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Behavior Modification Techniques Used to Prevent Gestational Diabetes: A Systematic Review of the Literature

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Abstract The prevalence of gestational diabetes mellitus (GDM) and obesity is increasing in developed countries, presenting significant challenges to acute care and public health. The aim of this study is to systematically review published controlled trials evaluating behavior modification interventions to prevent the development of GDM. Nine studies were identified involving such techniques as repetition of information, use of verbal and written educational information, goal setting, and planning, in addition to group and individual counseling sessions. Of the 3 trials with GDM incidence as a primary outcome, only 1 showed a significant reduction. GDM was a secondary outcome in 6 studies where the prevention of excessive gestational weight gain was the primary outcome and only 1 trial study determined an effective intervention. The small number of effective interventions highlights a significant gap in evidence to inform maternity health policy and practice.

Keywords Gestational diabetes · Prevention · Intervention · Behavior modification techniques · Systematic review

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Introduction

The prevalence of gestational diabetes mellitus (GDM) is increasing with ranges from 1.7 %–9.6 % reported in developed countries [1–8]. A woman's body mass index (BMI) of >25 kg/m^2) and particularly a BMI of >30 kg/m^2 are recognized risk factors for developing GDM [5–8] and confer a 1.3–4.8 increased likelihood of developing GDM [6, 8]. In addition, 20 % of women retain at least 5 kg of gestational weight gain and this is a strong predictor of obesity in later life [9–11]. Excessive gestational weight gain is also associated with impaired glucose tolerance [12, 13].

Weight gain in pregnancy is caused by a number of factors, however, the efficacy of insulin or a resistance to it has a significant contributory impact on the total amount gained [14]. This biological mechanism, which is designed to increase available nutrients to the growing baby, has a negative effect when combined with excessive energy consumption resulting from a poor diet and a sedentary lifestyle. Under these conditions the adverse outcomes of GDM and excessive gestational weight gain can easily result.

There is consistent, strong evidence of the short- and long-term health impacts on both the mother and her baby resulting from GDM in pregnancy. Children of mothers with GDM have an increased risk of obesity, type 2 diabetes mellitus, metabolic syndrome, and cardiovascular disease [5, 15, 16]; GDM is the strongest known predictor of subsequent maternal type 2 diabetes [17, 18] and cohort studies have found that women with GDM are more likely to have a higher prepregnancy BMI than those who do not develop GDM [3, 19]. Currently, our understanding of strategies that are effective in preventing GDM is limited.

Given the close inter-relationship between excessive gestational weight gain and GDM, both outcomes are often measured when testing lifestyle intervention. Using information from studies that have targeted modifiable obesogenic

risk factors could guide strategies designed to prevent GDM [20]. To modify these obesogenic risks, a change in lifestyle for pregnant women is needed, in particular, a positive change in nutrition and exercise habits. Behavior modification techniques aim to improve a person's health and wellbeing through the alteration of specific behaviors [21]. A robust application of these techniques is enabled through the use of theories of behavior change, such as social cognitive theory [22, 23], the trans-theoretical model [24], or the theory of planned behavior [25] to underpin interventions. Previous systematic reviews have not identified or evaluated behavior modification techniques for GDM [3, 26–28]. Our review was based on the guidelines set out by the PRISMA statement for systematic reviews and the primary aim was to evaluate the effective elements of behavioral techniques used in lifestyle programs designed to modify risk factors for GDM (See Appendix 1) [29, 30].

Four recent systematic reviews of the GDM literature were identified during the literature search; however, none of these identified or evaluated behavior modification techniques [3, 26–28].

Methods

Data Sources and Searches

A search of Academic Search Complete, CINAHL, Global Health, PsycInfo, and MEDLINE databases was performed to identify all relevant publications over the last decade between January 2002 and September 2013. We applied a language restriction and considered English language publications. Databases were searched using key words intervent*, prevent*, manage* combined with Gestational Diabetes Mellitus or GDM, Type Two Diabetes Mellitus or T2DM or Type 2 Diabetes, pregnant, pregnancy, mother, physical activity, exercise, lifestyle, health, and diet. These terms were combined using Boolean operators. The full search strategy for the MEDLINE database (Table 1) was complemented with another approach involving the review of reference lists of sentinel papers. One of the authors (H. Morris) independently screened the titles and abstracts of identified citations for potential eligibility. All authors examined the full-text articles of eligible studies.

Study Selection

Studies investigating the effectiveness of behavioral interventions designed to prevent GDM were included in this review. Criteria included studies where the incidence, prevalence, or treatment of GDM was the primary or secondary outcome, irrespective of study design. No limits on the method in which the intervention was administered (eg, via telephone, internet, in person) were set. Exclusion criteria included preliminary studies such as feasibility studies, pilot studies, and studies published in the grey literature (nonpeer reviewed or without scientific credibility).

Table 1 Interventions designed to prevent gestational diabetes

1. Intervent*
2. Prevent*
3. Manage*
4. Gestational Diabetes or GDM
5. 1 and 4
6. 2 and 4
7. 3 and 4
8. Pregnant*
9. 1 and 4 and 8
10. 2 and 4 and 8
11. 3 and 4 and 8
12. Type 2 diabetes or T2DM
13. 4 and 12
14. 2 and 4 and 12
15. 1 and 4 and 12
16. 1 and 4 and 8 and 12
17. Mother or maternal
18. 4 and 17
19. 1 and 4 and 17
20. Lifestyle modification
21. 1 and 4 and 20
22. 1 and 8 and 20
23. Nutrition or diet*
24. 1 and 4 and 23
25. Exercise
26. 1 and 4 and 25
27. 1 and 4 and 23 and 25

Full electronic search strategy for Medline

Limiters: January 2002 to September 2012, scholarly (peer reviewed) journals, English language

Data Extraction and Quality Assessment

From each paper we extracted the following information: name of first author, year of publication, intervention duration, type of education, education specifics, exercise, behavior modification strategies used, group and individual counseling, frequency of seeing the practitioner, and the type of practitioner who implemented the intervention (Table 2). Demographic characteristics of the included studies were collated as was comprehensive descriptive information about each intervention (Table 3).

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [31, 32] was used to analyze the overall quality of the evidence of the

Table 2 Overview of specific intervention characteristics

First author	Intervention duration	Education		Education specifics	Exercise		Behavior Modification Techniques			Group counseling	Individual counseling	Frequency of seeing practitioner	Type of Practitioner
		Verbal	Written		Supplied	Encouraged	Goal setting	Self - monitoring	Planning				
Asbee 2009 [37]	Unknown	✓	✓	Pregnancy specific dietary and lifestyle choices. Weight gain guidelines.	✘	✓	✘	✘	✘	✘	✓ x1	Once	Doctor or nurse
Hui 2012 [38]	Approx 16 wk	✓	✘	Dietician used Food Choice map to personalize dietary counseling based on results, pregnancy week, weight gain, and Health Canada guidelines.	✓ 1 wk	✓ 3-5xw k	✓	✓	✘	✓	✓ x2	Weekly contact with project coordinator 2 meetings with dietician	Licensed fitness trainers and registered dietician
Jefferies 2009 [39]	Approx 20 wk	✓	✓	Weight gain ranges. Information on healthy eating.	✘	✘	✓	✓	✘	✘	✘	Usual clinic visit	Nurse
Luoto 2011 [34•]	8–12 week gestation to 37 wk	✓	✓	Recommendations for gestational weigh gain. Nutrition advice to consume at least 5 veg, fruit and berry portions, select high fiber bread, and whole meal products, low fat dairy and meat, eat fish 2x wk, seldom have high sugar/fat foods.	✓ 1 mo	✓	✓	✓	✓	✘	✓ 5 for physical activity and 4 for diet.	Each antenatal clinic	Nurse
Polley 2002 [40]	Start at approx 15 wk through 6 wk postpartum	✓	✓	Appropriate weight gain, exercise, and healthy eating.	✘	✓	✓	✓	✓	✘	✓ Phone calls between visits.	Each clinic visit	Masters or Doctoral students
Quinlivan 2011 [36•]	Unknown Began at first clinic visit	✓	✘	Information on food labels, shopping lists, and recipes for healthy pregnancy diet.	✘	✘	✘	✘	✘	✘	✓	Each clinic visit, unknown frequency	Food technologist and clinical psychologist
Shirizan 2010 [41]	Unknown	✓	✓	Obesity and pregnancy, healthy eating and nutrition, calorie counting, food label reading, overcoming barriers, identifying dietary improvements.	✘	✓	✓	✓	✘	✓ x6	✓ x6 phone calls	At seminars	Study coordinators
Stafne 2012 [35•]	12 wk	✓	✘	Pelvic floor exercises, diet, and pregnancy related pelvic pain.	✓ 1 wk	✓ 2 wk	✘	✘	✘	✓	✘	Once a wk	Exercise Physiologist
Thornton 2009 [42]	Unknown Start time varied from 12–28 wk. Finished at 6 wk postpartum	✓	✘	Prenatal nutrition guidelines	✘	✓	✘	✓	✘	✘	✓	Once	Trained dietician and primary care provider

Table 3 A compilation of demographic characteristics from reviewed papers

Name (first author) Study	BMI intervention average ± (SD) *Range BMI*	BMI control	Ethnicity Ethnicity	Age intervention average±(SD)	Age control average±(SD)
Asbee [37]	25.5±(6.0)	25.6±(5.1)	African American Caucasian Hispanic Other	26.7±(6.0)	26.4±(5.0)
Hui [38]	25.7±(5.1)	25.7±(5.1)	First Nations Other (assume Caucasian)	30.1±(5.2)	28.7±(5.9)
Jefferies [39]	≤ 19.8– >29*	≤19.8- >29*	Unknown	Unspecified	Unspecified
Luoto [34•]	26.3±(4.9)	26.4±(4.3)	Finnish	29.5±(4.8)	30.0±(4.7)
Polley [40]	NW 22.8±(1.9) OW 31.4±(6.0)	NW 22.5±(2.0) OW 34.1±(7.2)	African American Caucasian	25.5±(4.8)	25.5±(4.8)
Quinlivan [36•]	25–40+*	25–40+	Asian Caucasian Other	28.3	29.5±(0.71)
Shirazian [41]	36.20±(5.23)	34.24±(5.23)	Hispanic African American	29.00±(5.09)	24.35±(5.61)
Stafne [35•]	24.7±(3.0)	25.0±(3.4)	Norwegian	30.5±(4.4)	30.4±(4.3)
Thornton [42]	38.22±(7.48)	38.22±(7.48)	Caucasian African American Hispanic Indian	26.8	27.3

NW normal weight, *OW* overweight, *SD* standard deviation

relevant studies. Each individual study was evaluated using 5 key factors known to compromise the quality of evidence: limitations (risk of bias), inconsistency, indirectness, imprecision, and publication bias, as well as 3 factors that increase quality of evidence: large magnitude of effect, plausible confounding, and dose-response gradient.

Risk of Bias

Risk of bias for each study was determined using the validity scoring system referred to in the work by Gardner et al [33]. This system assigns a score to allocation concealment, intention-to-treat analysis, and attrition/loss to follow-up [33]. Studies were allocated a score of 2 for concealment, 1 where concealment was not applicable or unclear, and 0 where concealment was applicable and not used. If no intention-to-treat analysis was used or this was unclear, studies were awarded a score of 0, and a score of 2 was awarded if such analysis was used. To attain a score for loss to follow-up a cut-off of 10 % was applied in accordance with Gardner et al. Studies with >10 % attrition received a score of 0, and studies reporting attrition of ≤10 % were awarded a score of 2. Scores could range from 0–6 after analysis with lower scores suggesting a higher risk of bias.

Data Synthesis and Analysis

Data from the included studies were collected, synthesized manually, and collated in tabular form to assist comparison of aims, sample and design, theory underpinning the intervention, intervention delivery, intervention time points, measures, and findings. Analysis was undertaken manually using the collated information.

Results

The initial search identified 192 studies, following the removal of duplicates there was a total of 148, of which 9 were deemed relevant for the current review. An outline of the search strategy and flow of study selection is provided (Fig. 1) together with a list of excluded studies with reasons for exclusion (Table 4). The details pertaining to study aim(s) and hypotheses, sample and setting, design and intervention, variables targeted, and their measurement and findings are outlined (Table 5). Preventing GDM was the primary outcome in 3 randomized controlled trial (RCT) studies; they were conducted in Finland [34•], Norway [35•], and Australia [36•]. In all 6 studies where the prevention of GDM was a secondary outcome [37–42], attempting to prevent excessive gestational weight gain was the primary outcome. Five studies employed an RCT design and 1 study used a prospective matched controlled design [41]. Four of the 6 studies were conducted in the United States [37, 40–42], 1 in Australia [39], the other in Canada [38].

In all studies the ages of women in the intervention and control groups were similar at baseline (Table 2). Three

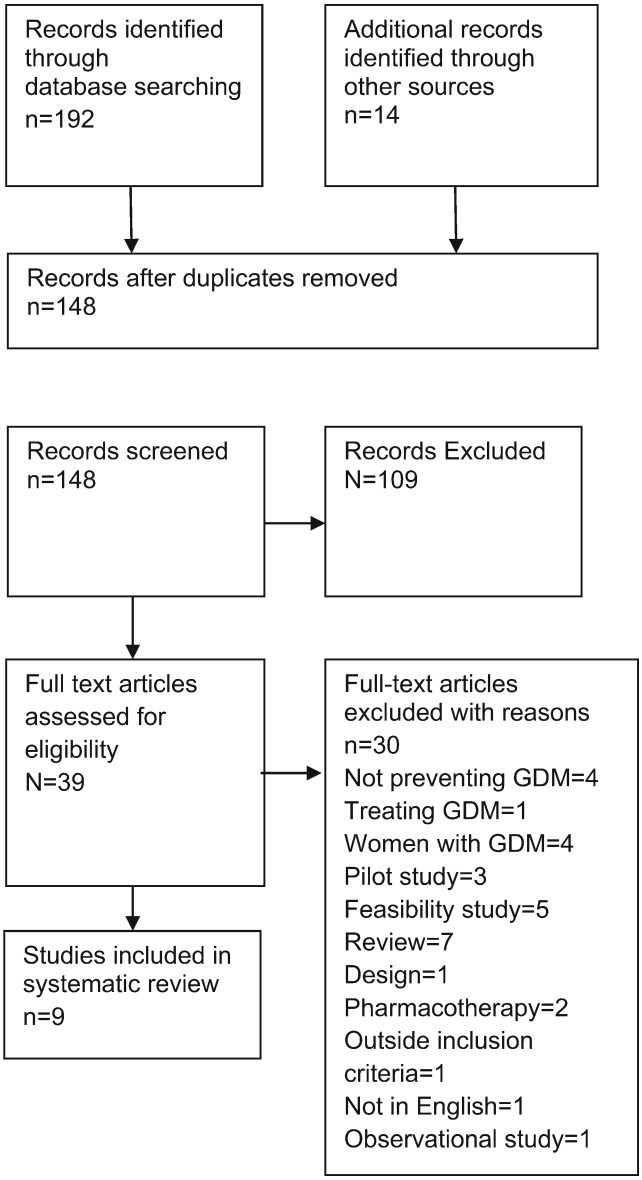

Fig. 1 Search flow diagram

studies exclusively recruited women who were obese [36•, 41, 42]. The ethnicities represented were African American [37, 40–42], Hispanic [37, 41, 42], Asian [36•] European [34•, 35•], Australian [36•, 39], and Northern American [37, 38, 40, 42]. Exclusion criteria noted across the 9 studies included multiple pregnancy, pre-existing diabetes, hypertension, a BMI >40, age younger than 18 years or older than 45 years.

Risk of Bias

Average risk of bias across all studies was 3.4 out of a possible 6.0, using the scoring system of Gardner [33]. One study achieved a score of 5 [35•], 3 studies achieved a score of 4 [34•, 36•, 40], 4 studies achieved a score of 3 [37, 38, 41, 42] and 1 a score of 2 [39].

Table 4 Excluded studies with reasons

Author and year	Reason to exclude
Aittasalo et al. (2012)	Not preventing incidence of GDM
Amann-Gassner et al. (2008)	Review; German language
Artal et al. (2007)	Women had GDM already
Barakat et al. (2009)	GDM prevention not the purpose of the intervention
Callaway et al. (2010)	Pilot study
Chasan-Taber et al. (2009)	Feasibility study
Cheung et al. (2011)	Pilot/feasibility study
DiNallo et al. (2007)	Review
Fappa et al. (2007)	Not preventing GDM
Ferrara et al. (2011)	Feasibility study
Gray-Donald (2000)	Outside of inclusion criteria
Hans et al. (2012)	Cochrane Review
Harrison et al. (2012)	Observational study
Hui et al. (2006)	Pilot study
Korpi-Hyövälti et al. (2011)	Feasibility study
Korpi-Hyövälti et al. (2012)	Feasibility study
Landen et al. (2009)	Treating not preventing GDM
Limruangrong et al. (2011)	Women had GDM already
Luoto et al. (2010)	Use of probiotics with intervention
Mendelson et al. (2008)	Women had GDM already
Morriset et al. (2010)	Review
Oostdam et al. (2009)	Design of a RCT, no results
Oostdam et al. (2010)	Review
Oostdam et al.(2012)	Not preventing GDM; rather improve fasting blood glucose
Oteng-Ntim et al. 2012	Review
Perichart-Perera et al. (2009)	Women had GDM already
Ratner et al. (2008)	Use of pharmacotherapy
Renzaho et al. (2010)	Review
Tieu et al. (2008)	Review
Vadheim et al. (2010)	Feasibility study

The Lifestyle Focus of the Interventions: Nutrition and/or Exercise

Diet and exercise education, and in some studies structured activities, were the major intervention methods used in the prevention of GDM. Six interventions focused on changing dietary intake either to prevent GDM [34•, 36•] or avoid excessive gestational weight gain [37, 38, 40, 42]. One intervention was designed to prevent GDM through exercise alone [35•]. The behavior modification techniques used in these studies were designed specifically to interrupt habitual patterns of choosing food and to initiate new modes of healthy attitudes and behaviors (Table 2). Overall, a reduction in energy dense foods and an increase fruit and vegetable intake was recommended. Portion control was not specifically addressed in any of the interventions, however, 2 studies did educate about calorie counting [37, 41].

Table 5 Detailed description of each study reviewed

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
Studies with the aim of primary prevention of gestational diabetes					
Luoto 2011 [34•]	Aim: To see if individual counselling on physical activity, diet, and weight gain could prevent the development of GDM and newborns' high birth weight adjusted for gestational age, when integrated into routine maternity care visits.	Location: Maternity clinics in primary health care centers were used. 14 municipalities in Pirkanmaa region participated and they are situated in southwest Finland. Sample: The final number of participants 219 in the intervention group and 180 in the usual care group. The mean age of the women was 30 yr. 47 % were primiparous in the intervention and 41 % in the usual care group. The average BMI before pregnancy was 26 kg/m2 in both groups.	Design: A cluster-randomized trial Intervention: The intervention started at the first maternity clinic visit (8–12 wk gestation) and continued until 37 wk gestation. Recommendations for gestational weight gain were discussed at the first visit and a weight gain graph was selected for the participant to monitor her weight gain. The first physical activity counselling began at 8–12 wk gestation and the first dietary counselling session at 16–18 wk gestation. Physical activity counselling was repeated 4 times, and diet counselling 3 times. If OGTT was abnormal at 26–28 wk gestation, women were also referred to other health care specialists. Women in the usual care group received no counselling beyond usual care.	Outcomes: Primary: The number of women with GDM based on 26–28 gestation wk OGTT Newborns' birth weight adjusted for gestational age (neonatal outcome). Secondary (1) gestational weight gain calculated on the basis of self-reported pre pregnancy weight and the last measured weight during pregnancy in the maternal care (2) the need for insulin or other diabetic medication from 26–28 wk gestation onwards, (3) child weight after delivery. Evaluation of leisure-time physical activity was based on a validated self-report at baseline, 26–28 wk gestation, and 36–37 wk gestation.	Findings: There were no significant differences between the intervention and the usual care group at baseline or at 26–28 wk gestation in glucose intolerance measurements. Using different criteria to measure GDM did not result in any difference between groups. Other secondary outcomes were similar between groups. Gestational age at delivery was similar in both groups (39.4 ±1.9 wk vs 39.6±1.3 wk). The average newborns' birth weight was lower in the intervention group than in the usual care group (3.532 g vs 3.659 g, adjusted P=0.035) The proportion of LGA infants was lower in the intervention (12.1 %) than in the usual care group (19.7 %, P=0.042). The intervention was beneficial improving 4 of the 5 dietary aims. A statistically nonsignificant tendency for lower decrease in moderate activity MET m. by 26–28 wk gestation was observed in the intervention group alone.
Quinlivan 2011 [36•]	Aim: To trial a 4-step multi-disciplinary approach for the management of obese pregnant women.	Location: A maternity service in a public hospital that serves a socioeconomically disadvantaged area in Melbourne, Australia.	Design: A randomized controlled trial Intervention: Women attended a specific antenatal clinic, which	Outcomes: The primary outcome was the prevalence of the combined diagnoses of decreased gestational	Findings: There was a significant difference between groups (Z=2.02, P=0.043). This represented a reduction

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
		Final data on 63 in the intervention and 61 in the control groups	differed in routine care by offering (1) continuity of care; (2) weighing on arrival; (3) brief dietary intervention by a food technologist at every antenatal visit; and (4) psychological assessment and intervention if indicated. If these women were diagnosed with GDM, they stayed in the obesity clinic but were treated with identical clinical care guidelines as women in the general obstetric diabetes clinic.	glucose tolerance and GDM. For the purposes of the trial, the primary outcome depended upon the 75 g OGTT. Secondary outcomes: (1) weight gain in pregnancy. The difference between the booking weight and weight at the onset of labor (2) birthweight, as measured by the attending midwife immediately following birth on neonatal scales, which had been calibrated monthly	in the odds of decreased gestational glucose tolerance and gestational diabetes mellitus in the intervention group by 83 % (OR=0.17, 95 % CI 0.03–0.95) when compared with the control group. Significant results were also obtained in the comparisons of weight gain during pregnancy between groups (t110=5.57, P <0.001).
Stafne 2012 [35•]	Aim: To assess whether exercise during pregnancy can prevent GDM and improve insulin resistance.	Location: Three hospitals in Norway; St. Olav's Hospital, Trondheim University Hospital, and Stavanger University Hospital. Participants: recruited from April 2007-June 2009, and women in Stavanger were recruited from October 2007-January 2009. Final data was on 375 intervention group and 327 control group	Design: Two-armed, 2-center, RCT of a 12-wk regular exercise program. Intervention: Women in the intervention group received a standardized exercise program including aerobic activity, strength training, and balance exercises. Training sessions of 60 m. in groups of 8–15 women instructed by a physiotherapist. These sessions were offered once per wk over a period of 12 wk (between 20–36 wk gestation). Each group session had 3 parts. The first included 30–35 m. of low-impact aerobics (no running or jumping). The second included 20–25 m. of strength exercises using body weight as resistance, 3 sets of 10 repetitions of each exercise were performed. The third included 5–10 m.	Outcomes: The primary outcomes were the prevalence of GDM and insulin resistance estimated by the homeostasis model assessment method. Secondary outcomes: Maternal weight, body mass index, pregnancy complications, and outcomes.	Findings: No differences were found in the prevalence of GDM between groups; 25 of 375 (7 %, 95 % CI 4.3–9.7) intervention group women compared with 18 of 327 (6 %, 95 % CI 3.3–8.6) control group women (P = .52). There was no difference between groups in weight gain, weight, BMI, and blood pressure at follow-up.

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
			of light stretching, body awareness, breathing, and relaxation exercises. In addition, women were encouraged to follow a written 45-minute home exercise program at least twice per wk (30 m. of endurance training and 15 m. of strength and balance exercises).		
GDM prevention secondary to excessive GWG prevention					
Asbee 2009 [37]	Aim: To compare a program of intensive counselling regarding diet and lifestyle during pregnancy with routine prenatal care. To examine whether the intervention would reduce the number of women who exceed the IOM recommendations for weight gain during pregnancy.	Location: Women who presented to the Resident Obstetric Clinic in Charlotte, North Carolina from Oct 2005-Apr 2007 The sample a total of 100 women. Participants stratified by BMI category (under- and normal weight BMI <26, overweight BMI 26–30, obese BMI >30).	Design: Randomized Control Trial Intervention group – underwent physical examination with specific attention paid to prepregnancy, weight current weight, height, and BMI. They also received intensive standardised counselling session by a dietician on diet and lifestyle during pregnancy and information about appropriate weight gain during pregnancy in accordance with the IOM guidelines, at their 1st obstetric visit (13 wk). Weight gain was measured at each appointment and recorded on a chart in front of the participants, along with routine prenatal care for the remaining obstetric visits. If weight gain was not within the IOM guidelines, the participant's diet and exercise regimen was reviewed and advice given.	Primary outcome: The rate of adherence to the IOM guidelines. Weight gain in kg – measured at all prenatal visits, from 13 wk to just prior to delivery (on arrival at the medical centre) Prepregnancy weight (collection method not stated). Secondary outcome: The effects of weight gain on mode of delivery and delivery or pregnancy complications, rate of operative vaginal delivery, neonatal weight, incidence of preeclampsia, gestational diabetes mellitus, vaginal perineal lacerations, and shoulder dystocia.	Findings: Participants in intensive counselling group (28.7± 12.5 lb.) gained less weight than those in routine care group (36.6±15.5 lb, P=.01). No difference between groups in the rate of adherence to the IOM guidelines was found. Intervention: 61.4 % adherent Control: 48.8 % adherent (P=.21) Analysis of BMI groups found that overweight and obese women were less likely to adhere to IOM guidelines. Obese women in each of the groups were adherent 33.3 % (intensive counselling) and 20.0 % (routine care) of the time, compared with 80.0 % (intensive counselling) and 68.8 % (routine care) among participants with healthy BMIs. There was no statistically significant difference in adherence across BMI groups

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
					between the intensive counselling and routine care groups when adjusted for BMI No statistically significant differences were noted between the groups in adherence to IOM guidelines, rate of caesarean delivery, pre-eclampsia, gestational diabetes mellitus (GDM), operative vaginal delivery, or vaginal lacerations.
Jeffries 2009 [39]	Aim: To determine if regular weight measurement throughout pregnancy can reduce excessive gestational weight gain.	Setting: Women recruited at their 1st antenatal appointment at the outpatient's clinic at a public tertiary obstetric hospital in Melbourne. Sample 236 pregnant women recruited at ≤14 wk' gestation. Intervention group, n=125 Control group, n=111	Design: A single blind randomised controlled trial All women enrolled in the study received standard antenatal care. Including brief dietary history taken by midwives and written information on healthy eating. All participants completed 2 questionnaires about eating habits and energy expenditure in 12 mo. before pregnancy. Intervention group - Women were given an optimal gestational weight-gain range for their pregnancy (defined by their BMI and IOM guidelines) and were told to record their weight at 16, 20, 24, 28, 30, 32, and 34 wk gestation on a graph or table. Participants were given nutrition and PA questionnaires and were blinded to the true nature of the research. Follow-up weight measurement occurred at 36–38 wk gestation.	Primary outcome: Weight change in kg (weighed at 1st antenatal appointment and 36 wk' gestation). **used 1990 IOM guidelines to measure BMI (overweight > 26)* Secondary outcomes: Gestational age, infant birth weight, complications during pregnancy or delivery Apgar scores	Findings: The mean rate of weight gain for the control group was 0.46±0.156 kg/wk, compared with 0.44± 0.173 kg/wk for the intervention group (95%CI, -0.02 to 0.07 kg/wk, NS). For the overweight group (BMI >26 to ≤29 kg/m2), there was a statistically significant reduction in gestational weight gain with a mean difference of 0.12 kg/wk (95 % CI, 0.03 to 0.22 kg/wk, P=.01) between the intervention and control groups. There was no significant difference between intervention and control groups for infant birth weight (3416±452.4 g vs 3421±504.7 g, respectively, P=.95). There were no significant differences between the 2 groups for pregnancy or

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
					delivery complications (P=.10–.99).
Hui 2012 [38]	Aim: To see if an exercise and dietary intervention during pregnancy will improve dietary habit, increase physical activity, and reduce excessive gestational weight gain (GWG) in pregnant women.	Setting: Community-based. Population: Nondiabetic urban-living pregnant women (<26 wk of gestation). A total of 190 participants (88 in the control group and 102 in the intervention group) completed their program and delivered babies before July 31, 2010. Nondiabetic pregnant women (<26 wk of pregnancy, n=227) living in Winnipeg were recruited on a voluntary basis between July 2004 and February 2010 from prenatal classes or community clinics through posters and local newspaper advertisements in Winnipeg.	Design: Randomized controlled trial. Intervention: An exercise regimen, 3–5 times per wk (including a wkly exercise session and multiple home sessions) of mild-to-moderate exercise for 30–45 m./session was recommended to participants in the intervention group. It was recommended that the exercise program started between 20 and 26 wk of pregnancy and ended at 36 wk of pregnancy. An exercise instruction video designed for pregnant women by exercise physiologists was provided to participants in the intervention group to assist their home exercise. Participants in the intervention group were taught to record daily physical activities in activity logbooks, which were collected wkly by the project coordinator from the participants in the intervention group. Dietary interviews and counseling were provided twice to each participant in the intervention group by registered dietitians, the first at enrolment and the second 2 mo. after enrolment.	Outcomes: The primary outcome is the prevalence of excessive gestational weight gain. Other measured variables included food intake, physical activity, the prevalence of large-for-gestational- age, gestational diabetes mellitus, weight-related obstetric procedures, gestational weight gain, and birth weights.	Findings: The intervention group had significantly lower prevalence of excessive gestational weight gain (35.3 %, 36 out of 102) compared with that in the control group (chi-square 7.10, 95 % CI 0.47–0.90, P=0.008). The prevalence of gestational diabetes mellitus (GDM) or caesarean section between the 2 groups was not significantly different neither was gestational wk, birth weights of offspring, and the prevalence of large-for-gestational-age infants.
Thornton 2009 [42]	Aim: To determine if adverse pregnancy outcomes would result from the implementation of balanced nutrition regimen in obese women.	Location: Ambulatory obstetric clinics of 3 tertiary care medical centers between June 1998 and May 2005—Morristown Memorial Hospital (1998-2000),	Design: Randomized, parallel-group trial Intervention: The study group was placed on an 18 to 24 kcal/kg balanced nutritional regimen,	Outcomes: (1) to compare perinatal outcomes of obese pregnant women treated in the conventional manner (control group) to outcomes	Findings: Statistically significant differences between the study and control groups regarding 3 variables: (1) gestational hypertension,

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
		St Luke's-Roosevelt Hospital Center (2001-2002), and Jamaica Hospital Medical Center (2002-2005). Each study site was an urban, public clinic of a teaching hospital. 257 patients were included.	consisting of 40 % carbohydrates, 30 % protein, and 30 % fat. All women in the study group were asked to record in a diary all of the foods and beverages consumed during each day. These records were reviewed at each prenatal visit by the physician. Six wk after delivery, the patient was weighed during her postpartum visit and exited the study. The food diary notebooks were collected from each patient at the end of the study. Patients in both groups were weighed at each prenatal visit. Participants in both groups were encouraged to engage in 30 m. of walking per day.	of nutritionally monitored obese pregnant women (study group); (2) to determine the effects of weight stabilization during pregnancy in obese pregnant women between the control and study groups on perinatal morbidity and on birth weight of their newborns; (3) to determine perinatal differences in the study group's adherence vs non-adherence to a prescribed nutritional regimen applicable to the general practice of obstetrics; (4) to evaluate perinatal outcomes of obese pregnant women who had a gain of 15 lb. or more during their pregnancy compared with those who gained fewer than 15 lb., irrespective of whether they were in the control or study group; and (5) to evaluate perinatal outcomes of obese pregnant women who had a gain of fewer than 10 lb. during their pregnancy compared with those who gained 10 lb. or more, irrespective of whether they were in the control or study group.	$P<.46$; (2) mother's last weight before delivery, $P<.001$; and (3) mother's 6-wk postpartum weight, $P<.001$. Patients gaining 15 lb. or more during their pregnancy showed statistically significant differences between the groups for 8 variables.
Shirazian 2010 [41]	Aim: To evaluate the impact of a lifestyle modification program on weight gain in pregnancy and evaluate its effects on	Location: Mount Sinai Hospital Ob/Gyn Associates clinic in New York City. From 2007-2008 Sample:	Design: A prospective matched controlled study Intervention: The aim was to limit weight gain to no more than 15 lb. On enrolment, participants	Outcomes: The primary outcome was weight gain in pregnancy. Secondary outcomes were adverse pregnancy outcomes including	Findings: Patients in the intervention group gained significantly less in their pregnancies 10.51, 25.02, $P=0.003$.

Table 5 (continued)

First Author's name and year of publication	Study aims/ research questions/ hypotheses	Sample and setting	Design and intervention	Variables targeted and their measurement.	Outcomes/findings
	adverse pregnancy outcomes.	Final analysis was conducted on 21 patients.	received written education, a food diary, and pedometer. Six seminars were conducted followed by 5 one-on-one counselling sessions or phone calls.	preeclampsia, gestational diabetes, gestational hypertension, caesarean section, fetal macrosomia, and other postpartum complications.	Gestational age and other secondary outcomes were not significantly different to the control group.
Polley 2002 [40]	Aim: To determine whether a stepped care, behavioral intervention will decrease the percentage of women who gain more than the IOM recommendation.	Setting: Hospital-based clinic serving low-income women. Pregnant women were recruited before 20 wk gestation (mean± S.D=14.5±3.1 wk) from an obstetric clinic for low-income women at a hospital in Pittsburgh, PA, USA. Sample: The final sample of 110 women included 57 in the treatment group (30 normal weight, 27 overweight) and 53 in the control group (31 normal weight, 22 overweight).	Design: Randomized controlled trial Intervention: The intervention was delivered at regularly scheduled clinic visits Shortly after recruitment, women in the intervention condition were given written and oral information. Newsletters prompting healthy eating and exercise habits were mailed biweekly. In addition, after each clinic visit, women in the intervention condition were sent a personalized graph of their weight gain. Women whose weight gains exceeded the recommended levels were given additional individualized nutrition and behavioral counseling. A stepped care approach was used, where the woman was given increasingly structured behavioral goals at each visit if her weight continued to exceed the recommended levels. The exercise intervention focused on increasing walking and developing an active lifestyle. Between clinic visits women were contacted by telephone to discuss progress toward the goals set at the previous visit.	Primary Outcome: The primary goal of the intervention was to decrease the percentage of women who exceeded the IOM guidelines from prepregnancy to the end of pregnancy. Secondary Outcome: Secondary aims were to assess the effects of treatment group and BMI category on total weight gain, weight gain from recruitment to delivery, postpartum weight loss and weight retention.	Findings: The intervention significantly decreased the percentage of normal-weight women who exceeded the IOM recommendations (33 % vs 58 %, P <0.05). There was a nonsignificant (P=0.09) effect in the opposite direction among overweight women (59 % of intervention and 32 % of control gained more than recommended). Postpartum weight retention was strongly related to weight gain during pregnancy (r=0.89). Weight gain from prepregnancy to delivery was related to prepregnancy weight (P<0.05), wk of gestation at delivery (P<0.05) and the amount of weight gained before recruitment (P< *0.001),* but was unrelated to any of the baseline demographic variables. There was a significant race effect for postpartum weight loss (P=0.01), with Black women losing less weight than White women, with losses of 17.8 and 22.1 lb. (8.1 and 10.0 kg), respectively.

Intervention Intensity

Most interventions commenced in the second trimester of pregnancy and concluded close to term or in the early postpartum period, allowing only a maximum of 24–26 weeks for the intervention to occur; this differs from type 2 diabetes intervention programs that often take place over 12 months or longer [43]. Many of the studies did not state the exact duration of the study, rather providing a range in weeks [42] or standard clinic visits [34•, 36•, 37, 40] as a timeline. Participants in Polley et al's study [40] had the most intervention exposure as the study commenced at 15 weeks gestation and continued with bi-weekly contact until 6 weeks postpartum. Four studies with a high frequency of contact were effective [36•, 38, 40, 41], suggesting that high intensity interactions may lead to positive outcomes [44].

Information Delivery Methods

Written and Verbal Education

Written and verbal methods were used in 7 of the 9 studies [34•, 37, 42], with 2 studies presenting their information in verbal form only [35•, 36•]. In most cases the written materials were either pre-written or were developed for the study specifically and in some cases standardized [34•, 38, 40]. In 1 study, written material was translated into Spanish for Hispanic participants [41].

Group and Individual Counseling

Two distinct ways to provide the information were utilized: a one-on-one discussion or a group session; the reasoning behind the choice of using both, or one over another, was not provided in any study. Two studies that resulted in effective outcomes provided education using both methods [38, 41]. One had a dietician work with a food choice map over 2 sessions and provided group exercise in community gymnasia [38]. The other offered 6 structured group seminars to provide information about nutrition and exercise, assist in overcoming barriers, and up to 5 one-on-one sessions [41]. Four effective interventions used individual education only [36•, 37, 40, 42]. Given the success of both group and individual education, it is difficult to ascertain which form of information delivery is better at facilitating behavior change in participants.

Behavior Modification Techniques

Self-Monitoring

Self-monitoring is a useful behavior modification technique, providing personal control and immediate feedback, which is important for motivation [45]. In two-thirds of the interventions, self-monitoring involved record keeping using log books, diaries, or marking progress on a graph provided at the intervention's commencement [34•, 37–42]. Food intake was monitored using food diaries and weight gain was tracked using charts [39]. In all except 1 case [34•], self-monitoring was used in studies that provided evidence of preventing excessive GWG or GDM.

Goal Setting

Goal setting can assist in initiating and maintaining behavior change [46] and was included in 5 of the interventions [34•, 38–41]. No fidelity measures were reported in any study and consequently, the extent to which participants set goals and adhered to them is not known. Two studies included problem solving strategies to assist in the goal achievement [40, 41]. Goal setting was used in studies that demonstrated prevention of excessive GWG [38–41], however, it was used in 1 study that did not demonstrate an effect on GDM [34•]. The limited number of studies available in the primary prevention of GDM indicates that the efficacy of goal setting for GDM prevention is yet to be established.

Planning

Two studies used planning in conjunction with goal setting as part of their intervention [3, 4, 40] and this pairing was used to instigate goal-oriented behavior [47]. However, the lack of fidelity measures means, there are no data to evaluate how well planning assisted in goal achievement.

The Prevention or Reduction of GDM Incidence as a Primary Outcome

The findings of an Australian study with obese women showed a significant reduction in the combined incidence of GDM and decreased gestational glucose tolerance (6 % vs 29 %, OR 0.17 95 % CI 0.03–0.95, P=0.04) [36•]. Women were diagnosed using a 75 g fasting 2-hour oral glucose tolerance test (OGTT); decreased glucose tolerance was defined as 2-hour blood glucose >6.6 mmol/L, and GDM blood glucose of >7.7 mmol/L. The protocol used the regular antenatal visits to educate about diet, food shopping, and reading of labels. It was postulated that the reduction in GDM occurred as a result of the intervention group's significantly lower weight gain than the control group (7.0 kg (SE=0.65) vs 13.8 kg (SE=0.67) [36•]. These results should be interpreted with caution due to the combined incidence of GDM and impaired glucose intolerance.

In a study of 855 participants, a 12-week exercise program was compared with standard care for the primary prevention of GDM [35•]. There was a basic discussion of diet; however, the focus was on increasing exercise to 3 times a week (1 at the

study location and 2 at home). A 75 g, 2-hour OGTT was conducted on inclusion to the study and upon completion, with the World Health Organization criteria used for diagnosis. The findings of this study revealed no difference in the incidence of GDM between the intervention and control groups (P=0.52) [35•].

A Finnish intervention study, modeled on the effective national diabetes prevention study, was designed specifically to prevent GDM through physical activity and diet [34•]. Participants had at least 1 risk factor for GDM. The diagnosis of GDM was made using an unspecified glucose load and a 2-hour fasting blood glucose of >8.6 mmol/L. The findings revealed a positive impact on a number of dietary outcomes; however, the intervention did not reduce the incidence of GDM. Overall, 15.8 % (34/216) in the intervention group and 12.4 % (22/179) in usual care developed GDM (absolute effect size 1.36, 95 % confidence interval [CI] 0.71–2.62, P= 0.36) and there was a reduction in neonatal birth weight in the intervention group (absolute effect size -133 g, 95 % CI -231 to -35, P=0.008) as well as a reduction in the number of large for gestational age babies (26/216, 12.1 % vs 34/179, 19.7 %, P=0.04). This Finnish study included intensive dietary and physical activity education, graphing, verbal and written material, and a medical practitioner for information delivery (Table 2).

These 3 studies have major limitations that downgraded the quality of evidence from high to low using the GRADE classification. The risk of bias was created due to a lack of blinding, differing criteria used to determine GDM, and a nonstandardized method for determining BMI (Table 6). Both Quinlivan et al [36•] and Luoto et al [34•] had a high level of participant contact, and yet one was able to prevent GDM and the other was not. While in this example there was 1 large and 1 small study, this should not cause the variability in outcomes therefore calling into question the underlying treatment effect.

The Prevention or Reduction of GDM Incidence as a Secondary Outcome

Each study that focused on the prevention of excessive GWG was successful [37–42]. In contrast, only 1 study that had GDM as a secondary outcome measure was able to decrease the incidence of GDM [42]. The remaining 5 of the 6 [37–41] studies showed no significant effect in preventing GDM. Only 2 of these 5 studies [39, 40] were adequately powered to measure GDM incidence.

The GRADE evaluation of these 6 papers again rates them between low and very low (Table 6). The limitations mirror those in the primary outcome group. The rating for the prospective matched controlled trial begins at low as it is not a RCT and is further downgraded due to the limitations in design [41].

Discussion

In order to explore the effectiveness of interventions aimed at GDM prevention, we have critically examined the behavioral components of interventions within 9 eligible studies. Although all of the lifestyle modification interventions have similar behavior modification techniques, differences exist between the nature of the interventions and their effectiveness. None of the reviewed interventions were based specifically on a theoretical framework and this is an area where significant improvement can be made.

Information Delivery Methods

Reinforcing information using a variety of methods has been used to instigate behavior change and may be a valuable tool in the prevention GDM [21]. Interventions with a high frequency of interaction and reinforcement of material had increased efficacy, and this was true for both the prevention of GDM [36•] and excessive GWG [38, 40, 41].

Most studies gave specific advice about how to achieve healthy eating or increased exercise, and this was further strengthened by delivery from health professionals [36•, 37, 38, 42]. This advice was reinforced with written material [34•, 37, 39–41]. Phone calls also reinforced information allowing for further discussion on problem solving and goal development [40, 41]. This is important as it highlights that providing information is not enough, that working through ways to implement it is just as important. Overall, interventions that tailored dietetic information were effective in preventing excessive GWG and GDM [36•].

Studies including both education and exercise in a group environment [35•, 41] were no more effective in preventing GDM than studies that offered the intervention on an individual basis. The evidence is inconclusive in regards to the provision of education on an individual basis over a group format. Future research should aim to further explore which method or combination of methods is most effective in the prevention of GDM.

Effective Behavior Modification Techniques

Self-monitoring is a powerful behavior modification technique and when used in a clinical setting, it was used to monitor, provide praise, or extra education [38, 40]. A clinician can easily utilize this tool within the usual consultation time, gaining additional insight into their client and improving health care. This method was used successfully in Jefferies' [39] and Polley's [40] studies to prevent excessive gestational weight gain, indicating that diary keeping may be a successful tool in dietary modification.

The use of planning with goal development and achievement are 2 other behavior modification techniques that can be

Table 6 GRADE assessment

GRADE assessment of quality in research papers

Outcome	Design	Risk of bias or limitations in design	Inconsistency or heterogeneity	Indirectness	Imprecision	Publication Bias	Quality of evidence
Primary prevention of GDM	3 RCT's	Different guidelines used for the diagnosis of GDM. Lack of blinding BMI taken by self-reported pre pregnancy weight and BMI on appointment.	High intensity and low intensity interventions producing similar results.	None	None	None	Low
Secondary Prevention of GDM via excessive GWG prevention	5 RCT's	Lack of blinding BMI taken by self-reported pre pregnancy weight. Guidelines unknown for determining GDM, possibly varying across papers.	The same behavior techniques producing different results. High and low intensity interventions producing similar results.	None	None	None	Low
	1 Prospective matched control	Lack of randomization. Non adherence. Selection bias. Small population. Control group younger than study group.	None	None	None	None	Very Low

easily employed to improve a healthy lifestyle. In most cases where this technique was used an effective outcome was attained [37, 38, 40, 41]. These simple tools when used with appropriate guidance, monitoring and support can be highly effective and easy to introduce into clinical practice. The combination of planning and goals was used successfully to improve the diets of women [34•], however, GDM prevention was not attained. Future research is needed to clearly identify which of these behavior modification techniques can be modified or enhanced to prevent GDM.

Effect Disparity

Of the interventions reviewed, there was no clear connection between the intensity of the intervention (as defined by the number of contacts and participant involvement) and the outcomes achieved. Quinlivan et al [36•] were able to reduce the incidence of GDM and glucose intolerance with an inexpensive, non-labor intensive intervention on obese women. This is in contrast to Thornton et al [42] where obese participants allocated to the intervention group consumed a nutritionally balanced diet monitored using a daily log requiring intensive effort by staff. While the methods were vastly different, both studies were able to achieve a statistically significant reduction in the incidence of GDM. Unfortunately, without any further information the variability of results cannot be explained, and given the inconsistency of findings, the quality of evidence is therefore downgraded when using GRADE.

Control Groups

Ethically, control groups must be given basic advice about healthy eating and exercise in pregnancy; this basic education will often occur with hospital contact and with the primary care givers. The unintended outcome from this lack of blinding may have reduced the measured effect of the intervention causing a bias. This risk of bias downgrades the quality of evidence using the GRADE. Furthermore, the degree of contamination between intervention and control groups was not measured in any of the studies. It is possible that the impact of interventions may have been underestimated as a result.

Gaps, Strengths, and Limitations

The conclusions of this review have been limited by the small number of recent studies and their evidence quality. This hampers efforts to inform primary care providers accurately and the development of best practice protocols for GDM prevention. None of the studies reviewed explained the rationale behind the behavior modification strategies that were used; this limits any conclusions that can be made about the

reasons why the particular behavior modification techniques were adopted. It is recommended that future interventions should elucidate the underpinning theoretical approach as a rationale for the behavior modification techniques employed, to guide both the development and evaluation of the intervention. Many of the interventions have been conducted on overweight or obese women and the conclusions of these studies may not be relevant to other populations like normal weighted women. Other gaps in evidence include a lack of longitudinal studies to measure the effect of lifestyle interventions in pregnancy and the incidence of type 2 diabetes in future. There is also no definitive understanding about the length of time an intervention should occur, that is, from GDM diagnosis, first trimester, conception or the pre conception period. Finally, no intervention has been conducted in a rural or regional setting, which may have further contextual factors that need to be considered.

The possibility of publication bias cannot be overlooked as grey literature and articles not written in English were not included in this review.

A significant limitation of the studies reviewed is the lack of fidelity measures used to assess the effectiveness of the individual components that make up the interventions. Reporting the outcomes from the behavior modification techniques that were used would assist in the future development of new interventions.

In contrast, a strength of this review is the identification of the paucity of evidence and lack of adequately powered interventions to prevent GDM has been highlighted and the need for urgent research in this area.

Conclusions

Clarifying the behavioral elements that reduce the prevalence of GDM is important in the context of an increasing incidence of GDM and prevalence if obesity. The findings of this review determine that the use of self-monitoring, goal setting, and achievement appear to be effective in the prevention of excessive gestational weight gain, especially when combined with a high frequency of intervention contact, individual attention, and professional involvement. Further research is needed to inform the combination of information delivery and behavior modification techniques that are effective in the prevention of GDM.

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Compliance with Ethics Guidelines

Conflict of Interest Helen Skouteris declares that she has no conflict of interest. Heather Morris declares that she has no conflict of interest. Cate Nagle declares that she has no conflict of interest. Alison Nankervis declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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