *et al.*,[25] Brankston *et al.*[22] and Asbee *et al.*[21] recruited women of all BMI categories, with variable reporting of outcomes for women considered to be overweight or obese. The trials by Rae *et al.*,[26] Magee *et al.*[24] and Brankston *et al.*[22] recruited women with a diagnosis of gestational diabetes.

Methodological quality

The generation of the randomisation sequence using a random-number table was specifically stated for five trials,[21,22,27–29] but was unclear in four.[24–26,30] Allocation concealment was adequate, using sealed opaque sequentially numbered envelopes in five trials,[21,22,26–28] but was unclear in four.[23–25,29,30] Blinding of participants and caregivers was achieved in only one of the trials,[26] being unclear in the remainder.[21–25,27–30] Losses to follow up were >20% of the original randomised cohort for the trials by Guelinckx *et al.*,[30] Wolff *et al.*,[29] and Santos *et al.*[27] For further details of the characteristics of the studies included see Table 1, and for risk of bias in the studies see Figure 2.

Excluded studies

The study by Hui *et al.*[23] was excluded, as women of all BMI categories were recruited, with no specific reporting of outcomes for women who were overweight or obese. One report of a randomised trial was identified in abstract form only, and did not contain sufficient information to allow an assessment of the study quality.[31]

Ongoing studies

Nine ongoing randomised trials were identified, evaluating antenatal dietary and lifestyle interventions in obese and overweight women.[32,33,35–40] A further ongoing study was identified in which a dietary intervention was provided to women of all BMI categories, including women who are overweight or obese.[34] Further details are provided in Table 2.

Antenatal dietary intervention for women who are overweight or obese

Seven trials compared a dietary intervention with standard antenatal care (involving no intervention).[21,24–26,28–30] For the primary outcome, large-for-gestational-age infants, only three trials reported outcome data, with no statistically significant differences identified between women who received an antenatal intervention and those who did not (three studies; 366 women; RR 2.02; 95% CI 0.84, 4.86) (Figure 3; Table 3). Women who received an antenatal intervention gained significantly less weight during pregnancy (four studies; 416 women; WMD −5.37 kg; 95% CI −6.61, −4.13; fixed-effects model). The I^2 statistic indicated a high degree of heterogeneity (93%), and when a random-effects model was subsequently used the result no longer remained statistically significant (four studies; 416 women; WMD −3.10 kg; 95% CI −8.32, 2.13; random-effects model) (Figure 4). There were no other statistically significant differences identified for the other reported secondary outcomes: preterm birth at <37 weeks of gestation, pre-eclampsia, gestational diabetes, induction of labour, Caesarean section, postpartum haemorrhage, postpartum infection, mean infant birthweight, birthweight of <2500 g, birthweight of >4500 g, or infant Apgar score of <7 at 5 minutes of age.

Antenatal lifestyle (exercise) intervention for women who are overweight or obese

Two trials evaluated the effect of a lifestyle intervention focussing on aerobic and/or resistance exercise.[22,27] The trial by Brankston *et al.*[22] stated a reduction in insulin use in 20 women who were overweight or obese, although no figures were reported; no other maternal or infant clinical outcomes were reported. The trial by Santos *et al.*[27] reported no maternal or infant health outcomes, focussing instead on cardiorespiratory markers of exercise tolerance.

Conclusions

The results of our systematic review indicate that for women who are overweight or obese, the provision of antenatal dietary intervention is of uncertain benefit in limiting

Table 1. Characteristics of the studies included

Author	Setting	Population	Intervention	Outcomes	Quality
Asbee *et al.*[21]	USA; October 2005–April 2007	Inclusion: 16–26 weeks of gestation; 18- to 49-years old; singleton; all BMI categories Exclusion: multiple pregnancy; pre-existing diabetes, hypertension, or thyroid disease; pregnancy ending in preterm birth at <37 weeks of gestation; less than four antenatal visit Sample size: 144 randomised; 100 analysed; 40 overweight or obese	Women were randomised to: (1) routine antenatal care or (2) intervention (dietician visit and feedback on weight gain)	Adherence to IOM weight gain recommendations	Randomisation: computer-generated sequence Allocation concealment: sealed opaque envelopes Blinding: not stated Losses to follow up: 31% total; unable to assess for women who were overweight or obese
Guelinckx *et al.*[30]	Belgium; March 2006–January 2008	Inclusion: 15 weeks of gestation; BMI > 29 Exclusion: multiple pregnancy; pre-existing diabetes; renal disease; pregnancy ending in preterm birth at <37 weeks of gestation Sample size: 130 randomised; 85 analysed	Women were randomised to: (1) routine antenatal care or (2) intervention (three group sessions with dietician and written information)	Gestational weight gain	Randomisation: not stated Allocation concealment: not stated Blinding: not stated Losses to follow up: 35% of the randomised women were excluded after randomisation
Magee *et al.*[24]	USA	Inclusion: obese women with gestational diabetes mellitus Sample size: 12	Women were randomised to: (1) standard diabetic diet or (2) calorie-restricted diet for 1 week	Metabolic measures of glucose homeostasis; no clinical outcomes reported	Randomisation: unclear, 'women were randomized' Allocation concealment: not stated Blinding: not stated Losses to follow up: unable to assess
Polley *et al.*[25]	USA	Inclusion: women at <20 weeks of gestation; all BMI categories Exclusion: age <18 years; drug abuse; previous pregnancy complication; multiple pregnancy Sample size: 110 women, of whom 49 were overweight	Women were randomised to: (1) standard antenatal care or (2) intensive intervention (access to research dietician or psychologist at each antenatal visit)	Gestational weight gain; pre-eclampsia; hypertension; gestational diabetes; preterm birth; Caesarean section; infant birthweight	Randomisation: unclear, 'women were randomly assigned' Allocation concealment: not stated Blinding: not stated Losses to follow up: unable to assess
Rae *et al.*[26]	Australia; February 1992–June 1995	Inclusion: women with a diagnosis of gestational diabetes mellitus; <36 weeks of gestation; BMI > 110% ideal Sample size: 125 women randomised	Women were randomised to: (1) standard diabetic diet or (2) calorie-restricted diet (70% standard)	Frequency of insulin use	Randomisation: unclear, 'random draw of opaque envelopes' Allocation concealment: opaque envelopes Blinding: women and caregivers blinded Losses to follow up: 6%

Table 1. (*Continued*)

Author	Setting	Population	Intervention	Outcomes	Quality
Thornton *et al.*[28]	USA; June 1998–May 2005	Inclusion: singleton pregnancy; 12–28 weeks of gestation; BMI ≥ 30 Exclusion: pre-existing diabetes, hypertension, or chronic renal disease Sample size: 257 women randomised; 232 analysed	Women were randomised to: (1) standard antenatal care or (2) monitored group (visit to dietician and detailed diet protocol)	Mean gestational weight gain; pre-eclampsia; hypertension; gestational diabetes; preterm birth; Caesarean section; infant birthweight	Randomisation: random number table Allocation concealment: opaque envelopes Blinding: not stated Losses to follow up: 10%
Wolff *et al.*[29]	Denmark	Inclusion: 'early pregnancy'; BMI ≥ 30; non-diabetic; white Exclusion: smoking; age <18 or >45 years; multiple pregnancy; medical complications Sample size: 73 women randomised; 23 post-randomisation exclusions/loss; 50 women analysed	Women were randomised to: (1) standard antenatal care or (2) intensive intervention (ten 1-hour visits with dietician at each antenatal visit)	Mean gestational weight gain; pre-eclampsia; hypertension; gestational diabetes; Caesarean section; infant birthweight	Randomisation: computer-generated random number table Allocation concealment: not stated Blinding: not stated Losses to follow up: 32%
Brankston *et al.*[22]	Canada	Inclusion: maternal age 20–40 years; 26–32 weeks of gestation; BMI < 40; diagnosis of gestational diabetes mellitus; not involved in a regular exercise programme Sample size: 38 women randomised; 32 analysed	Women were randomised to: (1) standard diabetic diet or (2) diet plus circuit-type resistance training three times per week	Requirements for insulin; health outcomes not reported by BMI category	Randomisation: random number table Allocation concealment: opaque envelopes Blinding: not stated Losses to follow up: 15%
Santos *et al.*[27]	Brazil; March 2000–March 2002	Inclusion: age >20 years; <20 weeks of gestation; BMI 26–31 Exclusion: hypertension; diabetes; preterm labour; multiple pregnancy; thyroid disease Sample size: 92 women randomised; 72 analysed	Women were randomised to (1) standard care or (2) 1 hour, three times per week, aerobic and resistance exercise	Cardiorespiratory markers of exercise tolerance	Randomisation: random number table Allocation concealment: opaque envelopes Blinding: not stated Losses to follow up: 22%

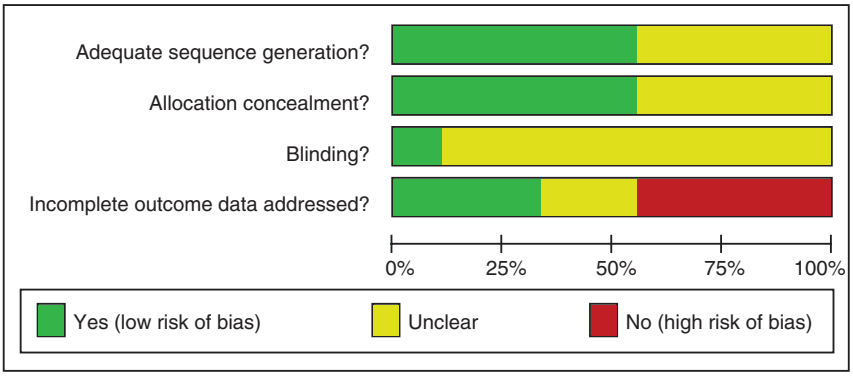

Figure 2. Study quality and assessment of risk of bias.

weight gain during pregnancy, as reported in four studies to date. We identified significant heterogeneity across the studies related primarily to the intensity of the intervention provided, ranging from a single dietetic visit[28] to additional dietetic sessions at each antenatal visit.[25,29] However, the direction and magnitude of treatment effect was similar for both the Thornton *et al.*[28] and Wolff *et al.*[29] trials, despite the differences in intervention intensities. This uncertainty of both the effect of an antenatal intervention and its optimal intensity significantly limits the ability to generate reliable recommendations relating to care in clinical practice.

The effect of an antenatal dietary intervention on other important maternal health outcomes, including gestational diabetes, pre-eclampsia, induction of labour, and Caesarean section is lacking, with the combined available sample size in our meta-analysis varying from 49 to 540 participants. Despite the total number of women in the studies identified for this systematic review being 743, there is clear inconsistency in outcome reporting, particularly related to maternal and infant health outcomes, with these only being reported in a small proportion of trials to date. Furthermore, outcomes were not reported separately for women who were overweight and for those who were obese.

Overall, the methodological quality of the included trials was poor to fair, with unclear methods of generating randomisation sequences in four trials,[24–26,30] unclear allocation concealment in four trials,[23–25,29,30] and losses to follow up of more than 20% of the original randomised cohort for three trials.[27,29,30] Given the nature of the intervention, blinding of participants and caregivers is difficult, and was only claimed to have been achieved in one trial.[26] Of greater relevance is the issue of blinding the outcome assessors, which was unclear in all of the included trials, thereby increasing the possibility of detection bias in the reported outcomes.

Our review identified considerable variation in the nature of the intervention provided, ranging from single sessions with a dietician up to additional dietetic counselling sessions associated with each antenatal visit. Although the provision of a more intensive dietetic counselling programme has been associated with greater weight loss in non-pregnant individuals,[41] the ability to provide this degree of intervention at a broader antenatal population level remains questionable.

Current guidelines from the American College of Obstetricians and Gynecologists[42] recommend that women be counselled prior to conception, and be encouraged to adopt lifestyle changes to minimise their risk of developing complications during pregnancy related to being overweight or obese. For many women, however, this is not achieved, and the focus is therefore on minimising the risk of complications during pregnancy. The recently updated and published guidelines from the Institute of Medicine (IOM)[43] differ little from the previously published recommendations,[44] with the exception that they reflect World Health Organisation BMI categories,[45] and provide a gestational weight gain range for women who are obese. Hence, the recommendation for women who are overweight in pregnancy is to gain between 7.0 and 11.5 kg, and for women who are obese to gain between 5.0 and 9.0 kg.[43] Although the current IOM guidelines recognise that 'interventions will be needed to assist women, particularly those who are overweight or obese at the time of conception'[43] to meet these recommendations, as highlighted by our systematic review there is little high-quality information available from randomised trials to inform practitioners of the effect of limiting weight gain in terms of important maternal and infant health measures.

Of particular relevance is the association between maternal obesity, infant birthweight and an individual's subsequent risk of obesity in later life. The occurrence of childhood obesity is at epidemic proportions, with estimates indicating that 16% of children aged 6–11 years are overweight, with a further 6% being obese.[15] Of greater concern is the incidence of younger children who are over-

Table 2. Characteristics of ongoing studies

Investigator	Population	Intervention	Outcomes	Contact
Adamo[33] ISRCTN75323409	Setting: Ottawa, ON, Canada Inclusion: BMI > 25; singleton pregnancy Exclusion: smoker; any significant medical or obstetric condition impacting on weight or exercise capacity; multiple pregnancy Sample size: 60	Women are randomised to: (1) standard care or (2) intervention group (detailed information including weight gain, dietetic counselling, exercise programme)	Gestational weight gain; infant birthweight	Dr Kristi Adamo kadamo@cheo.on.ca
Althuzien *et al.*[34] ISRCTN85313484	Setting: The Netherlands Inclusion: nulliparous women; <14 weeks of gestation; all BMI categories Exclusion: multiparous women Sample size: 275	Women are randomised to: (1) standard care or (2) intervention group (five counselling sessions)	BMI and skinfold thickness postpartum	Ellen Althuizen e.althuizen@vumc.nl
Dodd[35] ACTRN12607000161426	Setting: Adelaide, SA, Australia. Inclusion: BMI ≥ 25, with stratification for BMI category; singleton pregnancy; 10–20 weeks of gestation Exclusion: pre-existing diabetes; multiple pregnancy Sample size: 2574	Women are randomised to: (1) standard care or (2) intervention group (written information and series of inputs from research assistants and research dieticians)	Large-for-gestational-age infant	Dr Jodie Dodd jodie.dodd@adelaide.edu.au
Foxcroft and Callaway[36] ACTRN12606000271505	Setting: Brisbane, Qld, Australia Inclusion: BMI ≥ 30; singleton pregnancy; <12 weeks of gestation Exclusion: serious medical complication preventing exercise; multiple pregnancy Sample size: 50	Women are randomised to: (1) standard care or (2) intervention group (exercise programme of 30 minutes, five times per week)	Increased physical activity	Associate Leonie Callaway lcallaway@somc.uq.edu.au Trial recruitment is complete
Oostdam *et al.*[40] NTR1139	Setting: Amsterdam, The Netherlands Inclusion: BMI ≥ 30; previous macrosomic infant, previous gestational diabetes, or relative with type-II diabetes; 14–20 weeks of gestation Exclusion: pre-existing diabetes; hypertension; alcohol or drug abuse; serious medical complication preventing exercise Sample size: 160	Women are randomised to: (1) standard care or (2) intervention group (exercise programme of 60 minutes, two times per week)	Fasting maternal plasma glucose and insulin resistance; infant birthweight	Nicolette Oostdam n.oostdam@vumc.nl

Table 2. (*Continued*)

Investigator	Population	Intervention	Outcomes	Contact
Parat[37] NCT00804765	Setting: Paris, France Inclusion: BMI ≥ 30; singleton pregnancy; <21 weeks of gestation Exclusion: high-risk pregnancy; multiple pregnancy; previous obesity surgery Sample size: not stated	Women are randomised to: (1) standard care (including at least one dietary consultation) or (2) intervention group (four educational sessions and two dietician consultations)	Infant weight gain (at 30 months of age)	Dr Sophie Parat sophie.parat@nck.aphp.fr
Quinlivan[38] PTR543	Setting: Melbourne, Vic., Australia Inclusion: BMI ≥ 25; <20 weeks of gestation Exclusion: not stated Sample size: 160	Women are randomised to: (1) standard care or (2) multidisciplinary antenatal care	Incidence of gestational diabetes	Prof. Julie Quinlivan juliequinlivan@nd.edu.au Trial recruitment is complete
Smith[32] NCT00950235	Setting: OR, USA Inclusion: BMI ≥ 30; 12–16 weeks of gestation Exclusion: bariatric surgery; renal disease; multiple pregnancy; diabetes; hyperemesis requiring hospitalisation Sample size: not stated	Women are randomised to: (1) standard care or (2) intervention group (behavioural weight management)	Incidence of large-for-gestational-age infant	Sabina Smith sabina.smith@kpchr.org
Vinter[39] NCT00530439	Setting: Odense, Denmark Inclusion: BMI ≥ 30; singleton pregnancy Exclusion: chronic disease; previous preterm birth; alcohol or drug abuse Sample size: 360	Women are randomised to: (1) standard care or (2) intervention group (dietician counselling and physical training)	Caesarean section	Dr Christine Vinter c.vinter@dadlnet.dk

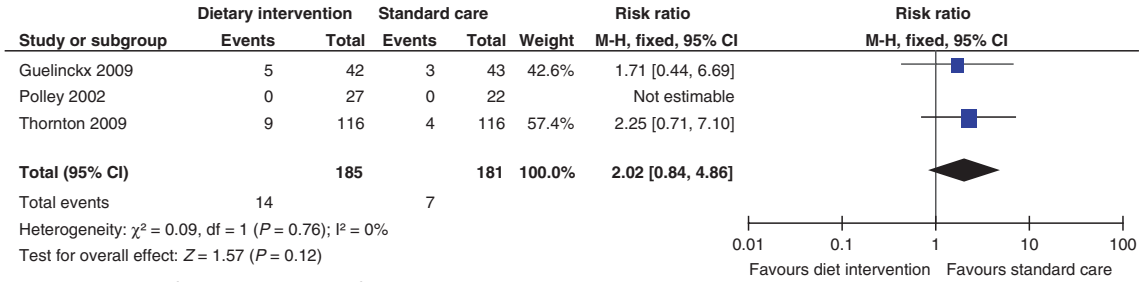

Figure 3. Forest plot: large-for-gestational-age infant.

Table 3. Outcomes for women provided an antenatal dietary intervention

Outcome	Studies	Participants	Effect estimate	95% CI
Primary				
Large-for-gestational-age infant	3	366	2.02	0.84, 4.86
Secondary maternal				
Mean gestational weight gain (kg)*,**	4	416	−3.10	−8.32, 2.13
Preterm birth at <37 weeks	2	281	0.58	0.19, 1.70
Pre-eclampsia	5	540	0.80	0.49, 1.31
Hypertension**	4	416	0.70	0.30, 1.61
Gestational diabetes	3	331	0.57	0.30, 1.08
Induction of labour	3	441	0.96	0.75, 1.24
Caesarean section	5	540	1.09	0.93, 1.28
Postpartum haemorrhage	1	232	0.60	0.15, 2.45
Postpartum infection	1	232	0.83	0.26, 2.65
Secondary infant				
Mean birthweight (g)*	3	367	−24.99	−135.37, 85.39
Birthweight >4500 g	1	49	Not estimable	Not estimable
Birthweight <2500 g	1	49	0.41	0.04, 4.20
Apgar <7 at 5 minutes of age	1	232	3.00	0.12, 72.89

Risk ratios are quoted, except *weight mean difference.
**Analysis using random-effects model because of the high degree of statistical heterogeneity (I^2 > 50%).

weight or obese, with over 20% of 2- to 3-year-old Australian children considered to be overweight or obese,[17] thereby increasing the overall lifetime exposure of an individual to the risk of adverse health consequences. A variety of factors have been identified as increasing an individual's risk of increased adiposity and obesity in childhood, including infant birthweight (both high and low), maternal and paternal obesity, increased gestational weight gain, gestational diabetes, breastfeeding, rapid early infant weight gain, and socio-economic status.[11–14,46–50] Of these, infant birthweight and high maternal BMI have both been consistently identified as being significant and independent of other factors.

Experimental manipulation of maternal diet during pregnancy in animal studies indicates a significant alteration of offspring body composition and adiposity, potentially through the modification of appetite and energy expenditure.[51,52] The effect in humans is less clear, although small cohort studies suggest that when compared with women of normal BMI, infants born to overweight or obese women have an increased percentage of body fat and fat mass, despite minimal differences in infant birthweight.[11]

Although it is possible that the antecedents of obesity may develop *in utero*, the precise contribution of the prenatal environment, maternal overnutrition, and genetic factors remains to be determined. It is, however, quite plausible that the optimal time to intervene in the prevention of obesity, with implications for the subsequent development of childhood and adulthood obesity, may be in the antenatal period when an individual's plasticity is at its greatest. It is therefore essential that the effects of antenatal dietary and/or lifestyle modification for women who are overweight or obese be appropriately evaluated in

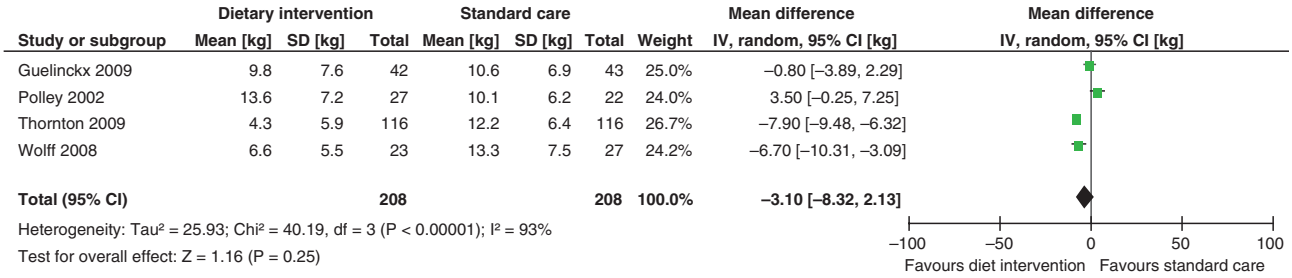

Figure 4. Forest plot: mean gestational weight gain.

high-quality randomised trials, with sufficient statistical power and reporting of important maternal and infant health outcomes. The ongoing research studies identified to date will contribute valuable information provided that the relevant clinical outcomes are reported. Of greater importance is the ongoing follow up of infant and childhood participants in any such established cohorts, if the *in utero* contributions to childhood obesity are to be elucidated.

Disclosure of interests

The authors have no competing interests to declare.

Contribution to authorship

All authors were involved in the development of the study design. JD and RG were involved in the assessment of studies for inclusion, quality assessment, and data extraction. JD drafted the original manuscript; all authors were involved in the interpretation of results, and reviewed the manuscript for content and approved the final version for publication.

Details of ethics approval

This article is a systematic review of published randomised trials, and ethics approval was not required.

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