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A lifestyle intervention of weight-gain restriction: diet and exercise in obese women with gestational diabetes mellitus

Raul Artal, Rosemary B. Catanzaro, Jeffrey A. Gavard, Dorothea J. Mostello, and Joann C. Friganza

Abstract: Objective: This study assessed whether a weight-gain restriction regimen, with or without exercise, would impact glycemic control, pregnancy outcome, and total pregnancy weight gain in obese subjects with gestational diabetes mellitus (GDM). A total of 96 subjects with GDM met the inclusion criteria and were sequentially recruited, with 39 subjects self-enrolled in the exercise and diet (ED) group, and the remaining 57 subjects self-enrolled in the diet (D) group owing to contraindications or a lack of personal preference to exercise. All patients were provided a eucaloric or hypocaloric consistent carbohydrate meal plan and instructed in the self-monitoring of blood glucose. In addition, all ED subjects were prescribed an exercise routine equivalent to a 60% symptom-limited $VO_{2\ max}$. Subjects were followed at weekly or biweekly office visits**.** Results showed maternal weight and body mass index (35.2 ± 7.2 (ED) vs. 33.5 ± 9.2 (D)) at study entry as well as number of weeks into the study (7.7 ± 5.7 (ED) vs. 9.4 ± 4.7 (D)) were similar in both the ED and D groups. Weight gain per week was significantly lower in the ED group than in the D group (0.1 ± 0.4 kg vs. 0.3 ± 0.4 kg; $p < 0.05$). Subjects (either ED or D) who gained weight had a higher percentage of macrosomic infants than those subjects who lost weight or had no weight change during pregnancy. Other pregnancy and fetal outcomes such as complications, gestational age at delivery, and rate of cesarean delivery were similar in both groups. Conclusions of this study were that caloric restriction and exercise result in limited weight gain in obese subjects with GDM, less macrosomic neonates, and no adverse pregnancy outcomes. Pregnancy is an ideal time for behaviour modification, and this intervention may also help promote long-term healthy lifestyle changes.

Key words: pregnancy, weight gain, gestational diabetes mellitus, obesity, exercise, diet.

Résumé : But de l'étude. Cette étude se propose de vérifier quel effet produit un programme de restriction alimentaire, associé ou non à la pratique de l'activité physique, sur le contrôle de la glycémie, sur l'issue de la grossesse et sur la prise de poids durant la grossesse chez des femmes obèses souffrant du diabète sucré de la grossesse (GDM). Méthodologie. Nous avons recruté 96 sujets souffrant de GDM et satisfaisant aux critères d'inclusion ; 39 sujets ont participé par libre choix au programme combinant la diète et l'activité physique (ED) et les 57 autres ont choisi le programme se limitant à la diète (D) compte tenu d'un manque d'intérêt pour l'activité physique ou à cause de contre-indications. Tous les patients ont reçu un programme d'alimentation constitué d'une diète eucalorique ou hypocalorique en glucides et ont appris à monitorer leur glucose sanguin. De plus, nous avons donné à tous les sujets du groupe ED un programme d'entraînement suscitant sur le plan de l'effort 60 % de leur VO_2 max limité par les symptômes. Les sujets ont été suivis en consultation externe chaque semaine ou deux fois par semaine selon le cas. Résultats. Au début de l'étude, on n'observe pas de différences de masse corporelle de la mère et d'indice de masse corporelle entre les deux groupes (35,2 ± 7,2 (ED) comparativement à 33,5 ± 9,2 (D)) ni au niveau du nombre de semaines (7,7 ± 5,7 (ED) comparativement à 9,4 ± 4,7 (D)) dans l'étude. La prise de poids à toutes les semaines est plus faible chez le groupe ED que chez le groupe D (+ 0,1 ± 0,4 kg comparativement à + 0,3 ± 0,4 kg, $p < 0,05$). Les femmes qui ont pris du poids dans un groupe ou dans l'autre ont eu, en pourcentage, plus d'enfants macrosomiques que celles qui ont perdu du poids ou qui n'en ont pas pris. On n'a pas observé de différences entre les deux groupes tant chez la mère que chez le bébé sur le plan des complications, de l'âge gestationnel et du nombre d'accouchements par césarienne. Conclusion. La réduction de l'apport énergétique combinée à la pratique de l'activité physique entraîne moins de prise de poids, moins de nouveaux-nés macrosomiques et moins de

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R. Artal,[1] R.B. Catanzaro, J.A. Gavard, and D.J. Mostello. Saint Louis University School of Medicine, Department of Obstetrics, Gynecology, and Women's Health, St. Louis, MO 63117, USA.
J.C. Friganza. St. Mary's Health Center, 1027 Bellevue Avenue, Suite 207, St. Louis, MO 63117, USA.

[1]Corresponding author (e-mail: artalr@slu.edu).

complications durant la grossesse. La grossesse est une excellente période pour modifier des comportements et peut contribuer à l'adoption à long terme de saines habitudes de vie.

Mots-clés : grossesse, prise de poids, diabète sucré de la grossesse, obésité, activité physique, diète.

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Introduction

The growing prevalence of maternal obesity has been linked to an increased prevalence of gestational diabetes mellitus (GDM) and adverse perinatal outcomes (Artal 2006). In 2003, 19.6% of women in the United States in the 18–44 year-old reproductive age category were considered obese (body mass index (BMI) ≥30 kg/m^2) (March of Dimes Perinatal Data Center 2003). Compared with normal-weight women, maternal obesity is associated with higher rates of cesarean delivery and postoperative complications (Crane et al. 1997). Infants of obese mothers are more likely to have neural tube defects, congenital heart malformations, and other multiple anomalies (Watkins et al. 2003).

Weight-gain guidelines for pregnancy established by the Institute of Medicine (IOM) specific to pregravid maternal BMI are as follows: underweight (BMI <19.8 kg/m^2) = 12.5–18 kg, normal weight (BMI 19.8–26 kg/m^2) = 11.5–16 kg, overweight (BMI 26.1–29 kg/m^2) = 7–11.5 kg, and obese (BMI > 29 kg/m^2) not more than 6 kg (Institute of Medicine 1990). The primary goal of the IOM weight-gain recommendations in pregnancy was to attain optimal birth weights. The guidelines, however, were issued prior to the widespread practice of ultrasound fetal weight measurements. The IOM guidelines were based primarily on the observed association of limited weight gain during pregnancy and low birth weight with increased infant morbidity and mortality, and the increased risk of low-birth-weight infants among women who gain lower amounts of weight. Critics argue that the IOM's recommendations for weight gain did not improve fetal outcome and may actually have resulted in increased adverse maternal and fetal outcomes (Johnson and Yancey 1996).

Most previous studies focused on sufficient weight gain during pregnancy rather than avoidance of excessive weight gain. The use of nutrition and exercise intervention methods during pregnancies complicated by GDM may not only benefit a current pregnancy but also lower the risk of subsequent obesity and overt diabetes. Several studies have documented that, in nonpregnant individuals, even small weight losses help reduce obesity-related comorbidities and that improvements in these risk factors persist with maintenance of modest weight loss.

Given that with each subsequent pregnancy there is greater postpartum weight retention (Beazley and Swinhoe 1979), coupled with the increasing incidence of maternal obesity and GDM, a greater focus is needed on the prevention of excessive weight gain during pregnancy. The goal of this study was to determine whether a lifestyle intervention of diet and exercise would impact weight gain, glycemic control, and pregnancy outcomes, and reduce comorbidities.

Materials and methods

Participants in this study included subjects referred to the Maternal Fetal Medicine Division of Saint Louis University, Department of Obstetrics, Gynecology, and Women's Health for obstetrical care, following diagnosis of GDM. The study protocol was approved by the Saint Louis University Institutional Review Board, with informed consent being obtained from each participant prior to study enrollment. Subjects sequentially entered into either the Exercise and Diet (ED) group or Diet (D) group, based on pre-existing contraindications (American College of Obstetrics and Gynecology 2002) or personal preferences to exercise. Subjects in both groups were considered eligible to participate if they entered the program at less than 33 weeks gestation, had a BMI >25 kg/m^2, were not yet managed with insulin, and were over the age of 18 years. Subjects who declined or had contraindications to exercise were entered into the D group. The ED regimen included the following: education on healthy low-fat, consistent carbohydrate intake at meals; moderate exercise; and weight-gain goals according to BMI classifications. All subjects were provided medical nutrition therapy (MNT) and participated in a GDM management program. If glucose control (criteria defined below) was not obtained within the 1 week visit, insulin therapy was prescribed and the subjects were dropped from the study. A total of 2 ED-group and 6 D-group subjects were prescribed early insulin therapy and were dropped from the study, which was not statistically significantly different between the groups ($p = 0.47$). To evaluate glycemic control and program efficacy, a comparison was made between both groups for the need of insulin to maintain normal glycemia.

Medical nutrition therapy involved prescribing a eucaloric diet to all subjects in both groups by a registered dietitian and instruction by a diabetes nurse specialist on self-monitoring of blood glucose and risks associated with GDM. A consistent carbohydrate meal plan was provided based on the following caloric needs: 25 kcal/kg (overweight BMI = 25–29.9 kg/m^2), 20 kcal/kg (obese BMI = 30–39.9 kg/m^2), and 15 kcal/kg (morbidly obese BMI ≥40 kg/m^2). The meal plan was designed to maintain euglycemia with a carbohydrate content of 40%–45% of calories, with a distribution of 12.5% at breakfast and each of 3 snacks, and 25% at the lunch and supper meals. Target blood glucose (BG) values were established at <95 mg/dL for fasting values and <130 mg/dL for 1 h postprandial values. Subjects kept blood glucose logs with fasting and 1 h postprandial blood glucose values recorded (4 times/day) and a daily diary regarding food intake and exercise for adjustments in the carbohydrate content of the meal plan or a change in regimen such as beginning insulin therapy to maintain normal glycemia. Urine ketone testing and daily food logs were used to determine whether carbohydrate and energy intake were being restricted by the subject to avoid insulin therapy. Sub-

sequently, if on more than 2 occasions, fasting blood glucose (FBG) exceeded 95 mg/dL within 1 week, or if more than 3 BG values exceeded 130 mg/dL at 1 h postprandial for the same meal, then subjects were prescribed insulin therapy.

Subjects were weighed on a Siltec® digital electronic scale with a maximum weight capacity of 455 kg. Initial weight and subsequent weights were recorded with each obstetrical visit. Maternal weight was documented at the last prenatal visit, which occurred within 2 weeks prior to delivery. Weight change during program participation was recorded as gain, loss, or no change, and was defined as the difference in last prenatal weight and initial program weight. The average weight change per week was determined by dividing the weight change during the entire program participation by the number of weeks in the study.

Inclusion criteria for those enrolled in the ED group was the ability to engage in and maintain a moderate exercise routine based on a 60% symptom-limited $VO_{2\ max}$ exercise test on a semi-recumbent cycle ergometer. A moderate exercise program was prescribed not to exceed the 60% $VO_{2\ max}$. The ED participants were encouraged to exercise in the laboratory once a week by walking on a treadmill or by riding a semirecumbent cycle ergometer based on an exercise prescription under the supervision of an exercise physiologist, while maintaining an unsupervised exercise routine on the remaining 6 days/week at home. Subjects recorded the type and number of minutes of exercise for each session in a pocket-sized exercise journal or on food and blood glucose log sheets that they brought to their weekly and biweekly obstetrical visits. Blood glucose, fetal heart rate (FHR), and reactivity were assessed before and after the exercise test and during the supervised exercise laboratory sessions. The American College of Obstetrics and Gynecology guidelines for exercise in pregnancy were used to allow for safe exercise (American College of Obstetrics and Gynecology 2002). Exclusion criteria consisted of ACOG contraindications to exercise in pregnancy such as active myocardial disease; congestive heart failure; rheumatic heart disease (Class II and above); uncontrolled hypertension; recent pulmonary emboli; risk for preterm labor, including incompetent cervix; uterine bleeding; rupture of membranes; intrauterine growth restriction; thrombophlebitis; uncertain fetal status; severe anemia; and vasculopathy.

Statistical analysis

Differences between the ED group and the D group were analyzed by a Student's *t* test for continuous variables and χ^2 test and Fisher's exact test for categorical variables. All statistical analyses were performed using SPSS, version 13.0 for Windows (Chicago) and EPI Info, version 6.04b (CDCP, Atlanta, Georgia).

Results

A total of 96 subjects diagnosed with GDM met the inclusion criteria and were sequentially enrolled into the study. Thirty-nine subjects agreed to participate in the ED program whereas the remaining 57 subjects chose to participate in the D program because of contraindications or a lack of personal preference to exercise. Table 1 lists the demographic factors, pregnancy history, and glycemic measurements at the time of diagnosis using the fasting values and the 1 h values from the 100 g oral glucose tolerance test (OGTT). There were no significant differences between the ED and D groups on gravidity, parity, race, gestational age at study entry, or the 1 h values from the 100 g OGTT. During the course of study, 22 (38.6%) subjects in the D group and 13 (35.1%) in the ED group were prescribed insulin to maintain normal glucose values. A borderline significantly higher proportion of subjects in the ED group kept food logs during the study than did subjects in the D group (80.6% vs. 63.2%; $p = 0.07$).

Anthropometric data of the subjects are summarized in Table 2. Maternal weight and BMI at study entry were similar in both groups. Maternal BMI was 35.2 ± 7.2 kg/m^2 in the ED group and 33.5 ± 9.2 kg/m^2 in the D group ($p = 0.36$), values consistent with obesity grades IIb and IIa, respectively (WHO classification). The ED group had significantly more subjects who either lost weight or had no weight change from the time of intervention to the time of delivery than the D group (46.2% vs. 21.1%), with consequently 53.8% gaining weight in the ED group compared with 78.9% in the D group ($p < 0.01$). Average weight gain per week was 0.1 ± 0.4 kg/week in the ED group compared with 0.3 ± 0.4 kg/week in the D group ($p < 0.05$). All 39 women in the ED group reported engaging in exercise, with 30 of the 39 women regularly documenting exercise in their journals. Of these 30 women in the ED group, an average exercise of 153.0 min/week (SD ± 91.4 min/week) was reported for the duration of the study. Fifty percent of the women in the ED group documenting exercise were found to have exercised for >150 min/week. Thirty min/day for 5 days/week for a total of 150 min/week is the recommended exercise guideline in the nonpregnant population.

Pregnancy outcomes were compared between the two groups. Infant birth weight was slightly higher in the ED group, but not statistically different from the D group (Table 2). The rates of vaginal deliveries and cesarean deliveries were similar in both groups. No fetal heart abnormalities were observed during this study. Infant birth weight, infant birth weight category, and delivery method were unknown for 5 patients in the ED group, and gestational age at delivery was unknown for 7 patients in the ED group. Infant birth weight was unknown for 12 patients in the D group, infant birth weight category was unknown for 11 patients in the D group, and gestational age at delivery and delivery method were unknown for 10 patients in the D group.

Pregnancy outcomes associated with maternal weight change during the course of the study are summarized in Table 3. There were 27 subjects who had an average weight loss per week, 66 subjects who had an average weight gain per week, and 3 subjects who had no weight change. The mean weight loss was 0.25 ± 0.21 kg/week for subjects who had lost weight, with a range of 0.03–0.91 kg lost per week. The mean weight gain was 0.41 ± 0.29 kg/week for subjects who had gained weight, with a range of 0.02–1.70 kg gained per week. Subjects who had gained weight had a greater percentage of macrosomic infants than subjects who had lost weight or had no average weight change (17.9% vs. 4.2%), but this was not statistically different ($p = 0.12$). Similar rates of cesarean delivery were found

Table 1. Selected demographic, glucose, and compliance data.

	Subjects in exercise and diet intervention (n = 39)			Subjects in diet intervention (n = 57)			
Characteristic	Mean±SD	n	%	Mean±SD	n	%	p value
Maternal age (y)	32.4±5.3			30.6±5.5			0.12
Gravidity	2.4±1.2			2.7±1.5			0.21
Parity	1.0±0.9			1.0±1.0			0.90
Race							
Caucasian		24	61.5		32	56.1	0.52
African-American		11	28.2		17	29.8	
Hispanic		2	5.1		1	1.8	
Other		2	5.1		7	12.3	
Gestational age at study entry (week)	29.4±4.9			28.0±5.1			0.20
Fasting blood glucose at entry (mg/dL)	96.6±14.9			88.4±11.3			<0.01
1 h blood glucose (mg/dL)*	200.2±23.3			192.1±22.2			0.12
Placed on insulin during course of study							
Yes		13	35.1		22	38.6	
No		24	64.9		35	61.4	0.90
Followed diet/kept food logs							
Yes		29	80.6		36	63.2	
No		7	19.4		21	36.8	0.07

*Oral glucose tolerance test after 100 g glucose load.

Table 2. Anthropometric and pregnancy outcome data.

	Subjects in exercise and diet intervention (n = 39)			Subjects in diet intervention (n = 57)			
Characteristic	Mean±SD	n	%	Mean±SD	n	%	p value
Maternal weight at study entry (kg)	95.0±22.6			92.3±28.9			0.63
Body mass index at study entry (kg/m^2)	35.2±7.2			33.5±9.2			0.36
Number of weeks in study	7.7±5.7			9.4±4.7			0.11
Maternal weight at last visit (kg)	95.7±21.5			94.8±29.8			0.88
Weight change							
Gain		21	53.8		45	78.9	<0.01
None or loss		18	46.2		12	21.1	
Average change/week (kg)	0.1±0.4			0.3±0.4			<0.05
Infant birth weight (g)	3407.5±484.2			3259.7±598.8			0.24
Infant weight category							
Normal		28	82.4		38	82.6	
Large for gestational age (>4000 g)		4	11.8		7	15.2	0.64
Small for gestational age (<2500 g)		2	5.9		1	2.2	
Gestational age at delivery (week)	38.5±1.3			38.1±1.6			0.19
Delivery method							
C-section		17	50.0		21	44.7	
Vaginal		17	50.0		26	55.3	0.80

for subjects who had gained weight and subjects who had lost weight or had no average weight change (49.1% vs. 41.7%; p = 0.71).

Discussion

The study findings suggest that a lifestyle intervention of weight maintenance or weight loss with nutritional guidance along with an exercise program during pregnancy for overweight, obese, and morbidly obese GDM women does not adversely impact maternal and fetal pregnancy outcomes and, at the same time, may have a beneficial aspect by limiting maternal weight gain and resulting in potentially less macrosomic neonates. Pregnant women more readily seek medical care and are highly motivated to make healthy lifestyle changes, making pregnancy an opportune time for behaviour modification. Such lifestyle changes could persist beyond pregnancy. Moderate exercise in obese and morbidly obese patients with GDM appears to be beneficial, when used in combination with an isocaloric or hypocaloric consistent carbohydrate diet, to limit maternal weight gain during pregnancy.

Table 3. Pregnancy outcomes by weight change status.

	Average weight change per week over the course of the study						
	Subjects who lost weight or had no average weight change (n = 30)			Subjects who gained weight (n = 66)			
Characteristic	Mean±SD	n	%	Mean±SD	n	%	p value
Infant birth weight (g)	3286.3±399.0			3339.5±612.0			0.70
Infant weight category							
Normal		23	95.8		43	76.8	
Large for gestational age (>4000 g)		1	4.2		10	17.9	0.12
Small for gestational age (<2500 g)		0	0.0		3	5.4	
Gestational age at delivery (week)	38.6±1.4			38.1±1.5			0.17
Delivery method							
C-section		10	41.7		28	49.1	0.71
Vaginal		14	58.3		29	50.9	

Note: Infant birth weight category was unknown for 6 subjects who had lost weight or had no average weight change and for 10 subjects who had gained weight.

Because of the small sample size, this study did not have enough power to demonstrate significant improvements in fetal outcomes. However, we observed several trends in that birth weights were more likely to be in the normal range among infants born to women who either lost weight or did not gain weight from the time of intervention to the time of delivery, along with a consequently smaller percentage of large for gestational age or small for gestational age infants (p = 0.12). Further research in a large population-based cohort is needed to demonstrate whether limiting weight gain in pregnancy, with or without exercise, can improve both maternal and fetal outcomes of pregnancies complicated by obesity and GDM. Beyond a certain level of weight gain in obese women, there may be diminishing returns at the expense of maternal and fetal postpartum complications associated with obesity (Luke et al. 1996).

In the nonpregnant population, a weight reduction of 5% to 10% has been shown to decrease the incidence of type 2 diabetes mellitus by 58% in individuals with impaired glucose tolerance over a 3 year period (Knowler et al. 2002). Exercise and weight reduction are recognized as essential components in the prevention and management of type 2 diabetes. Approximately 7% of all pregnancies are complicated by GDM, with a prevalence of 1% to 14% depending on the population and screening test (American Diabetes Association 2002). Women with GDM have a higher rate of developing GDM in a subsequent pregnancy, and have a 40% chance of developing type 2 diabetes mellitus within 4 years, when entering a pregnancy classified as obese (Kjos et al. 1995). In a previous study, it has been demonstrated that GDM can be prevented in obese subjects participating in physical activities (Dye et al. 1997). Overweight, obese, and extremely obese women are predisposed to an earlier onset of type 2 diabetes. Limiting weight gain in pregnancy may result in lower postpartum weight retention, thus decreasing the incidence of type 2 diabetes and other obesity-related comorbidities.

Recently, a CDC/ATSDR preconception-care workgroup and panel issued 10 recommendations that should lead to a reduction in pregnancy complications, among them obesity and comorbidities such as GDM: (*i*) individual responsibility across the lifespan, (*ii*) consumer awareness, (*iii*) preventative visits, (*iv*) interventions for identified risks, (*v*) interconception care, (*vi*) prepregnancy check-up, (*vii*) health insurance coverage for women with low incomes, (*viii*) public health programs and strategies, (*ix*) research, and (*x*) monitoring improvements (Johnson et al. 2006). With the increasing rates of obesity in the United States and worldwide, pregnancy weight gain often leads to postpartum weight retention and, therefore, must be considered when assessing maternal weight and pregnancy outcome (Galtier-Dereure et al. 2000). It has been reported that 27% of women reported they received no medical advice about how much weight to gain in pregnancy (Cogswell et al. 1999). Greater efforts are needed by health care providers to educate women on healthy eating habits and limiting weight gain, especially if entering pregnancy overweight or obese. Only approximately one-third of women gain weight within the recommended IOM weight-gain guidelines, with most women exceeding the limits (Ratner et al. 1991). The retention of weight gained during pregnancy appears more problematic if women gain above the recommended amounts (Siega-Riz et al. 2004).

The major short-fall of this study is the lack of randomization. The subjects were sequentially entered into each group based on contraindications to physical activity, or self-enrollment based on personal preference to exercise, as previously defined. Self-selection bias could have been operating, in that women in the two groups could have been vastly different on factors that could influence weight gain or weight loss during pregnancy and fetal outcomes. The two groups were not significantly different, however, on virtually all variables measured at study entry: maternal age, gravidity, parity, race, gestational age, 1 h blood glucose level on the 100 g OGTT, maternal weight, or BMI. The only statistically significant difference found between the two groups at study entry was that women in the ED group had higher fasting blood glucose than women in the D group. Any self-selection bias that could have been operating in this study appears to be minimal. This greatly increases the validity of our findings.

Insulin therapy is recognized as a potential cause for

weight gain; therefore, the difference in physical activity alone between the two groups may not have been the only factor accounting for the higher rate of weight gain in the D group. The ED and D groups, however, had similar percentages of women placed on insulin during the course of the study (35.1% vs. 38.6%).

Another short-fall of this study was the small sample size in each group. Major outcome differences may be present between the two groups, but our samples were so small that we did not have the statistical power to detect them. This may be especially true in the infant birth weight category variable, which had a *p* value of 0.64 between the ED group and the D group (Table 2). The lack of significant adverse fetal outcomes in the ED group, however, again supports the position that lesser amounts of weight gain during pregnancy do not adversely affect the fetus. Furthermore, even with the small sample sizes, a statistically significant difference was found for the major outcome variable of average weight gain during pregnancy, with a lower average weight gain per week being found in the ED group than in the D group. This finding is important in that, although fetal outcomes were not significantly different between the ED group and the D group, the women who had gained weight during pregnancy had a higher percentage of macrosomic newborns than the women who had lost weight or had no average weight change (17.9% (10) vs. 4.2% (1)) and a higher percentage of small for gestational age infants (5.4% (3) vs. 0.0% (0)) (Table 3). These findings, although not having overall statistical significance, are suggestive that favourable fetal outcomes occur despite lower (not greater) weight gain during pregnancy.

Conclusion

We conclude that a lifestyle intervention strategy of weight-gain restriction in pregnancy using diet and exercise in obese women with GDM could optimize pregnancy outcomes and have a significant impact on future behaviours.

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