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One-year weight losses in the Tianjin Gestational Diabetes Mellitus Prevention Program: A Randomized Clinical Trial

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Abstract

Aims—To report the findings on weight loss after the first year of the lifestyle intervention trial among women with gestational diabetes mellitus (GDM).

Methods—A total of 1180 GDM women were randomly assigned (1:1) to receive a 4-year lifestyle intervention (intervention group, n=586) or standard care (control group, n=594) between August 2009 and July, 2011. Major elements of the intervention included six face-to-face sessions with study dietitians and two telephone calls in the first year, and two individual sessions and two telephone calls in each subsequent year.

Results—Among 79% of participants who completed the Year 1 trial, mean weight loss was 0.82 kg (1.12% of initial weight) in the intervention group and 0.09 kg (0.03% of initial weight) in the control group (p=0.001). In a prespecified subgroup analysis of subjects who completed the trial, weight loss was more pronounced in women who were overweight (body mass index ≥ 24 kg/m²) at baseline: mean weight loss was 2.01 kg (2.87% of initial weight) in the intervention group and 0.44 kg (0.52% of initial weight) in the control group (p<0.001). Compared with those in the control group, women in the intervention group had a greater decrease in waist circumference (1.76 cm vs 0.73 cm; p=0.003) and body fat (0.50% vs 0.05% increase; p=0.001).

Conclusion—The 1 year lifestyle intervention led to significant weight losses after delivery in women who had GDM, and such an effect was more pronounced in overweight GDM women.

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Conflict of interest

The authors have no relevant financial interest to declare.

Keywords

Gestational diabetes; randomized clinical trials; weight loss

1. Introduction

Gestational diabetes mellitus (GDM) becomes increasingly common around the world.^{1–3} In China, the prevalence of GDM has increased from 2.4% in 1999 to 8.1% in 2012,^{4,5} now similar to the US (~7%) and Europe (~6%) levels.^{1,2} Among women diagnosed with GDM, about 30–50% will develop type 2 diabetes within 5 years of the index pregnancy.^{6,7} Women with GDM usually have a higher body weight before pregnancy, during pregnancy and after delivery compared with women without GDM.^{5,8,9} Meanwhile, overweight and obesity are associated with an increased risk of diabetes. A recent meta-analysis has shown that per unit increase in body mass index (BMI) increases an 18% risk of diabetes.¹⁰

Several recent randomized clinical trials (RCTs) have shown that a lifestyle intervention can prevent or delay type 2 diabetes risk in overweight/obese adults with impaired glucose tolerance.^{11–13} These RCTs generally have several intervention goals, and weight loss has been chosen as the primary intervention goal. Thus far, very few ongoing or planned RCTs have tested whether a postpartum lifestyle intervention can prevent or delay type 2 diabetes risk among women with GDM during the early postpartum period. The Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMPP) aims to investigate the extent to which a postpartum lifestyle intervention given soon after delivery can reduce the risk or delay the onset of type 2 diabetes in women with GDM. The aim of the present study was to present weight loss results after the first year of the intervention in the TGDMPP.

2. Subjects and Methods

2.1. Study design and participants

The Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMPP) is a two-aim, 4-year randomized controlled trial done at the Tianjin Women's and Children's Health Center, Tianjin, China.¹⁴ The study design including recruitment, screening visits, inclusion and exclusion criteria has been described in detail elsewhere.^{14–18} We recruited women (aged >24 years) with GDM diagnosed on the basis of the World Health Organization (WHO) criteria¹⁹ from six urban districts in Tianjin between July 1, 2005, and June 30, 2009. All pregnant women at 26–30 gestational weeks participated in a 1-h oral glucose tolerance test (OGTT) with 50-g glucose load. Women who had a glucose reading ≥ 7.8 mmol/l were invited to undergo a 2-h OGTT with a 75-g glucose load at the Tianjin Women's and Children's Health Center. Women with a 75-g glucose 2-h OGTT result confirming either diabetes (fasting glucose ≥ 7 mmol/l or 2-h glucose ≥ 11.1 mmol/l) or IGT (2-h glucose ≥ 7.8 and <11.1 mmol/l) using WHO's criteria are regarded as having GDM.⁴ After participants completed the baseline survey administered by health workers from the study center between August 1, 2009, and July 31, 2011, 1,180 eligible women with GDM were randomized to either a 4-year lifestyle intervention (n=586) or a control group (n=594).¹⁴ Ethics approval was granted by the Human Subjects Committee of the Tianjin Women's and

Children's Health Center, and all participants provided written informed consent. This trial is registered with ClinicalTrials.gov, number NCT01554358, and is ongoing.

The inclusion criteria were: 1) age 20–49 years at baseline survey; and 2) women with GDM between 2005 and 2009. The exclusion criteria were: 1) age <20 or ≥50 years; 2) at the screening visit: a) fasting glucose ≥7.0 mmol/l or 2-h glucose ≥11.1 mmol/l in the oral glucose tolerance test (OGTT); and b) taking medicines known to alter OGTT; 3) presence of any chronic diseases that could seriously reduce their life expectancy or their ability to participate in the trial/study; 4) unable or unwilling to give informed consent or communicate with study staff; 5) currently pregnant, or planning to become pregnant in the next two years ¹⁴.

2.2. Run-in

Before randomisation, eligible participants received two classes on general principles of lifestyle intervention for the prevention of type 2 diabetes and obesity. Participants discussed previous experience with lifestyle changes and obstacles encountered. Accumulating evidence showing that lifestyle intervention is effective for the prevention of type 2 diabetes had been presented. The specific lifestyle intervention program begun after randomisation.

2.3. Randomization and masking

Participants were randomised after the project physician and project director determined that she: a) demonstrated satisfactory interests in joining lifestyle intervention during the run-in; b) expressed willingness to continue in the trial regardless of the group they might be randomly allocated; c) met all inclusion/exclusion criteria, and d) provided all baseline data. Statistical Package for the Social Science was used to generate a list of 1200 random allocation statuses, and the list of random assignments was kept centrally by an independent person. After exclusion, 1180 eligible women with GDM were randomly assigned (1:1) to receive a 4-year lifestyle intervention (intervention group) or standard care (control group) (Online Figure 1). Because of the nature of the intervention, the participants and study coordinator could not be blinded to the study group assignment. However, the team members involved in assessing outcomes of the participants and data analysts were blinded to group assignment.

2.4. Lifestyle intervention

The intervention methods have been described in a previous report.¹⁴ The present description is limited to the first year of the trial. Major elements of the intervention included six face-to-face sessions with study dietitians and two telephone calls in the first year.

Intervention group—the first year was a weight loss phase.

Dietary intervention (Weeks 1–4): In the 1st week, each participant met one-on-one with a dietitian who instructed the participant on how to achieve the five goals of the intervention, including: 1) reduction in 5–10% of initial body weight in women with BMI ≥24 kg/m² through the reduction of at least 10% of total calories of their normal meals, and no weight

loss for GDM women with BMI <24 kg/m², using the Chinese BMI classification standard; 2) total fat intake <30% of energy consumed; 3) carbohydrate intake 55–65% of energy consumed; 4) fibre intake 20–30 g per day; and 5) moderate or vigorous exercise for at least 30 minutes daily, seven days each week. Based on each participant's current status of body weight, breast feeding, physical activity, along with food and nutrient intakes which had been assessed at the baseline survey examination, the dietitian provided them advice on how to modify their diet, which included a) intake of appropriate energy, b) inclusion of appropriate amounts of fish, eggs, low-fat milk, lean meat and reduction in fatty meat, animal fat in the diet, c) avoidance/reduction of simple sugars and refined carbohydrates, and d) inclusion of more fibre-rich food, such as whole grains, wheat flour with standard grade, corn/corn starch, brown rice, vegetables and fruits. To help participants meet these healthy diet goals, the dietitian provided the participants a suggestive daily menu for five days. Taking into consideration individual food preferences, the dietitian established with the subjects a minimum of 5 breakfasts, 5 lunches and 5 dinners that the subjects ate within the 5-day cycle menu. Moreover, the dietitian taught each participant to self-select a diet that matched her specific diet prescription for macronutrients and energy, and also introduced a method to exchange foods as depicted in a handbook.

Physical activity intervention (Weeks 1–4): the physical activity goal was to gradually increase the physical activity from 15 to 30 min per day during the first four weeks. Participants had been instructed to engage in moderate or vigorous physical activity during commuting (walking or cycling to/from work) or leisure time (e.g., walking, bicycling, etc.) for at least 15 min per day, seven days per week during Week 1. The level of physical activity had been increased to at least 30 min per day, seven days per week in Week 4, and maintained there during the entire trial period.

Diet and physical activity monitoring (Week 4–Month 12): each subject completed a questionnaire on changes in major dietary habits and physical activity habits from the last visit, and 3-day 24-hour food records five times during the first year for assessment by the dietitian. The dietitian reviewed questionnaires and food records, calculated the nutrient intakes using the dietary analysis software developed by China CDC, provided an assessment about deviations from the suggested diets and exercises, and then offered specific suggestions at each visit. Body weight had been measured at each visit to monitor compliance.

Telephone intervention: The participants received two phone calls to encourage continued compliance with the intervention in the first year. The dietitian adjusted treatment advice to improve dietary adherence to weight goals. Almost 100% of mothers have mobile phone service.

Usual-care group—Before randomization the women in the usual-care group had been educated regarding general principles of healthy lifestyle that benefits type 2 diabetes and obesity prevention, and also informed about the current evidence showing that the lifestyle intervention is effective in women at high risk for type 2 diabetes. They had been given general oral and written information about awareness of diabetes, dietary modification and physical activity increase at subsequent annual visits, but no specific individualized

programs had been offered. They completed a questionnaire on changes in major dietary and exercise habits, 3-day 24-hour food records and questionnaires at baseline and at the first year annual visit. The completeness of the food records had been checked at the face-to-face session with a dietitian at each visit.

2.5. Measurement

All study participants filled in a questionnaire about their socio-demographics (age, marital status, education, income, and occupation), history of GDM (values of fasting and 2-hour glucose in the OGTT and treatment of GDM during the pregnancy), family history (diabetes, CHD, stroke, cancer and hypertension), medical history (hypertension, diabetes, and hypercholesterolemia), pregnancy outcomes (pre-pregnancy weight, weight gain in pregnancy, and number of children), postpartum weight and fasting glucose status, dietary habits (a self-administered food frequency questionnaire (FFQ) to measure the frequency and quantity of intake of 33 major food groups and beverages during the past year),²¹ alcohol intake, smoking habits, physical activity (the frequency and duration of five domains of physical activity including occupational, commuting [walking or cycling to/from work], leisure time [11 recreational activities], household [cooking, washing clothes, cleaning, and looking after children] and sedentary activities),^{22,23} and sleep status (duration of usual sleep and night shift work) at the baseline survey.

Changes in lifestyle: a questionnaire on changes in major dietary and physical activity habits from the last visit, and a 3-day 24-hour food record had been completed at each clinical visit by women in the intervention group, a 3-day 24-hour food record and a self-administered questionnaire had been completed at the first year annual visit. The performance of 3-day 24-hour food records,²¹ the food frequency questionnaire,²¹ and the questionnaire assessing physical activity^{22,23} that had been validated in the China National Nutrition and Health Survey in 2002.

Body weight, height, waist and hip circumferences, body fat (by Tanita Body Composition Analyzers SC-240), blood pressure, and heart rate had been measured in all women using the standardized protocol at the baseline and first year annual visits. Body weight had been measured at each clinical visit in women in the intervention group.

Statistical analysis

The primary outcome of the present analyses was the change in body weight or percentage reduction in initial weight from baseline to Year 1. The secondary outcomes included changes in waist circumference, body fat, energy intake, and leisure-time physical activity from baseline to Year 1. Furthermore, we also assessed the changes in body weight, energy intake, leisure-time physical activity from baseline to Months 1, 3, 6, and 9 among women in the intervention group. A two-tailed paired t test if normal distribution was not rejected or Mann–Whitney U-test otherwise was used to analyze the differences in continuous measures while Chi-square test was used to compare the differences in categorical measures between the two groups at baseline and at Year 1. A p value less than 0.05 was considered statistically significant. Statistical analyses were performed with IBM SPSS Statistics 23.0 (IBM SPSS, Chicago, IL, USA).

We performed an intention-to-treat analysis in which long-term weight loss for persons who withdrew early from the study (after at least 3 months of participation) was imputed on the basis of a rate of 0.3 kg per month of regained weight after withdrawal.²⁴ Weight regain was estimated from time of dropout up to 3, 6, 9, or 12 months according to this rate, however regain was truncated at no change from baseline whenever the extrapolation would lead to a positive weight gain. When an individual's weight at dropout represented a gain in weight relative to baseline, no additional gain was imputed, but the unfavourable gain was simply carried forward to 3, 6, 9 or 12 months as needed. Zero weight change was assumed for 10 participants who did not return after 3 months and all participants in the control group who did not attend the Year 1 visit. Waist circumference and body fat were also analysed according to the intention-to-treat principle, with zero change from baseline imputed for missing data.

3. Results

Between August 1, 2009, and July 31, 2011, we recruited and randomly assigned 1180 women into the intervention group (n=586) or the control group (n=594) (Online Figure 1). Of them, 930 (79%) women completed the Year 1 study visit. The completed rates were 78.5% in the intervention group and 79.1% in the control group (P=0.83). Baseline characteristics were similar among all participants assigned to the intervention or the control group, and among participants assigned to the intervention or the control group who completed the Year 1 study, as well as between all participants and those who completed the Year 1 study (Tables 1 and Online Table 1).

At the end of Year 1, mean weight loss among all participants was 0.64 kg (0.86% of initial weight) in the intervention group and 0.07 kg (0.02% of initial weight; p=0.002; p=0.003) in the control group (Figure 1. A and C). Among 79% of participants who completed the Year 1 study, mean weight loss was 0.82 kg (1.12% of initial weight) in the intervention group and 0.09 kg (0.03% of initial weight; p=0.001; p=0.002) in the control group (Table 2 and Figure 1. B and D). Compared with those in the control group, women in the intervention group had a greater decrease in waist circumference (1.39 cm vs 0.58 cm in all participants, p=0.004; 1.76 cm vs 0.73 cm among those who completed the Year 1 study, p=0.003) (Table 2 and Figure 1. E and F) and body fat (0.39% vs 0.04% increase in all participants, p=0.001; 0.50% vs 0.05% increase among those who completed the Year 1 study, p=0.001) (Table 2 and Figure 1. G and H). Women in the intervention group were also more likely to achieve the goals of intervention compared with those in the control group: weight reduction goal among overweight women at baseline 30.2% vs. 17.5%, p=0.003; exercise goal among all participants: 22.4% vs. 14.3%, p=0.001, respectively (Table 2).

In a prespecified subgroup analysis, weight loss was more pronounced in women who were overweight (BMI ≥ 24 kg/m²) at baseline and completed the Year 1 study: mean weight loss was 2.01 kg (2.87% of initial weight) in the intervention group and 0.44 kg (0.52% of initial weight; p<0.001) in the control group (Table 2 and Figure 1. B and D). Women in the intervention group who were overweight at baseline were more likely to decrease their waist circumference and body fat compared with overweight women in the control group (p<0.001) (Figure 1. E, F, G, and H).

Table 3 and Figure 2 present changes in body weight, energy intake and leisure time physical activity from baseline to Months 1, 3, 6, and 9 among participants in the intervention group. Participants who completed interventions at one of the visits at Months 1, 3, 6, and 9, lost weight of a mean of 0.41 kg at Month 1, 0.68 kg at Month 3, 0.74 kg at Month 6, and 1.00 kg at Month 9. Participants in the intervention group reduced daily energy intake up to 89 kcals and increased daily leisure-time physical activity up to 2.3 minutes from baseline to Months 1–9. Women who were overweight at baseline were more likely to lose weight, reduce daily energy intake and increase daily leisure-time physical activity within the first year compared with women with normal weight at baseline.

4. Discussion

The principal finding of the present study was that the 1-year lifestyle intervention led to a significant weight loss in women who had recent history of GDM after short delivery, and such an effect was more pronounced in those who were overweight after delivery. Lifestyle intervention also decreased waist circumference and body fat among women with GDM.

The available data from several RCTs, such as the Da Qing Diabetes Prevention Study,¹¹ the Finnish Diabetes Prevention Study,¹² and the Diabetes Prevention Program (DPP)¹³ have demonstrated that effective lifestyle intervention strategies can prevent or delay the progression to type 2 diabetes among overweight or obese adults with impaired glucose tolerance. A weight reduction of at least 5–7% of initial body weight through a reducing energy intake, a healthy diet and an increasing physical activity had been chosen as the principal intervention goal among overweight or obese participants in these RCTs.^{12,13}

GDM affects about 6–14% of pregnancies worldwide.^{1–5} Women with GDM are seven times more likely to develop type 2 diabetes than those without GDM.^{6,7} Women with GDM usually have a higher body weight before pregnancy, during pregnancy and after delivery, and higher postpartum weight retention compared with women without GDM.^{5,8,9} To our knowledge, no successfully completed RCTs have tested whether lifestyle intervention during the early postpartum period can prevent or delay type 2 diabetes risk among women with history of GDM. To date very few RCTs with small sample sizes or a short intervention period have tested whether a lifestyle intervention could improve postpartum weight retention among women with GDM after early delivery. One study of 75 women with GDM indicated that a web-based lifestyle modification program for women with recent GDM decreased postpartum weight retention from 6 weeks to 12 months postpartum.²⁵ The Gestational Diabetes' Effects on Moms RCT found that a DPP-derived telephone-based lifestyle intervention modestly reduced postpartum weight retention and increased vigorous-intensity physical activity during the first 12 month postpartum period.²⁶ It seemed that the reduction in postpartum weight retention might be explained by the significant increase in vigorous intensity activity among women in the intervention group, since no differences were observed for changes in daily total energy intake.²⁶ One recent cohort study showed that 81% of women had higher body weight at 3 months postpartum compared with their body weight before pregnancy, and 74.4% of women lost weight from 3 to 12 months postpartum; this weight loss might be associated with changes in breastfeeding status and leisure-time physical activity.²⁷ It has been shown that most women naturally lose weight

throughout the breastfeeding process.²⁸ Thus an increase in physical activity and breastfeeding exclusively might help GDM women to manage their weight during the early postpartum period.

The present study found that lifestyle intervention led to a significant weight loss in GDM women, and such an effect was more pronounced in those who were overweight after 1–5 years delivery. All participants in the present study started their lifestyle intervention RCT at 1–5 years postpartum (means 27.1 months). Almost all of them stopped breastfeeding before the study and the mean duration of breastfeeding was 10.4 months. Thus their energy intake levels and body weight might be stable before the baseline survey, with exception of intentional active weight loss efforts. Unlike the few previous RCTs,^{25,26} we found that the significant reduction of daily energy intake (115–176 kcal/day) within the first year of the RCT among overweight women and an increase in leisure-time physical activity (0.42–2.32 minutes/day) among all participants might result in the significant weight loss among GDM women in the intervention group compared with those in the control group. It seems that the significant reduction of daily energy intake at Months 3–9 (131–176 kcal/day) might contribute to a greater weight loss among overweight women with GDM in the intervention group.

An important strength of this study is the thus far largest RCTs on type 2 diabetes prevention through diet and lifestyle modifications in women with GDM at 1–5 years postpartum. One limitation of this study is the 79% retention rate during the follow-up. However, this retention rate of the present RCT is similar to another large weight loss RCT – the POUNDS Lost (80%)²⁹ and higher than other large GDM intervention RCTs, such as the Gestational Diabetes' Effects on Moms (67.3%).²⁶ Moreover, intention-to-treat analysis that included all randomized participants had been conducted in the present study.

The 1-year lifestyle intervention led to significant weight loss after delivery in women who had been diagnosed GDM 1–5 years earlier. The efficacy was more pronounced in those who were overweight at 1–5 years delivery. Our findings indicate that lifestyle intervention is feasible and effective in women with GDM soon after delivery.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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References

1. American Diabetes Association. Gestational diabetes mellitus. *Diabetes Care*. 2003; 26(Suppl 1):S103–105. [PubMed: 12502631]

2. Eades CE, Cameron DM, Evans JMM. Prevalence of gestational diabetes mellitus in europe: A meta-analysis. *Diabetes Res Clin Pract.* 2017; 129:173–181. [PubMed: 28531829]
3. Wang Y, Chen L, Xiao K, Horswell R, Besse J, Johnson J, Ryan DH, Hu G. Increasing incidence of gestational diabetes mellitus in louisiana, 1997–2009. *J Womens Health (Larchmt).* 2012; 21:319–325. [PubMed: 22023415]
4. Zhang F, Dong L, Zhang C, Li B, Wen J, Gao W, Sun S, Lv F, Tian H, Tuomilehto J, Qi L, Zhang C, Yu Z, Yang L, Hu G. Increasing prevalence of gestational diabetes mellitus in chinese women from 1999 to 2008. *Diabet Med.* 2011;652–657. [PubMed: 21569085]
5. Leng J, Shao P, Zhang C, Tian H, Zhang F, Zhang S, Dong L, Li L, Yu Z, Chan JC, Hu G, Yang X. Prevalence of gestational diabetes mellitus and its risk factors in chinese pregnant women: A prospective population-based study in tianjin, china. *PLoS One.* 2015; 10:e0121029. [PubMed: 25799433]
6. Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes: A systematic review. *Diabetes Care.* 2002; 25:1862–1868. [PubMed: 12351492]
7. Bellamy L, Casas JP, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: A systematic review and meta-analysis. *Lancet.* 2009; 373:1773–1779. [PubMed: 19465232]
8. Kramer CK, Swaminathan B, Hanley AJ, Connelly PW, Sermer M, Zinman B, Retnakaran R. Each degree of glucose intolerance in pregnancy predicts distinct trajectories of beta-cell function, insulin sensitivity, and glycemia in the first 3 years postpartum. *Diabetes Care.* 2014; 37:3262–3269. [PubMed: 25231898]
9. Wang Y, Chen L, Horswell R, Xiao K, Besse J, Johnson J, Ryan DH, Hu G. Racial differences in the association between gestational diabetes mellitus and risk of type 2 diabetes. *J Womens Health (Larchmt).* 2012; 21:628–633. [PubMed: 22385105]
10. Hartemink N, Boshuizen HC, Nagelkerke NJ, Jacobs MA, van Houwelingen HC. Combining risk estimates from observational studies with different exposure cutpoints: A meta-analysis on body mass index and diabetes type 2. *Am J Epidemiol.* 2006; 163:1042–1052. [PubMed: 16611666]
11. Pan X, Li G, Hu Y, Wang J, Yang W, An Z, Hu Z, Lin J, Xiao J, Cao H, Liu P, Jiang X, Jiang Y, Wang J, Zheng H, Zhang H, Bennett P, Howard B. Effects of diet and exercise in preventing niddm in people with impaired glucose tolerance. The da qing igt and diabetes study. *Diabetes Care.* 1997; 20:537–544. [PubMed: 9096977]
12. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, Keinanen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med.* 2001; 344:1343–1350. [PubMed: 11333990]
13. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med.* 2002; 346:393–403. [PubMed: 11832527]
14. Hu G, Tian H, Zhang F, Liu H, Zhang C, Zhang S, Wang L, Liu G, Yu Z, Yang X, Qi L, Wang H, Li M, Leng J, Li Y, Dong L, Tuomilehto J. Tianjin gestational diabetes mellitus prevention program: Study design, methods, and 1-year interim report on the feasibility of lifestyle intervention program. *Diabetes Res Clin Pract.* 2012; 98:508–517. [PubMed: 23010556]
15. Liu H, Zhang C, Zhang S, Wang L, Leng J, Liu D, Fang H, Li W, Yu Z, Yang X, Dong L, Hu G. Joint effects of pre-pregnancy body mass index and weight change on postpartum diabetes risk among gestational diabetes women. *Obesity (Silver Spring).* 2014; 22:1560–1567. [PubMed: 24616432]
16. Liu H, Zhang S, Wang L, Leng J, Li W, Li N, Li M, Qiao Y, Tian H, Tuomilehto J, Yang X, Yu Z, Hu G. Fasting and 2-hour plasma glucose, and hba1c in pregnancy and the postpartum risk of diabetes among chinese women with gestational diabetes. *Diabetes Res Clin Pract.* 2016; 112:30–36. [PubMed: 26686048]
17. Li W, Zhang S, Liu H, Wang L, Zhang C, Leng J, Yu Z, Yang X, Tian H, Hu G. Different associations of diabetes with beta-cell dysfunction and insulin resistance among obese and nonobese chinese women with prior gestational diabetes mellitus. *Diabetes Care.* 2014; 37:2533–2539. [PubMed: 24914241]

18. Wang L, Leng J, Liu H, Zhang S, Wang J, Li W, Li W, Li N, Zhang T, Baccarelli AA, Hou L, Yang X, Yu Z, Hu G. Association between hypertensive disorders of pregnancy and the risk of postpartum hypertension: A cohort study in women with gestational diabetes. *Journal of human hypertension*. 2017; 31:725–730. [PubMed: 28660887]
19. WHO Consultation. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: Diagnosis and classification of diabetes mellitus. Geneva: World Health Organisation; 1999.
20. Wang Y, Mi J, Shan XY, Wang QJ, Ge KY. Is china facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in china. *Int J Obes (Lond)*. 2007; 31:177–188. [PubMed: 16652128]
21. Li YP, He YN, Zhai FY, Yang XG, Hu XQ, WHZ, Ma G. Comparison of assessment of food intakes by using 3 dietary survey methods. *Chin J Prev Med*. 2006; 40:273–279.
22. Ma G, Luan D, Li Y, Liu A, Hu X, Cui Z, Zhai F, Yang X. Physical activity level and its association with metabolic syndrome among an employed population in china. *Obes Rev*. 2008; 9(Suppl 1):113–118. [PubMed: 18307712]
23. Ma G, Luan D, Liu A, Li Y, Cui Z, Hu X, Yang X. The analysis and evaluation of a physical activity questionnaire of chinese employed population. *Nutrition Transaction*. 2007; 29:217–221.
24. Wadden TA, Berkowitz RI, Sarwer DB, Prus-Wisniewski R, Steinberg C. Benefits of lifestyle modification in the pharmacologic treatment of obesity: A randomized trial. *Arch Intern Med*. 2001; 161:218–227. [PubMed: 11176735]
25. Nicklas JM, Zera CA, England LJ, Rosner BA, Horton E, Levkoff SE, Seely EW. A web-based lifestyle intervention for women with recent gestational diabetes mellitus: A randomized controlled trial. *Obstet Gynecol*. 2014; 124:563–570. [PubMed: 25162257]
26. Ferrara A, Hedderson MM, Brown SD, Albright CL, Ehrlich SF, Tsai AL, Caan BJ, Sternfeld B, Gordon NP, Schmittiel JA, Gunderson EP, Mevi AA, Herman WH, Ching J, Crites Y, Quesenberry CP Jr. The comparative effectiveness of diabetes prevention strategies to reduce postpartum weight retention in women with gestational diabetes mellitus: The gestational diabetes' effects on moms (gem) cluster randomized controlled trial. *Diabetes Care*. 2016; 39:65–74. [PubMed: 26657945]
27. Kew S, Ye C, Hanley AJ, Connelly PW, Sermer M, Zinman B, Retnakaran R. Cardiometabolic implications of postpartum weight changes in the first year after delivery. *Diabetes Care*. 2014; 37:1998–2006. [PubMed: 24667457]
28. Mastroeni MF, Mastroeni S, Czarnobay SA, Ekwaru JP, Loehr SA, Veugelers PJ. Breast-feeding duration for the prevention of excess body weight of mother-child pairs concurrently: A 2-year cohort study. *Public health nutrition*. 2017:1–12.
29. Sacks FM, Bray GA, Carey VJ, Smith SR, Ryan DH, Anton SD, McManus K, Champagne CM, Bishop LM, Laranjo N, Leboff MS, Rood JC, de Jonge L, Greenway FL, Loria CM, Obarzanek E, Williamson DA. Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates. *N Engl J Med*. 2009; 360:859–873. [PubMed: 19246357]

Figure 1.

Changes in body weight, percentage reduction of initial weight, waist circumference and body fat from baseline to Year 1 in the participants in the intervention and control groups. Panels A, C, E and G show the change in body weight, the change in percentage reduction of initial weight, the change in waist circumference, and the change in body fat, respectively, for all participants (a total of 1180 women); missing data were imputed. Panels B, D, F and H show the change in body weight, the change in percentage reduction of initial weight, the change in waist circumference, and the change in body fat, respectively, for participants who finished Year 1 visit (a total of 930 women).

Figure 2.

Changes in body weight and percentage reduction of initial weight from baseline to the end of Month 1, 3, 6, 9 and 12 among participants who completed study visits.

Table 1

Baseline characteristics of women with gestational diabetes mellitus

	All participants		P value	Participants who completed the Year 1 study		P value
	Intervention Group	Control Group		Intervention Group	Control Group	
Numbers of participants	586	594		460	470	
Age (years)	32.3 (3.4)	32.4 (3.6)	0.58	32.5 (3.4)	32.5 (3.6)	0.90
Time from delivery to baseline (months)	27.2 (10.4)	27.1 (10.3)	0.82	26.9 (10.5)	27.0 (10.3)	0.84
Time from delivery to the end of the Year 1 (months)	-	-		42.5 (12.0)	42.2 (11.8)	0.68
Height (cm)	160 (5.6)	160 (5.1)	0.70	160 (5.6)	160 (5.1)	0.70
Body weight (kg)	61.3 (10.4)	61.8 (10.6)	0.46	60.9 (10.1)	61.9 (10.2)	0.13
Body mass index (kg/m ²)	23.8 (3.7)	24.0 (3.9)	0.33	23.7 (3.6)	24.0 (3.9)	0.11
Body mass index categories (%) [*]			0.71			0.25
<24 kg/m ²	57.3	55.2		58.9	53.8	
24–27.9 kg/m ²	28.7	30.8		28.7	31.1	
≥28 kg/m ²	14.0	14.0		12.4	15.1	
Waist circumference (cm)	79.8 (9.1)	80.3 (9.3)	0.41	79.4 (8.9)	80.3 (9.3)	0.16
Body fat (%)	32.6 (5.6)	32.9 (5.8)	0.41	32.4 (5.6)	32.9 (5.8)	0.11
Education (%)			0.025			0.016
<13 years	23.4	19.9		22.8	19.8	
13–16 years	67.4	74.1		67.4	74.7	
≥16 years	9.2	6.1		9.8	5.5	
Family income (yuan/month)			0.84			0.82
<5000	25.9	27.1		26.7	28.5	
5000–8000	37.7	36.2		36.3	36.0	
≥8000	36.3	36.7		37.0	35.5	
Family history of diabetes (%)	34.5	33.7	0.77	34.6	33.8	0.81
Current smoking (%)	1.5	2.4	0.56	1.3	1.9	0.63
Passive smoking (%)	51.7	54.9	0.27	51.3	55.5	0.20
Current alcohol drinkers (%)	22.2	20.9	0.58	22.2	19.8	0.37

	All participants		P value	Participants who completed the Year 1 study		P value
	Intervention Group	Control Group		Intervention Group	Control Group	
Occupational physical activity (%)			0.27			0.10
Light	26.1	25.6		25.7	26.4	
Moderate	57.0	53.9		58.7	53.0	
Vigorous	16.9	20.5		15.7	20.6	
Walking or cycling to and from work (%)			0.036			0.08
0 minute/day	75.1	81.1		75.9	81.7	
1–29 minutes/day	5.3	4.5		5.0	3.2	
30 minutes/day	19.6	14.3		19.1	15.1	
Leisure time physical activity (%)			0.81			0.47
0 minute/day	78.5	79.0		77.8	81.1	
1–29 minutes/day	19.1	19.2		19.8	17.0	
30 minutes/day	2.4	1.9		2.4	1.9	
Sitting time at home (hours/day)	3.2 (2.2)	3.2 (2.0)	0.51	3.1 (2.2)	3.2 (1.9)	0.34
Sleep time (hours/day)	7.9 (1.1)	7.8 (1.0)	0.13	7.8 (1.0)	7.7 (1.1)	0.24
Dietary intakes [†]						
Energy (kcal/day)	1685 (415)	1697 (469)	0.65	1705 (408)	1701 (465)	0.89
Protein (% of energy)	16.9 (2.7)	17.1 (2.9)	0.25	16.2 (2.5)	16.4 (2.7)	0.11
Fat (% of energy)	33.5 (6.3)	33.5 (6.4)	0.89	33.7 (6.3)	33.6 (6.2)	0.64
Carbohydrate (% of energy)	49.6 (7.1)	49.4 (7.5)	0.63	50.1 (6.9)	50.0(7.2)	0.86
Fiber (g/1000 kcal)	6.2 (1.9)	6.2 (2.0)	0.41	6.2 (1.8)	6.3 (2.1)	0.81
Vegetable intake (g/day)	258 (119)	256 (127)	0.84	261 (116)	257 (125)	0.62
Fruit intake (g/day)	126 (131)	121 (115)	0.48	123 (122)	123 (118)	0.99

Data are mean (SD), and percentage (%) unless otherwise indicated.

* According to the Chinese standard, BMI is classified as normal (BMI <24 kg/m²), overweight (BMI 24–27.9 kg/m²), and obese (BMI ≥ 28 kg/m²).

[†] Dietary intakes are assessed by 3-day 24-hour food records.

Table 2

Changes in body weight, waist circumference, and major lifestyle factors from baseline to the end of Year 1 among participants who completed the Year 1 study

	Intervention group	Control group	P values
Numbers of participants	460	470	
Change in weight			
In kilograms	−0.82 (3.52)	−0.09 (3.29)	0.001
Percent reduction in initial weight	−1.12 (5.43)	−0.03 (4.99)	0.002
Change in body mass index (kg/m ²)	−0.32 (1.38)	−0.04 (1.27)	0.001
Change in waist circumference (cm)	−1.76 (5.40)	−0.73 (5.18)	0.003
Change in body fat (%)	−0.50 (2.59)	0.05 (2.19)	0.001
Change in energy intakes (kcal/day) *	5.81 (490)	2.66 (525)	0.095
Change in leisure time activity (minutes/day)	1.76 (9.73)	0.36 (11.9)	0.048
Interventional goals (%)			
Weight reduction >5% in initial weight	19.3	13.2	0.011
Fat intake <30% of energy intake *	41.7	40.2	0.64
Carbohydrate intake >55% of energy intake *	50.2	51.9	0.60
Fiber intake >20g/day *	5.0	2.1	0.018
Exercise >30 min/day (commute and leisure)	22.4	14.3	0.001
Numbers of participants with baseline body mass index <24 kg/m²	271	253	
Change in weight			
In kilograms	0.02 (2.52)	0.20 (2.51)	0.42
Percent reduction in initial weight	0.11 (4.53)	0.39 (4.51)	0.48
Change in body mass index (kg/m ²)	0.01 (0.98)	0.07 (0.96)	0.42
Change in waist circumference (cm)	−0.84 (4.72)	−0.76 (4.57)	0.85
Change in body fat (%)	−0.01 (2.34)	0.20 (2.16)	0.28
Change in energy intakes (kcal/day) *	63.5 (463)	0.12 (493)	0.13
Change in leisure time activity (min/day)	1.34 (9.68)	−0.29 (11.7)	0.083
Interventional goals (%)			
Weight reduction >5% in initial weight	11.8	9.5	0.39
Fat intake <30% of energy intake *	44.6	41.9	0.52
Carbohydrate intake >55% of energy intake *	53.9	53.8	0.97
Fiber intake >20g/day *	5.5	2.4	0.065
Exercise >30 minutes/day (commute and leisure)	26.6	13.0	<0.001
Numbers of participants with baseline body mass index ≥24 kg/m²	189	217	
Change in weight			
In kilograms	−2.01 (4.33)	−0.44 (4.00)	<0.001
Percent reduction in initial weight	−2.87 (6.10)	−0.52 (5.46)	<0.001
Change in body mass index (kg/m ²)	−0.79 (1.69)	−0.17 (1.55)	<0.001
Change in waist circumference (cm)	−3.10 (6.02)	−0.71 (5.82)	<0.001

	Intervention group	Control group	P values
Change in body fat (%)	−1.20 (2.76)	−0.13 (2.22)	<0.001
Change in energy intakes (kcal/day) *	−76.9 (515)	5.62 (561)	0.12
Change in leisure time activity (minutes/day)	2.38 (9.80)	1.11 (12.0)	0.25
Interventional goals (%)			
Weight reduction >5% in initial weight	30.2	17.5	0.003
Fat intake <30% of energy intake *	37.6	38.2	0.89
Carbohydrate intake >55% of energy intake *	45.0	49.8	0.33
Fiber intake >20g/day *	4.2	1.8	0.16
Exercise >30 min/day	16.4	15.7	0.84

Data are changes in mean (SD), and percentage (%) unless otherwise indicated.

* Dietary intakes are assessed by 3-day 24-hour food records.

Table 3

Changes in body weight, energy intake and leisure-time physical activity from baseline to the end of Months 1, 3, 6, and 9 in the intervention group among participants who completed study visits

	Month 1	Month 3	Month 6	Month 9
Numbers of participants	423	434	490	371
Change in weight				
In kilograms	−0.41 (1.69)	−0.68 (2.04)	−0.74 (2.54)	−1.00 (3.11)
Percent reduction in initial weight	−0.59 (2.66)	−1.01 (3.22)	−1.07 (3.91)	−1.46 (4.66)
Change in energy intakes (kcal/day) *	−57.7 (452)	−89.2 (461)	−85.9 (478)	−63.4 (491)
Change in leisure time activity (minutes/day)	0.42 (8.01)	1.07 (10.8)	1.45 (10.0)	2.32 (10.0)
Numbers of participants with baseline body mass index <24 kg/m ²	229	247	280	206
Change in weight				
In kilograms	−0.10 (1.41)	−0.24 (1.69)	−0.13 (1.82)	−0.19 (2.00)
Percent reduction in initial weight	−0.18 (2.57)	−0.44 (3.07)	−0.22 (3.28)	−0.32 (3.54)
Change in energy intakes (kcal/day) *	−9.00 (393)	−33.3 (431)	−18.4 (442)	−9.50 (446)
Change in leisure time activity (minutes/day)	0.50 (7.72)	0.02 (9.23)	0.67 (10.5)	1.76 (9.08)
Numbers of participants with baseline body mass index ≥ 24 kg/m ²	194	187	210	165
Change in weight				
In kilograms	−0.78 (1.91)	−1.25 (2.31)	−1.56 (3.08)	−2.01 (3.87)
Percent reduction in initial weight	−1.07 (2.69)	−1.76 (3.27)	−2.21 (4.38)	−2.88 (5.45)
Change in energy intakes (kcal/day) *	−115 (508)	−163 (489)	−176 (510)	−131 (536)
Change in leisure time activity (minutes/day)	0.32 (8.36)	2.46 (12.4)	2.48 (9.27)	3.01 (11.1)

Data are changes in mean (SD) unless otherwise indicated.

* Dietary intakes are assessed by 3-day 24-hour food records.