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Can physical activity and dietary interventions improve maternal and fetal outcomes in women with gestational diabetes mellitus? A systematic review and meta-analysis

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A table summarising all the papers in this study can be found at rcm.org.uk/access-evidence-based-midwifery-journal

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Abstract

Objective. To assess the effect of increasing physical activity or modifying diet on maternal and fetal outcomes for women with gestational diabetes mellitus.

Methods. Five electronic databases and Google Scholar were searched to identify randomised controlled trials (RCTs) of physical activity or diet interventions, published before August 2017. Interventions were included if participants had gestational diabetes, there was a control/comparison group and at least one outcome of interest was reported: insulin use, caesarean section or birth weight.

Findings. Twenty-one studies (1613 participants) were included in the systematic review, 14 were diet and seven were physical activity interventions. Diet types included low glycaemic, energy restricted and dietary approaches to stop hypertension (DASH). Physical activity included brisk walking, resistance training and home-based cycling. Meta-analysis of 17/21 RCTs suggested physical activity reduced insulin use by 47% (OR 0.53, 95% CI 0.29,0.97, P=0.04) and the DASH diet reduced insulin use by 89% (OR 0.11, (95% CI 0.04, 0.29, P<0.00001). Neither physical activity or combined diet interventions reduced the number of caesarean sections and only the diet interventions reduced birth weight -289.80g (95% CI -526.87, -52.72, I2=98%). The DASH intervention produced statistically significant results across all three outcomes. In the meta-analysis, 15/17 studies scored a high-risk of bias on at least one domain.

Conclusions. Physical activity interventions can reduce insulin use and diet interventions can reduce birth weight in women with gestational diabetes. Further intervention studies are needed that are theoretically underpinned and provide social support as these elements were lacking in the included studies.

Key words: Gestational diabetes, systematic review, meta-analysis, physical activity, diet, interventions, evidence-based midwifery

Background

Gestational diabetes mellitus (GDM) is glucose intolerance, which begins or is first diagnosed during pregnancy (Metzger and Coustan, 1998). Although worldwide prevalence is difficult to predict accurately due to differing diagnostic criteria (Meek, 2017), it is estimated to be between 1.7% and 11.6% (Schneider et al, 2012). Increasing prevalence is thought to be due to higher maternal age (Dietl et al, 2015), changes in diagnostic criteria (Laafira et al, 2015) and increasing levels of overweight and obesity (NCD Risk Factor Collaboration, 2016).

The burden of GDM, economically and for mothers' and babies' health, is considerable (Chiefari et al, 2017). Women diagnosed with GDM during pregnancy are at greater risk of preeclampsia (Nerenberg et al, 2013), having a macrosomic baby and instrumental deliveries (Ovesen et al, 2015), and up to 10 times more likely to develop type 2 diabetes (Herath et al, 2017). Babies born to mothers with GDM are more likely to be obese adults due to intrauterine programming (RCOG), 2011). Risk factors for GDM include a BMI of 25 kg/m2 or over (Pons et al, 2015); high maternal age (Dietl et al, 2015); a first degree relative with type 2 diabetes; previous pregnancy with GDM (Teh et al, 2011); South Asian origin (Bhopal, 2012); having a previous baby weighing over 4.5kg (NICE, 2015); and being sedentary or inactive (Tobias et al, 2011).

The management and treatment of GDM varies between hospitals and countries (Chiefari et al, 2017). Women diagnosed with GDM are often advised in the first instance to try to control their glucose levels through diet and physical activity (RCOG, 2011). However, there is a lack of consensus around the type of diet and physical activity that has the greatest impact. If blood glucose levels cannot be controlled through lifestyle modification it may be necessary for women with GDM to take medication such as insulin (Saleh et al, 2016).

Pregnancy has been described as a "teachable moment" where a woman is more likely to make lifestyle changes due to concerns over her health and that of her baby's (Phelan, 2010) and, therefore, an important time to intervene. However, the evidence on the duration, type and timing of physical activity, for improving outcomes for women with GDM has been equivocal. Findings from dietary interventions have also been mixed.

The purpose of this systematic literature review and meta-analysis is to assess the effect of increasing physical activity or modifying diet on maternal and fetal outcomes for women with GDM.

Objective

To assess the effect of increasing physical activity or modifying diet on maternal and fetal outcomes for women with GDM.

Review questions

- Do physical activity or diet interventions impact on maternal and fetal outcomes for women with GDM?
- Can physical activity or diet interventions reduce insulin use in women with GDM?

Methods

The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines were used for the review, along with the *Cochrane Handbook for Systematic Reviews of Interventions* (The Cochrane Collaboration, 2011) to guide the assessment of risk of bias.

Search strategy

The research question was structured around the PICOS framework, interventions were included if: participants had GDM, intervention types were PA or diet, there was a control/comparison group, at least one outcome of interest was reported (insulin use, caesarean section or birth weight), and studies were RCTs or pilot RCTs. Five databases and Google Scholar were searched: CINAHL Plus (1937-2015), Embase (1980-2015), Medline (1948-2015), PsycINFO (1806-2015) and Cochrane CENTRAL library. All databases were searched from inception to 16 November 2015. The following search terms were used in various combinations: gestational diabetes, GDM, pregnancy diabetes, motor activity, physical activity, exercise, resistance training, plyometric exercise, muscle stretching exercises, yoga, diet, nutrition, maternal nutrition. Hand searches of journals and conference proceedings were also undertaken. The searches were rerun to include 2015-2017 to search for any new papers up until 10 August 2017.

Outcomes of interest

Outcomes of interest were: insulin use, birth weight and caesarean section.

Inclusion criteria

- Published RCTs or pilot RCTs
- Pregnant women with GDM
- Interventions that involved PA or diet or both
- Control/comparison groups where the participants received only 'usual care' or a 'conventional diet' and no intervention
- Reported at least one outcome of interest (need for insulin, birth weight, caesarean section).

Exclusion criteria

- RCTs not published in English
- Interventions without a 'true' control group
- Full text not available
- Intervention focused on preventing the occurrence of GDM
- Intervention with women who had type 1 or 2 diabetes
- Did not report any outcomes of interest

Study selection and data extraction

All citations retrieved from electronic databases were imported into RefWorks, a bibliography and database manager, and duplicates removed. The titles and abstracts of papers retrieved from the search were reviewed to identify studies for possible inclusion. Papers were screened independently by two reviewers (MH and MM). After the initial screen of titles and abstracts, 90 papers remained for full text screening. Any disagreements were resolved by a third and fourth reviewer (KC and MS). Full texts were excluded for a number of reasons, including: no maternal or fetal outcomes given, paper not in English, not an RCT and no control/comparison group.

Data from included papers were extracted into a standardised data extraction form based on recommendations from the Centre for Reviews and Dissemination (The University of York, 2009). Extracted data included the following: author, title, year, number of participants, age (mean), BMI (pre-pregnancy), aims and objectives, study design (intervention type, inclusion/exclusion criteria, recruitment, randomisation, GDM diagnostic criteria), PA and/or diet characteristics, maternal and fetal outcomes (need for insulin, birth weight and caesarean sections).

Risk of bias

Risk of bias was assessed using the *Cochrane Handbook for Systematic Reviews of Interventions* (The Cochrane Collaboration, 2011). The tool tests the internal validity of each study included in the systematic review under seven domains: random sequence generation, allocation of concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other bias. A priori, it was decided the other bias category assessed was whether or not the study was adequately powered. Studies were rated as low, high or unclear in the seven domains. This assessment was carried out independently by two members of the research team (MH and MM) and results were compared and consensus reached for each study. Where agreement could not be reached the other two members of the research team were consulted (MS and KC).

Meta-analysis

Where two or more studies reported the required data, meta-analytic techniques were used to combine the results. Revman version 5.3 was used to create odds ratios with 95% confidence intervals for the dichotomous variables (need for insulin and caesarean section) and for the continuous variable (birth weight) the mean difference (MD) with 95% confidence intervals were calculated. Separate subgroup analyses were run for each intervention type (PA, low GI diet, dietary approaches to stop hypertension (DASH) and energy-restricted diet) where data were available. Data were assessed for heterogeneity. If the I2 value was above 50% it was considered a moderate to high level of heterogeneity and a random effects model was used. If I2 was lower than 50% a fixed effect model was used. Where there was more than one intervention group, data for PA (intervention) were used and no PA (control) (Bo et al. 2014). Sensitivity analysis was performed to assess the effect on the result: due to 15/17 studies scoring a high risk of bias it was inappropriate to omit studies based on risk of bias, therefore, each study was omitted one at a time and a summarised odds ratio (insulin use and caesarean section) or mean difference (birth weight) was calculated for the remaining studies. Due to the small number of studies included in the meta-analysis it was not appropriate to create funnel plots to assess publication bias.

Findings

Study selection

From 5786 records screened, 21 studies were eventually included in the systematic review with 17 of these included in the meta-analysis.

General study characteristics

Studies published between 1989 and 2017 were conducted across eight countries: USA (n=5), Australia (n=4), Canada (n=3), China (n=3), Italy (n=2), Iran (n=2), Brazil (n=1) and Spain (n=1). The sample size ranged from 12 (Hernandez et al, 2015) to 300 (Garner et al, 1997). There were 1613 participants across the 21 studies. Out of the 21 studies, 14 involved a diet intervention and seven involve a physical activity intervention. The interventions ranged in duration from four to 16 weeks depending on when women gave birth.

GDM diagnostic criteria

Various criteria for GDM were used, including: American Diabetes Association (2004), Canadian Diabetes Association (Meltzer et al, 2008) and Metzger and Coustan (1998).

Types of interventions

Interventions included a range of diets: low GI, DASH and calorie/energy restricted diets. Physical activity interventions included elements such as home-based cycling, walking and resistance training.

Participant characteristics

Participants' mean age was reported in 20 of the 21 studies and ranged from 28 to 36 years. The mean pre-pregnancy BMI was reported in 17 studies and ranged from 21.15kg/m2 to 34.3kg/m2. The majority of the studies excluded smokers from taking part and limited inclusion criteria to only include singleton pregnancies.

Intervention settings

The majority of studies were conducted in high-income countries (n=15), with the remainder of studies taking place in upper middle-income countries (n=6). Recruitment and assessments took place mainly in hospitals with only one study reporting baseline assessments being conducted at the research facility (Symons Downs et al, 2017). Five of the seven physical activity studies reported location of the physical activity intervention: all took place at home or away from the hospital.

Physical activity

Seven studies included a physical activity intervention (Symons Downs et al, 2017; Halse et al, 2015; Bo et al, 2014; de Barros et al, 2010; Brankston et al, 2003; Avery et al, 1997; Jovanovic-Paterson et al, 1989). Activities varied between the studies and included an arm ergometer (Jovanovic-Peterson et al, 1989), aerobic exercise (Avery et al, 1997), resistance training (Brankston et al, 2003; de Barros et al, 2010), brisk walking (Bo et al, 2014), home-based cycling (Halse et al, 2015) home-based exercise instruction and face-to-face exercise instruction (Symons Downs et al, 2017). Four interventions lasted from diagnosis until birth (Symons Downs et al, 2017; de Barros et al, 2010; Brankston et al, 2003; Avery et al, 1997), two lasted six weeks (Halse et al, 2015; Jovanovic-Peterson et al, 1989) and one lasted from diagnosis at approximately 24-26 weeks until 38 weeks (Bo et al, 2014).

All studies reported target exercise intensity, four aimed for 12-14 on the Borg rating of Perceived Exertion Scale, which relates to 'somewhat hard' (Halse et al, 2015; Bo et al, 2014; de Barros et al, 2010; Brankston et al, 2003), two aimed for 70% of age calculated maximum heart rate, with heart rate no higher than 140 beats per minute (Avery et al, 1997; Jovanovic-Paterson et al, 1989) and one reported the exercise as moderate intensity (Symons Downs et al, 2017).

The most common exercise frequency was three times per week (de Barros et al, 2010; Brankston et al, 2003; Avery et al, 1997; Jovanovic-Paterson et al, 1989), one study reported two sessions per week and sessions were 70 minutes (Symons Downs et al, 2017), with one reporting five sessions per week, three of these were supervised and two unsupervised (Halse et al, 2015), and one reported 20 minutes of brisk walking per day (Bo et al, 2014).

Compliance across studies was high, ranging from 100% to 64% (Symons Downs et al, 2017; Bo et al, 2014; Jovanovic-Paterson et al, 1989). Completed sessions per week were 2±0.9 out of 3 (Brankston et al, 2003), 2.26±0.4 out of 3 (de Barros et al, 2010) and 3.0±0.6 out of 4 (Avery et al, 1997).

Diet

There were 14 diet interventions. Four used a low GI diet (Grant et al, 2011; Louie et al, 2011; Ma et al, 2014; Moses et al, 2009), three employed the DASH diet (Yao et al, 2015; Asemi et al, 2014; Asemi et al, 2013), two used calorie/energy restricted diets (Rae et al, 2000; Garner at al, 1997), one used a low carbohydrate diet (Moreno-Castilla et al, 2013), one used a high fibre diet (Reece et al, 1995), one used a high carbohydrate diet (Hernandez et al, 2015), one used an ethnic meal plan (Valentini et al, 2012) and one used an oil-rich diet (Wang et al, 2015).

Low glycemic index

Four studies assigned a low GI diet to the intervention group (Ma et al, 2014; Grant et al, 2011; Louie et al, 2011; Moses et al, 2009). The mean GI of the four studies ranged from 53-58 in the control groups and 47-50 in the intervention groups. All studies used a 0-100 GI rating scale to rank foods. All interventions lasted from diagnosis (between 20 and 32 weeks) until delivery. The sample size across the studies ranged from 47 to 99. The diagnosis of GDM was based on different guidelines for each study: Canadian Diabetes Association (2008) (Grant et al, 2011; Meltzer et al, 2008), National Health and Medical Research Council Australia (2006) (Moses et al, 2009), Chinese Medical Association and American Diabetes Association (2004) (Ma et al, 2014) and a modified version of the Australasian Diabetes in Pregnancy Society (2002) (Louie et al, 2011).

Dietary approaches to stop hypertension (DASH)

The DASH diet was followed in three studies (Yao et al, 2015; Asemi et al, 2014; Asemi et al, 2013). DASH was high in fruit, vegetables, whole grains and low fat dairy products and low in saturated fat, cholesterol, refined grains and sweets. All three studies used the American Diabetes Association criteria for diagnoses of GDM. All studies lasted for four weeks and finished before birth, two studies reported insulin use post intervention (Yao et al, 2015; Asemi et al, 2014) and one study reported insulin use post-birth (Asemi et al, 2013). In all three studies the calorie content and protein composition was similar to the control diet, 2000kcal and 15% to 20% protein.

Calorie/energy-restricted diets

Two studies tested the effects of low calorie/energy restricted diets (Rae et al, 2000; Garner et al, 1997) – with one recommending 35kcal/kg of ideal body weight per day and advising good spacing of meals and snacks to avoid glucose fluctuations (Garner et al, 1997) and the other implementing a moderate energy restriction of 1590 to 1776kcal/day, 70% of the recommended dietary intake for pregnant women (National Health and Medical Research Council for Australia) (Rae et al, 2000). In one control group participants were instructed in a diabetic diet that was not energy restricted (Rae et al, 2000), with the second control group being recommended an unrestricted diet, based on the standards of the Canada Food Guide (Garner et al, 1997).

Other diets

Five studies employed a range of diets, one low carbohydrate diet (Moreno-Castilla et al, 2013), one high fibre diet (Reece et al, 1995), one ethnic meal plan (Valentini et al, 2012), one oil rich diet (Wang et al, 2015), and one high carbohydrate diet (Hernandez et al, 2015).

Risk of bias of included studies

The majority (19 out of 21) of studies scored a high risk of bias on at least one domain. Due to the nature of physical activity and diet interventions and the resulting difficulties in blinding participants all but three studies scored a high risk of bias under the domain performance bias (Asemi et al, 2013; Louie et al, 2011; Rae et al, 2000). These three studies all reported that study personnel and participants were blinded to dietary assignment. The risk of detection bias was varied throughout the studies, the main reason studies were judged to have an unclear risk was because there was insufficient information to determine whether outcome assessors had been blinded.

The domain 'other bias' was used to assess whether or not studies had undertaken a power calculation and if the required sample size had been reached. Thirteen studies scored a high risk of bias due to either not carrying out a power calculation or not reaching the required sample size. Eight studies (Asemi et al, 2014; ; Asemi et al, 2013; Moreno-Castilla et al, 2013; de Barros et al, 2010; Bo et al, 2004; Brankston et al, 2003; Rae et al, 2000; Reece et al, 1995) scored a low risk of bias as they had carried out a power calculation and achieved the required sample size. The power calculations were based on various outcomes; birth weight (Asemi et al, 2014), need for insulin (Moreno-Castilla et al, 2013; de Barros et al, 2010; Brankston et al, 2003; Rae et al, 2000), fasting glucose (Bo et al, 2004), glucose control (Reece et al, 1995) and serum HDL-cholesterol (Asemi et al, 2013).

Forest plots of some of the meta-analysis can be seen in Figures 1 and 2. Five physical activity interventions (de Barros et al, 2010; Bo et al, 2004; Brankston et al, 2003; Avery et al, 1997; Jovanovic-Peterson et al, 1989) with 344 women provided data on insulin use. One of the six studies (Jovanovic-Peterson et al, 1989) could not be used in the meta-analysis as there were no reported cases of insulin use. There was moderate heterogeneity (I2=41% P=0.17). PA reduced insulin use by 47% (OR 0.53, 95% CI 0.29,0.97, P=0.04). Post sensitivity analysis removing de Barros et al, (2010) showed a smaller reduction in insulin use and the difference between those physically active and those not physically active was not statistically significant (OR 0.83 95% CI 0.39, 1.80, I2=0%) or Brankston et al.

Eight diet interventions (Wang et al, 2015; Yao et al, 2015; Asemi et al, 2014; Moreno-Castilla et al, 2013; Valentini et al, 2012; Louie et al, 2011; Rae et al, 2000; Reece et al, 1995) were suitable to include in the analysis of insulin use. There was high heterogeneity (I2=70% P=0.006). The results suggested that insulin use was lower in intervention than control groups but were not statistically significant (OR 0.50, 95% CI 0.22, 1.14), P=0.10). The sensitivity analysis produced similar results.

In the separate analysis of the various diet types, all three of the interventions testing DASH (Yao et al, 2015; Asemi et al, 2014; Asemi et al, 2013) provided data on insulin use. However, Asemi et al, (2013) was excluded as it reported insulin use post-delivery. There was no evidence of heterogeneity between the two studies (I2=0% P=0.94). Results indicated that women consuming the DASH diet were 89% less likely to require insulin compared to women in the control group (OR 0.11, 95% CI 0.04, 0.29, P<0.00001). It was not possible to carry out sub-analyses on the physical activity interventions due to a smaller number of interventions and large heterogeneity between intervention types.

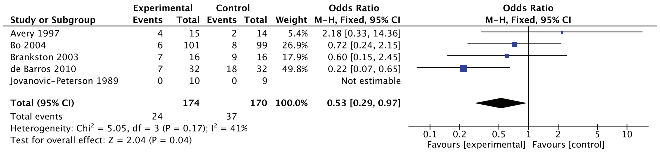
Three of the seven PA interventions (Halse et al, 2015; Bo et al, 2004; Avery et al, 1997) reported rates of caesarean section and therefore were included in the analysis of caesarean section (n=268). There was a non-statistically significant difference between the number of caesarean section in the intervention and control groups (OR 0.73, 95% CI 0.40,1.32, P=0.30). Heterogeneity was low (I2=0%, P=0.89). After conducting the sensitivity analysis all results remained non-statistically significant. However, due to the large sample size of Bo et al, (2004), the effect was smaller (OR 0.93, 95% CI 0.30,2.85, I2=0%) when this study was removed from the analysis.

Eight of the diet interventions (Hernandez et al, 2015; Yao et al, 2015; Asemi et al, 2014; Asemi et al, 2013; Moreno-Castilla et al, 2013; Valentini et al, 2012; Rae et al, 2000; Garner et al, 1997) were included in the analysis of caesarean section. There was high heterogeneity (I2=65%, P=0.006). The difference between the intervention and control groups was not statistically significant (OR 0.62, 95% CI 0.32, 1.21). The sensitivity analysis produced similar results.

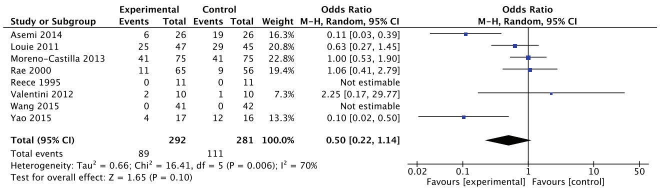
All three DASH diets were included in the analysis for

Figure 1. Odds ratio (95% CI) for insulin requirement intervention versus control group

Physical activity interventions



Diet interventions



DASH diet interventions

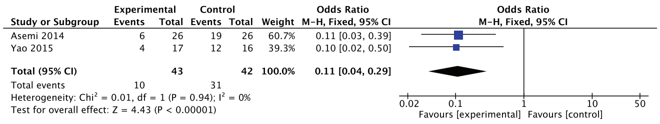
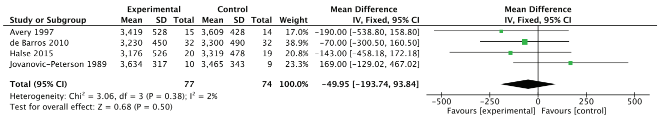
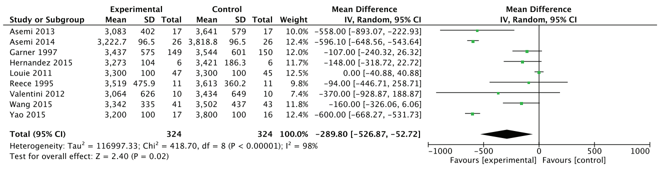


Figure 2. Mean difference (95% CI) in birth weight intervention versus control group

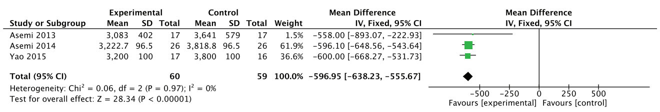
Physical activity interventions



Diet interventions



DASH diet interventions



number of caesarean sections (119 women in total) (Yao et al, 2015; Asemi et al, 2014; Asemi et al, 2013). Women who consumed the DASH diet were 83% less likely to require a caesarean section compared to women on the control diet (OR 0.17, CI 0.07,0.39, P<0.0001, I2=0%). Sensitivity analysis resulted in little change to the results.

Two energy-restricted diet interventions that reported the rate of caesarean section (420 women in total) (Rae et al, 2000; Garner et al, 1997) showed no statistically significant difference (OR 1.27, 95% CI 0.78, 2.08, P=0.34, I2=0%).

The birth weight was statistically significantly lower in the intervention groups when the diets were analysed together, with a mean reduction of -289.80g (95% CI -526.87, -52.72, I2=98%). The difference between the two groups was larger again when the DASH diets were analysed in isolation: mean reduction -596.95g (95% CI -638.23,-555.67, I2=0%). The sensitivity analysis did not change the results significantly. The PA interventions showed birth weights to be lower in the intervention group but the result was not statistically significant (-49.95g 95% CI -193.74, 93.84, I2=2%). The sensitivity analysis for the PA interventions did not change the statistical significance of the result.

Studies that did not have the required data to be used in the meta-analysis were reviewed descriptively. None of these studies found a statistically significant difference between the control and intervention groups with regards to insulin use, birth weight or rate of caesarean section.

Discussion

This systematic review and meta-analysis found that women with GDM who took part in a physical activity or DASH diet intervention were less likely to require insulin during their pregnancy than women in the control groups. Women in the intervention groups of the PA studies were 47% less likely to need insulin, and those on the DASH diet were 89% less likely to require insulin than the respective control groups. Due to the risk of bias issues caution should be taken when interpreting these results. Despite this, it is positive that the physical activity interventions and the DASH diet both appear to reduce insulin use during pregnancy for women with GDM.

The reduction in insulin use in the PA and DASH diet interventions is positive, as a retrospective analysis of medical files of women with GDM (n=601) found women who required insulin had higher rates of large for gestational age (LGA) infants (28.5% vs 13.1%, p<0.001) and a higher proportion of caesarean section (44.1% vs 27.0%, p=0.001) (Benhalima et al, 2015). The differences remained significant when adjusted for age, BMI, excess weight gain, ethnicity, mutli-parity and centre.

With regard to other outcomes, caesarean section and birth weight, the DASH diet was the only intervention type to significantly reduce the occurrence of caesarean section. PA and diets in general did not seem to reduce the occurrence of caesarean section. The reduction in caesarean sections is important as it has been found that women who gave birth by caesarean section and/or used epidural anaesthesia during labour had a higher risk of not breastfeeding for a minimum of two months (AOR 2.63, 95% CI 1.34,5.17) (Cato et al, 2017). Importantly, breastfeeding has been found to improve glucose metabolism and there is an association between longer duration of breastfeeding and lower incidence of type two diabetes two years after a pregnancy with GDM (Gunderson et al, 2015). A systematic review and meta-analysis found that longer lactation reduced the risk of women who had had GDM developing type two diabetes over five years or more (OR 0.22 95% CI 0.13,0.36) (Tanase-Nakao et al, 2017).

In addition, the reduction in the rate of caesarean section has financial implications. In the UK the cost for a planned vaginal birth has been estimated at around £1665 compared to £2369 for a planned caesarean section (NICE, 2011). Caesarean sections are major surgery and as a result are associated with risks such as postpartum sepsis (Field and Haloob, 2016). Vaginal births are also associated with shorter postnatal hospital stays than caesarean sections (NICE, 2012).

There was a statistically significant reduction in birth weight of babies born to mothers in the intervention groups in the combined diet analysis and the DASH diet studies, with a mean difference of -290g when the diet interventions were combined and -597g in the DASH diets. In a study by Choukem and colleagues (2016) they found a statistically significant association between high birth weight and shoulder dystocia ($p<0.01$), prolonged labour ($p=0.01$) and postpartum hemorrhage ($p<0.01$). Furthermore, it has been found that for each 500g increase in birth weight there is an increase in shoulder dystocia, with a tenfold increase at 4500g (Stotland et al, 2004). Therefore, the greater than 500g difference in birth weight found by adopting the DASH diet could potentially reduce some of these complications.

The results of this review imply that diet interventions can reduce birth weight for women with GDM, and that PA interventions can reduce insulin use but did not affect the other outcomes. The DASH diet was the only intervention type to improve all three outcomes. This review suggests the strongest intervention design to reduce the requirement for insulin for women with GDM would be one that incorporates physical activity and DASH.

It should be noted that only one study (Symons Downs et al, 2017) reported any theoretical background which is suggested by the Medical Research Council (MRC) guidelines for complex interventions (MRC, 2006). A theoretical underpinning is important as it provides a rationale for the intervention and aids understanding with regards to how the interventions cause change (MRC, 2006).

None of the interventions provided social support. Research has shown that women who are diagnosed with GDM reported distress when they lacked social support (Kopec et al, 2015). None of the trials used group exercise sessions which can provide social support and motivation to participants and may be worth exploring further. Furthermore, none of the physical activity interventions assessed sedentary behaviour. Sedentary behaviour has been identified as being a risk factor for a range of conditions, independent of an individual's PA levels (Lahjibi et al, 2013). Increased time spent sedentary has been found to be associated with abnormal glucose tolerance in non-pregnant women (Gollenberg et al, 2010). In a recent systematic literature review pregnant women were found to spend between 57.1% and 78% of their day in sedentary activities (Fazzi et al, 2017). One study found that pregnant women spent at least 70% of their awake time sedentary regardless of meeting PA guidelines (Di Fabio et al, 2015). This research highlights the need to look at both promoting PA and reducing sedentary behaviour when trying to improve maternal and fetal outcomes.

Strengths and limitations

This systematic review and meta-analysis followed the PRISMA guidelines. A further strength is that a risk of bias assessment was carried out on all of the included studies. In addition, sensitivity analysis showed little change in the results, indicating the robustness of the findings. This review included diet and physical activity interventions: modifying diet and increasing physical activity are the first recommendations in the NICE guidelines for women diagnosed with GDM to try and help control their blood glucose levels (NICE, 2015).

However, this review has limitations. High levels of heterogeneity across the interventions made comparisons difficult. The interventions varied in many respects including length, components and sample size. In addition a wide range of diagnostic criteria were used for GDM. The control groups across the studies varied in their approach, with some receiving no information or guidance on physical activity or diet and being left to follow their own plans, while others were given information or prescribed set diets. This may have underestimated the reported differences between the two groups. What is considered 'usual care' is likely to vary from hospital to hospital and country to country, making comparisons difficult.

Conclusion

This review provides new knowledge regarding physical activity and diet interventions for improving maternal and fetal outcomes for women with GDM. Our findings suggest the DASH diet could be a promising way to reduce insulin use, birth weight and caesarean section among women with GDM. PA was also shown to reduce insulin use. However, the results should be interpreted with caution as 19 out of the 21 studies had a high risk of bias in a least one domain. Further intervention studies are required that address the methodological flaws identified in this review, including blinding of personnel and use of a theoretical underpinning for the behaviour change interventions. A more effective intervention design may be one that focuses on both physical activity and diet.

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