Published in final edited form as:

Diabet Med. 2015 November ; 32(11): 1492–1499. doi:10.1111/dme.12790.

Metabolic syndrome of weight change from pre-pregnancy to 1–5 years post-partum among Chinese women with prior gestational diabetes

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Abstract

Aims—Few studies have evaluated the effect of weight change from pre-pregnancy to post partum with the risk of cardiometabolic diseases among women with a history of gestational diabetes mellitus. The aim of this study was to evaluate the association between weight change from pre-pregnancy to 1–5 years post partum with metabolic syndrome among Chinese women with prior gestational diabetes mellitus.

Methods—We performed a retrospective cohort study in 1263 women with gestational diabetes mellitus at 1–5 years post partum. Participants were divided into four groups based on their weight change from pre-pregnancy to 1–5 years post partum: loss of ≥ 3 kg, ± 3 kg, gain of 3–7 kg and gain of ≥ 7 kg.

Results—The prevalence of metabolic syndrome was 12.1%, 16.2%, 26.0% and 44.3% among women with weight loss ≥ 3 kg, stable weight (± 3 kg), weight gain 3–7 kg and weight gain ≥ 7 kg from pre-pregnancy to post partum, respectively. The positive association between weight change and metabolic syndrome was observed among women with pre-pregnancy normal weight (BMI < 24 kg/m²), overweight (BMI 24–27.9 kg/m²) and obesity (BMI ≥ 28 kg/m²). The prevalence of metabolic syndrome was almost similar among pre-pregnancy normal weight women with weight gain ≥ 7 kg, pre-pregnancy overweight women with stable weight (± 3 kg) and pre-pregnancy obese women with weight loss ≥ 3 kg from pre-pregnancy to post partum ($P = 0.62$).

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Author contributions

WL designed the study, acquired the data, performed the statistical analysis, interpreted the data, drafted the article and approved the final version to be published. GH designed the study, acquired the data, reviewed and critically revised the article and approved the final version to be published. HL, YQ, FL, SZ, LW, JL and HL performed the field work and critically revised the article, and approved the final version to be published. LQ and JT helped to interpret these analyses in the writing of the results and discussion, reviewed and critically revised the article. GH was responsible for the integrity of the work as a whole.

Competing interests

None declared.

Supporting information

The following Supporting Information is available in the online version of this article:

Conclusions—Women with gestational diabetes mellitus who had large weight gain from pre-pregnancy to post partum were more likely to develop metabolic syndrome. Women who are pre-pregnancy overweight/obesity and also diagnosed as gestational diabetes mellitus during pregnancy need more weight control after delivery.

Introduction

Gestational diabetes mellitus (GDM), defined as any degree of glucose intolerance with onset or first recognition during pregnancy [1], is one of the most common complications in pregnancy, affecting 2–10% of pregnancies in the USA [2]. In general, compared with other racial/ethnic groups in the USA, Asian women have a higher risk for gestational diabetes mellitus [3–6]. In urban China, the prevalence of gestational diabetes mellitus has increased from 2.4% in 1999 to 8.2% in 2012 [7]. Women with a history of gestational diabetes mellitus are at increased risk of Type 2 diabetes and metabolic syndrome later in life [8,9].

Pre-pregnancy weight and gestational weight gain are positively associated with a woman's long-term risk of metabolic syndrome, Type 2 diabetes and cardiovascular disease [10–12]. However, there are few studies evaluating the association of weight change from pre-pregnancy to early post partum with the risk of cardiometabolic diseases; and a paucity of studies has assessed the effects of both pre-pregnancy and post-partum weight on cardiometabolic disease among women, especially those with a history of gestational diabetes mellitus. Thus, this study aimed to evaluate the association of weight change from pre-pregnancy to 1–5 years post partum with metabolic syndrome among Chinese women with prior gestational diabetes mellitus.

Patients and methods

We performed a retrospective cohort study in 1263 women with a history of gestational diabetes mellitus at 1–5 years after delivery using the data of the participants of the Tianjin gestational diabetes mellitus prevention program [12–15].

Tianjin gestational diabetes mellitus screening project

Tianjin is the fourth largest city in Northern China, consisting of 16 county-level administrative areas. Among the 13 million residents, 4.3 million lived in six central urban districts in 2010. Since 1999, all pregnant women who live in the six urban districts have participated in universal screening for gestational diabetes mellitus, and the average proportion of screened pregnancies was over 91% from 1999 to 2008 [7]. All pregnant women at 26–30 gestational weeks participated in a 1-h 50-g glucose screening test (GCT). Women who had a glucose reading ≥ 7.8 mmol/l were invited to undergo a 2-h 75-g oral glucose tolerance test (OGTT) at the Tianjin Women and Children's Health Center [7]. Gestational diabetes mellitus is defined using the World Health Organization (WHO)'s criteria [16]. 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 impaired glucose tolerance (2-h glucose ≥ 7.8 and < 11.1 mmol/l) are regarded as having gestational diabetes mellitus. A total of 128 125 pregnant women took part in the gestational diabetes mellitus

screening programme and 6247 were diagnosed with gestational diabetes mellitus between December 1998 and December 2009 [13].

Study samples

The Tianjin Gestational Diabetes Mellitus Prevention Program has been described previously in detail [12–15]. Because we had set up a good healthcare registration system for gestational diabetes mellitus mothers' health and contact information, all pregnant women in six urban districts diagnosed with gestational diabetes mellitus between 2005 and 2009 ($N = 4644$) were invited to participate in a post-partum survey for the programme from August 2009 to July 2011. In total, 1263 women with a history of gestational diabetes mellitus (participation rate 27%) finished the post-partum survey. No differences in age (28.9 vs. 28.7 years), 2-h glucose (9.23 vs. 9.16 mmol/l), fasting glucose (5.34 vs. 5.34 mmol/l) and the prevalence of impaired glucose tolerance (90.9% vs. 91.8%) and diabetes (9.1% vs. 8.2%) at 26–30 gestational weeks' OGTT test were found between the returned and unreturned women with a history of gestational diabetes mellitus. The study was approved by the Human Subjects Committee of the Tianjin Women's and Children's Health Center, and informed consent was obtained from each participant.

Examinations

At the post-partum survey, all study participants filled in a questionnaire about their sociodemographics (age, marital status, education, income and occupation), history of gestational diabetes mellitus (values of fasting and 2-h glucose in the OGTT and treatment of gestational diabetes mellitus during the pregnancy), family history (diabetes, coronary heart disease, stroke, cancer and hypertension), medical history (hypertension, diabetes and hypercholesterolaemia), pregnancy outcomes (pre-pregnancy weight, weight gain in pregnancy and number of children), dietary habits (a self-administered food frequency questionnaire to measure the frequency and quantity of intake of 33 major food groups and beverages during the past year) [17], alcohol intake, smoking habits, passive smoking and physical activity (the frequency and duration of leisure time and sedentary activities). They also completed three-day 24-h food records using methods for dietary record collections taught by a dietician. The performance of three-day 24-h food records [17], the food frequency questionnaire [17] and the above questionnaire on assessing physical activity [18] has been validated in the China National Nutrition and Health Survey in 2002.

Body weight, height, waist circumference and blood pressure were measured for all women at the post-partum survey, using the standardized protocol by specially trained research doctors. Body weight and height were measured without shoes and with light clothing. Waist circumference was measured midway between the lower rib margin and iliac crest. The measurement of height and waist was rounded to the nearest half centimetre. Pre-pregnancy BMI and BMI at the post-partum survey were calculated by dividing pre-pregnancy or post-partum weight at the post-partum survey in kilograms by the square of height in metres. Weight change from pregnancy to post partum was calculated as difference between 1–5 years post-partum weight (current weight at the post-partum survey) and pre-pregnancy weight.

Peripheral venous EDTA-blood samples were collected before (fasting at least 12 h) and 2 h after the ingestion of 75 g glucose and centrifuged at 4 °C, 3000 rpm for 15 min. Glucose and lipid profile [total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triglycerides (TG)] were measured on an automatic analyser (Toshiba TBA-120FR, Japan). Low-density lipoprotein cholesterol (LDL cholesterol) was calculated with triglycerides below 4.5 mmol/l by the formula: LDL cholesterol = total cholesterol – HDL-C – (triglycerides/2.19) [19].

According to the definition from the International Diabetes Federation (IDF) and the American Heart Association and the National Heart, Lung and Blood Institute [20], metabolic syndrome was diagnosed as the presence of any three of five risk factors: waist circumference ≥ 90 cm (35 inches) in men and ≥ 80 cm (31 inches) in women for Asians, TG ≥ 150 mg/dl (1.7 mmol/l) or using drug treatment for elevated TG, HDL-C < 40 mg/dl (1.03 mmol/l) in men and < 50 mg/dl (1.3 mmol/l) in women or using drug treatment for reduced HDL-C, systolic blood pressure (SBP) ≥ 130 mmHg or diastolic blood pressure (DBP) ≥ 85 mmHg or using antihypertensive drug treatment, fasting glucose ≥ 100 mg/dl (5.6 mmol/l) or 2-h glucose ≥ 140 mg/dl (7.8 mmol/l) or using drug treatment for elevated glucose.

Statistical analyses

Study participants were categorized into four groups based on their weight change from pre-pregnancy to 1–5 years post partum: loss of ≥ 3 kg, stable weight ± 3 kg, gain of 3–7 kg and gain of ≥ 7 kg. Continuous variables were tested for normality of distribution, and natural log transformations of skewed variables were used in subsequent analyses where necessary. Kruskal–Wallis equality of populations rank tests were used to test the difference in ordinal variables (e.g. education, leisure time physical activity) across the four weight-change groups. Generalized linear models were used to assess the difference for continuous (cardiometabolic risk factors) and categorical variables (metabolic syndrome and its individual components). The multiple adjusted analyses were adjusted for: age, post-partum time, family income, sedentary time, energy intake, dietary fibre, intakes of monounsaturated fat, polyunsaturated fat and saturated fat (continuous variables for above all variables), education, family history of diabetes, smoking, passive smoking, alcohol drinking and leisure time physical activity (categorical variables for above all variables). All statistical analyses were performed by using SAS for Windows, version 9.3 (SAS Institute, Cary, NC). $P < 0.05$ was considered statistically significant.

Results

General characteristics of the participants at the post-partum survey are presented in Table 1. A total of 1263 women with a history of gestational diabetes mellitus were categorized into weight loss of ≥ 3 kg ($n = 132$), stable weight ± 3 kg ($n = 589$), gain of 3–7 kg ($n = 293$) and gain of ≥ 7 kg ($n = 249$), respectively, based on their weight change from pre-pregnancy to 1–5 years post partum.

The multiple adjusted mean values of the cardiometabolic risk factors among women with different weight changes from pre-pregnancy to 1–5 years post partum (four groups) are

presented in Table 2. There were significant positive associations between weight change from pre-pregnancy to 1–5 years post partum and several metabolic risk factors including fasting and 2-h glucose, HOMA-IR, waist circumference, TC, TG, LDL cholesterol, SBP and DBP, and an inverse association between weight change from pre-pregnancy to post partum and HDL-C (all $P < 0.05$). When stratified by pre-pregnancy BMI (< 24 , 24 – 27.9 and ≥ 28 kg/m²), the positive or inverse associations between weight change from pre-pregnancy to 1–5 years post partum and metabolic risk factors remained significant in most of the subgroups, especially among women with pre-pregnancy normal weight (BMI < 24 kg/m²) and overweight (24 – 27.9 kg/m²).

We also compared the prevalence of metabolic syndrome and its components among women with different weight change from pre-pregnancy to 1–5 years post partum after adjustment for major risk factors (Table 3). The overall prevalence of metabolic syndrome was 12.1%, 16.2%, 26.0% and 44.3% among women with weight loss ≥ 3 kg, stable weight (± 3 kg), gain of 3 – 7 kg, and gain of ≥ 7 kg from pre-pregnancy to post partum, respectively. The prevalence of elevated waist circumference, reduced HDL-C, elevated glucose, elevated TG and hypertension among women with prior gestational diabetes mellitus were 49.9%, 43.2%, 38.3%, 16.2% and 11.4%, respectively. We observed a similarly positive association between weight change from pre-pregnancy to post partum and each component of metabolic syndrome. Women with weight loss ≥ 3 kg from pre-pregnancy to post partum presented the lowest prevalence of each component of metabolic syndrome, whereas women with weight gain ≥ 7 kg from pre-pregnancy to post partum presented the highest.

When stratified by pre-pregnancy BMI (< 24 , 24 – 27.9 and ≥ 28 kg/m²), the positive associations of weight change from pre-pregnancy to 1–5 years post partum with overall metabolic syndrome and its individual components were observed among women with pre-pregnancy normal weight, overweight and obesity (BMI ≥ 28 kg/m²), with a few exceptions among women with pre-pregnancy obesity (Table 3). Women with pre-pregnancy normal weight and weight loss ≥ 3 kg from pre-pregnancy to post partum had the lowest prevalence of metabolic syndrome (0.0%), whereas women with pre-pregnancy obesity and weight gain ≥ 7 kg from pre-pregnancy to post partum had the highest prevalence of metabolic syndrome (78.3%). The prevalence of metabolic syndrome was almost similar for the following three groups: women with a history of gestational diabetes mellitus with pre-pregnancy normal weight and weight gain ≥ 7 kg from pre-pregnancy to post partum (33.3%), women with pre-pregnancy overweight and stable weight (± 3 kg) from pre-pregnancy to post partum (37.5%), and women with pre-pregnancy obesity and weight loss ≥ 3 kg from pre-pregnancy to post partum (41.4%) ($P = 0.62$).

Discussion

This study found a positive association between weight change from pre-pregnancy to 1–5 years post partum and metabolic syndrome among Chinese women with prior gestational diabetes mellitus. This positive association was consistently present among women with a history of gestational diabetes mellitus with pre-pregnancy normal weight, overweight and obesity.

It has been suggested that pre-pregnancy weight and gestational weight gain are positively associated with women's long-term cardiometabolic risk including metabolic syndrome, Type 2 diabetes and cardiovascular disease [10–12]. A recent study has found that women who did not lose weight between 3 and 12 months after delivery had an adverse cardiometabolic profile [21]. However, few studies have assessed both pre-pregnancy weight and weight change from pre-pregnancy to early post partum on post-partum cardiometabolic risk. This study is, to our knowledge, the first to find that both pre-pregnancy weight and weight change from pre-pregnancy to post partum were positively associated with post-partum metabolic syndrome among women with prior gestational diabetes mellitus. Compared with women with a history of gestational diabetes mellitus whose weight remained stable from pre-pregnancy to 1–5 years post partum (± 3 kg), women with a history of gestational diabetes mellitus who lost weight (loss of ≥ 3 kg) from pre-pregnancy to post partum were less likely to have metabolic syndrome, whereas women who gained weight from pre-pregnancy to post partum (gain of ≥ 3 kg) were more like to have metabolic syndrome.

It is noteworthy in our study that the prevalence of metabolic syndrome was almost similar among pre-pregnancy normal weight women with weight gain ≥ 7 kg from pre-pregnancy to post partum (33.3%), pre-pregnancy overweight women with stable weight (± 3 kg) from pre-pregnancy to post partum (37.5%) and pre-pregnancy obese women with weight loss ≥ 3 kg from pre-pregnancy to post partum (41.4%) (P for differences = 0.62). In addition, we found that women with pre-pregnancy overweight and weight loss ≥ 3 kg (weight loss of $\sim 5\%$ of their pre-pregnancy body weight) from pre-pregnancy to post partum had a lower prevalence of metabolic syndrome (8.2%) than those with pre-pregnancy normal weight and weight gain ≥ 7 kg ($\geq 10\%$ of weight gain of their pre-pregnancy body weight) from pre-pregnancy to post partum (33.3%). Thus, we suggested that women with pre-pregnancy normal weight should keep their weight stable from pre-pregnancy to post partum, and those with pre-pregnancy overweight should have at least a 5% weight loss from pre-pregnancy to post partum. We also suggested that those with pre-pregnancy obesity should have a reduction in at least a 7–10% of body weight from pre-pregnancy to post partum which can prevent the risk of post partum metabolic syndrome, however future studies with a large sample size will be needed to verify this. Several clinical trials have found that effective lifestyle intervention strategies can prevent or delay the progression to Type 2 diabetes among adults with impaired glucose tolerance [22–24].

This study found that approximately one quarter of women with a history of gestational diabetes mellitus in China had metabolic syndrome at 1–5 years post partum (mean time 2.3 years). Several previous studies have indicated that the prevalence of metabolic syndrome among Finnish women with a history of gestational diabetes mellitus at 1 year post partum was 18% [25], and the prevalence of metabolic syndrome among USA and Denmark women with a history of gestational diabetes mellitus at 10 years post partum was 30–40% [26,27]. As the prevalence of metabolic syndrome increases with a post-partum duration, an early post-partum lifestyle intervention of women with a history of gestational diabetes mellitus [13] is important for prevention of cardiometabolic implications, especially for prevention of high prevalence of elevated waist circumference, reduced HDL-C and elevated glucose.

An important strength is that, to our knowledge, this is the first large population-based study focusing on both pre-pregnancy BMI and weight change from pre-pregnancy to post partum with post-partum cardiometabolic risk among women with a history of gestational diabetes mellitus. Our study also has several limitations. First, the study was a retrospective cohort, which might produce recall bias. Second, the return rate was only 27%. Though there were no differences in age, 2-h glucose, fasting glucose and the prevalence of impaired glucose tolerance and diabetes at 26–30 gestational weeks' OGTT test between those returned and those not returned, whether there was a difference between the post-partum outcomes cannot be verified. Third, we could not separate gestational weight gain (weight gain during pregnancy) from post-partum weight gain from pre-pregnancy. These two types of weight gain may have different clinical implications, and be differently associated with the risk of subsequent diabetes. Thus, future studies, using more rigorous designs like prospective cohort studies, are needed to compare the different effects of gestational weight gain and post-partum weight change on subsequent cardiometabolic risk. Fourth, because this was an observational study, there might be selection bias. Case-control (metabolic syndrome and non-metabolic syndrome) matched analysis (1 : 3) was conducted and propensity score was used to reduce the selection bias (Table S1). Because the adjusted rates of metabolic syndrome from conditional logistic regression conducted among the matched population were similar to those from logistic regression among the original population, the selection bias could be accepted. Finally, even though our analyses adjusted for an extensive set of confounding factors, residual confounding resulting from measurement errors in the assessment of confounding factors or unmeasured factors cannot be excluded.

In conclusion, Chinese women with a history of gestational diabetes mellitus who lost weight from pre-pregnancy to post partum were less likely to have cardiometabolic implication, whereas those who gained weight from pre-pregnancy to post partum were more like, compared with those whose weight remained stable from pre-pregnancy to post partum. An early post-partum lifestyle intervention should be taken to reduce the likelihood of post-partum weight gain from pre-pregnancy and subsequent cardiometabolic implications.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding sources

European Foundation for the Study of Diabetes (EFSD)/Chinese Diabetes Society (CDS)/Lilly Programme for Collaborative Research between China and Europe, Tianjin Women's and Children's Health Center, Tianjin Public Health Bureau, and the National Institute Of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health under Award Number R01DK100790.

References

1. Metzger BE, Coustan DR. Summary and recommendations of the Fourth International Workshop-Conference on Gestational Diabetes Mellitus. The Organizing Committee. Diabetes Care. 1998; 21(Suppl 2):B161–167. [PubMed: 9704245]

2. Hunt KJ, Schuller KL. The increasing prevalence of diabetes in pregnancy. *Obstet Gynecol Clin North Am.* 2007; 34:173–199. vii. [PubMed: 17572266]
3. Chu SY, Abe K, Hall LR, Kim SY, Njoroge T, Qin C. Gestational diabetes mellitus: all Asians are not alike. *Prev Med.* 2009; 49:265–268. [PubMed: 19596364]
4. Ferrara A, Kahn HS, Quesenberry CP, Riley C, Hedderson MM. An increase in the incidence of gestational diabetes mellitus: northern California, 1991–2000. *Obstet Gynecol.* 2004; 103:526–533. [PubMed: 14990417]
5. Dabelea D, Snell-Bergeon JK, Hartsfield CL, Bischoff KJ, Hamman RF, McDuffie RS. Increasing prevalence of gestational diabetes mellitus (GDM) over time and by birth cohort: Kaiser Permanente of Colorado GDM Screening Program. *Diabetes Care.* 2005; 28:579–584. [PubMed: 15735191]
6. Wang Y, Chen L, Xiao K, Horswell R, Besse J, Johnson J, et al. Increasing incidence of gestational diabetes mellitus in Louisiana, 1997–2009. *J Womens Health (Larchmt).* 2012; 21:319–325. [PubMed: 22023415]
7. Zhang F, Dong L, Zhang CP, Li B, Wen J, Gao W, et al. Increasing prevalence of gestational diabetes mellitus in Chinese women from 1999 to 2008. *Diabet Med.* 2011; 28:652–657. [PubMed: 21569085]
8. 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]
9. Bo S, Monge L, Macchetta C, Menato G, Pinach S, Uberti B, et al. Prior gestational hyperglycemia: a long-term predictor of the metabolic syndrome. *J Endocrinol Invest.* 2004; 27:629–635. [PubMed: 15505985]
10. Fraser A, Tilling K, Macdonald-Wallis C, Hughes R, Sattar N, Nelson SM, et al. Associations of gestational weight gain with maternal body mass index, waist circumference, and blood pressure measured 16 y after pregnancy: the Avon Longitudinal Study of Parents and Children (ALSPAC). *Am J Clin Nutr.* 2011; 93:1285–1292. [PubMed: 21471282]
11. Willett WC, Manson JE, Stampfer MJ, Colditz GA, Rosner B, Speizer FE, et al. Weight, weight change, and coronary heart disease in women. Risk within the 'normal' weight range. *JAMA.* 1995; 273:461–465. [PubMed: 7654270]
12. Liu H, Zhang C, Zhang S, Wang L, Leng J, Liu D, et al. Prepregnancy body mass index and weight change on postpartum diabetes risk among gestational diabetes women. *Obesity (Silver Spring).* 2014; 22:1560–1567. [PubMed: 24616432]
13. Hu G, Tian H, Zhang F, Liu H, Zhang C, Zhang S, et al. 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]
14. Li W, Zhang S, Liu H, Wang L, Zhang C, Leng J, et al. 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]
15. Wang L, Liu H, Zhang S, Leng J, Liu G, Zhang C, et al. Obesity index and the risk of diabetes among Chinese women with prior gestational diabetes. *Diabet Med.* 2014; 31:1368–1377. [PubMed: 24961948]
16. WHO Consultation. Part 1: Diagnosis and Classification of Diabetes Mellitus. World Health Organisation; Geneva: 1999. Definition, Diagnosis and Classification of Diabetes Mellitus and its Complications.
17. Li YP, He YN, Zhai FY, Yang XG, Hu XQ, Zhao WH, et al. [Comparison of assessment of food intakes by using 3 dietary survey methods]. *Zhonghua Yu Fang Yi Xue Za Zhi.* 2006; 40:273–280. [PubMed: 17097008]
18. Ma G, Luan D, Li Y, Liu A, Hu X, Cui Z, et al. 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]
19. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem.* 1972; 18:499–502. [PubMed: 4337382]

20. Grundy SM, Cleeman JJ, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation*. 2005; 112:2735–2752. [PubMed: 16157765]
21. Kew S, Ye C, Hanley AJ, Connelly PW, Sermer M, Zinman B, et al. Cardiometabolic implications of postpartum weight changes in the first year after delivery. *Diabetes Care*. 2014; 37:1998–2006. [PubMed: 24667457]
22. Pan X, Li G, Hu Y, Wang J, Yang W, An Z, et al. 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]
23. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, et al. 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]
24. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, et al. Reduction in the incidence of Type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002; 346:393–403. [PubMed: 11832527]
25. Puhkala J, Kinnunen TI, Vasankari T, Kukkonen-Harjula K, Raitanen J, Luoto R. Prevalence of metabolic syndrome one year after delivery in Finnish women at increased risk for gestational diabetes mellitus during pregnancy. *J Pregnancy*. 2013; 2013:139049. [PubMed: 23577256]
26. Verma A, Boney CM, Tucker R, Vohr BR. Insulin resistance syndrome in women with prior history of gestational diabetes mellitus. *J Clin Endocrinol Metab*. 2002; 87:3227–3235. [PubMed: 12107230]
27. Lauenborg J, Mathiesen E, Hansen T, Glumer C, Jorgensen T, Borch-Johnsen K, et al. The prevalence of the metabolic syndrome in a danish population of women with previous gestational diabetes mellitus is three-fold higher than in the general population. *J Clin Endocrinol Metab*. 2005; 90:4004–4010. [PubMed: 15840755]

What's new?

- In the general population, pre-pregnancy weight and gestational weight gain are positively associated with a woman's long-term risk of metabolic syndrome, Type 2 diabetes and cardiovascular disease.
- This study added direct evidence that both pre-pregnancy and post-partum weight are associated with cardiometabolic disease among women with a history of gestational diabetes mellitus.

Table 1

General characteristics across different categories of weight change from pre-pregnancy to 1–5 years post-partum among women with gestational diabetes

	Weight change from pre-pregnancy to 1–5 years post-partum				P-value
	Loss of ≥ 3 kg (n = 132)	Loss of < 3 kg – gain of < 3 kg (n = 589)	Gain of $3\text{--}7$ kg (n = 293)	Gain of ≥ 7 kg (n = 249)	
Age, years	32.7 $\pm$ 3.7	32.5 $\pm$ 3.4	32.3 $\pm$ 3.6	31.9 $\pm$ 3.7	0.094
Postpartum time, months	26.6 $\pm$ 10	26.7 $\pm$ 10	28.1 $\pm$ 10	28.8 $\pm$ 11	0.025
Education (%)					0.001
< 13 years	17.4	19.9	22.9	30.9	
13–16 years	75.0	71.4	70.6	63.5	
> 16 years	7.6	8.7	6.5	5.6	
Family income category, 1000 yuan/month	7.74 $\pm$ 9.8	7.36 $\pm$ 6.9	7.13 $\pm$ 5.3	7.13 $\pm$ 7.5	0.83
Glucose at 26–30 gestational weeks gestational diabetes mellitus screening					
Fasting glucose, mmol/l	5.37 $\pm$ 0.9	5.29 $\pm$ 0.8	5.33 $\pm$ 0.7	5.4 $\pm$ 0.9	0.25
2-h glucose, mmol/l	9.39 $\pm$ 1.5	9.16 $\pm$ 1.3	9.08 $\pm$ 1.1	9.07 $\pm$ 1.3	0.084
Family history of diabetes (%)	37.1	35.9	33.9	37.3	0.85
Current smoking (%)	7.6	4.6	5.1	7.2	0.32
Passive smoking (%)	50.0	53.0	54.6	57.0	0.56
Current alcohol drinkers (%)	21.2	21.9	19.5	24.5	0.56
Leisure time physical activity (%)					0.52
0 min/day	77.3	80.0	79.2	76.3	
1–29 min/day	20.5	18.3	18.8	20.5	
30 min/day	2.3	1.7	2.1	3.2	
Sedentary time, h/day	3.13 $\pm$ 2.1	3.02 $\pm$ 2.0	3.43 $\pm$ 2.1	3.51 $\pm$ 2.4	0.004
Dietary intake [†]					
Energy intake (kcal/day)	1721 $\pm$ 447	1690 $\pm$ 429	1698 $\pm$ 444	1678 $\pm$ 462	0.83
Diet fibre (g/day)	11.1 $\pm$ 5.1	10.5 $\pm$ 3.9	10.4 $\pm$ 4.3	9.85 $\pm$ 3.8	0.035
Saturated fat (g/day)	9.66 $\pm$ 4.1	8.90 $\pm$ 4.0	8.75 $\pm$ 3.7	8.94 $\pm$ 4.4	0.17
Monounsaturated fat (g/day)	15.9 $\pm$ 5.7	14.9 $\pm$ 5.8	14.9 $\pm$ 5.2	15.0 $\pm$ 5.8	0.31
Polyunsaturated fat (g/day)	13.8 $\pm$ 5.5	13.6 $\pm$ 6.4	13.1 $\pm$ 5.3	13.0 $\pm$ 6.2	0.36

Data were means $\pm$ SD, or percentage. One-way ANOVA or χ^2 tests was used to assess the total differences. The Kruskal–Wallis equality of populations rank tests were used to test the difference in ordinal variables (education, leisure time physical activity) across the four weight change groups.

* Comparisons were performed on logarithmic scale.

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

Table 2

Mean adjusted levels for cardiometabolic risk factors across different categories of pre-pregnancy BMI and weight change from pre-pregnancy to 1–5 years post-partum

Weight change	No. subjects	Fasting glucose, mmol/l	2-h glucose, mmol/l	HOMA-IR	Waist circumference, cm	Total cholesterol, mmol/l	Triglyceride, mmol/l	HDL-C, mmol/l	LDL cholesterol, mmol/l	Systolic blood pressure, mmHg	Diastolic blood pressure, mmHg
All participants	1263	5.38 (0.03)	7.07 (0.07)	1.04 (0.01)	80.6 (0.3)	4.52 (0.02)	1.19 (0.02)	1.38 (0.01)	2.61 (0.02)	107 (0.3)	74 (0.3)
Loss of 3 kg	132	5.21 (0.08)	6.48 (0.21)	0.90 (0.04)	76.8 (0.7)	4.36 (0.07)	0.91 (0.08)	1.45 (0.02)	2.49 (0.07)	106 (1.0)	73 (0.8)
Loss of < 3 kg – gain of < 3 kg	589	5.35 (0.04)	6.84 (0.10)	0.92 (0.02)	77.2 (0.3)	4.43 (0.04)	1.12 (0.04)	1.40 (0.01)	2.52 (0.03)	106 (0.5)	73 (0.4)
Gain of 3–7 kg	293	5.36 (0.06)	7.14 (0.14)	1.07 (0.03)	81.8 (0.5)	4.59 (0.05)	1.25 (0.05)	1.35 (0.02)	2.67 (0.04)	108 (0.7)	75 (0.6)
Gain of 7 kg	249	5.56 (0.06)	7.88 (0.16)	1.35 (0.03)	89.1 (0.5)	4.76 (0.06)	1.43 (0.06)	1.31 (0.02)	2.79 (0.05)	112 (0.7)	77 (0.6)
<i>P</i> for overall difference		0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Stratified by pre-pregnancy BMI (kg/m ²)											
Pre-pregnancy BMI < 24	823	5.25 (0.03)	6.69 (0.08)	0.91 (0.01)	76.6 (0.2)	4.45 (0.03)	1.05 (0.02)	1.42 (0.01)	2.55 (0.03)	105 (0.4)	72 (0.3)
Loss of 3 kg	54	5.12 (0.13)	6.02 (0.32)	0.74 (0.06)	71.3 (0.8)	4.19 (0.12)	0.76 (0.12)	1.50 (0.04)	2.34 (0.10)	102 (1.5)	70 (1.2)
Loss of < 3 kg – gain of < 3 kg	428	5.22 (0.05)	6.55 (0.11)	0.82 (0.02)	74.1 (0.3)	4.37 (0.04)	0.99 (0.04)	1.44 (0.01)	2.48 (0.03)	104 (0.5)	71 (0.4)
Gain of 3–7 kg	194	5.32 (0.07)	6.82 (0.17)	0.96 (0.03)	78.2 (0.4)	4.51 (0.06)	1.14 (0.06)	1.39 (0.02)	2.60 (0.05)	107 (0.8)	73 (0.7)
Gain of 7 kg	147	5.39 (0.08)	7.36 (0.20)	1.16 (0.04)	84.3 (0.5)	4.70 (0.07)	1.24 (0.07)	1.36 (0.02)	2.77 (0.06)	108 (0.9)	74 (0.8)
<i>P</i> for overall difference		0.012	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.003	< 0.001	< 0.001	< 0.001
Pre-pregnancy BMI 24–27.9	335	5.49 (0.05)	7.48 (0.13)	1.22 (0.03)	86.3 (0.4)	4.65 (0.05)	1.40 (0.07)	1.30 (0.01)	2.71 (0.05)	111 (0.7)	77 (0.5)
Loss of 3 kg	49	5.15 (0.13)	6.32 (0.33)	0.88 (0.06)	77.8 (0.8)	4.49 (0.12)	0.96 (0.12)	1.45 (0.04)	2.61 (0.11)	107 (1.6)	73 (1.3)
Loss of < 3 kg – gain of < 3 kg	128	5.54 (0.08)	7.28 (0.21)	1.11 (0.04)	83.5 (0.5)	4.57 (0.08)	1.45 (0.08)	1.30 (0.03)	2.60 (0.07)	109 (1.0)	76 (0.8)
Gain of 3–7 kg	79	5.29 (0.10)	7.23 (0.26)	1.23 (0.05)	87.0 (0.7)	4.71 (0.10)	1.40 (0.10)	1.27 (0.03)	2.80 (0.08)	111 (1.2)	77 (1.0)
Gain of 7 kg	79	5.73 (0.11)	8.50 (0.26)	1.56 (0.05)	94.7 (0.7)	4.80 (0.10)	1.58 (0.10)	1.26 (0.03)	2.81 (0.09)	116 (1.3)	80 (1.0)
<i>P</i> for overall difference		< 0.001	< 0.001	< 0.001	< 0.001	0.28	0.088	< 0.001	0.25	< 0.001	< 0.001
Pre-pregnancy BMI ≥ 28	105	5.99 (0.17)	8.80 (0.34)	1.50 (0.07)	93.6 (0.9)	4.70 (0.09)	1.54 (0.08)	1.27 (0.03)	2.73 (0.07)	116 (1.3)	80 (1.1)
Loss of 3 kg	29	5.46 (0.17)	7.57 (0.44)	1.23 (0.08)	85.6 (1.1)	4.46 (0.16)	1.10 (0.16)	1.37 (0.05)	2.59 (0.14)	110 (2.1)	77 (1.7)
Loss of < 3 kg – gain of < 3 kg	33	6.31 (0.16)	8.92 (0.41)	1.45 (0.08)	92.5 (1.0)	4.64 (0.15)	1.39 (0.15)	1.25 (0.05)	2.76 (0.13)	116 (1.9)	79 (1.6)
Gain of 3–7 kg	20	6.00 (0.21)	9.77 (0.52)	1.50 (0.10)	95.5 (1.3)	4.80 (0.19)	1.68 (0.19)	1.28 (0.06)	2.76 (0.17)	112 (2.5)	80 (2.0)
Gain of 7 kg	23	6.07 (0.19)	9.17 (0.49)	1.91 (0.09)	102 (1.2)	5.01 (0.18)	2.12 (0.18)	1.21 (0.06)	2.84 (0.16)	124 (2.3)	85 (1.9)
<i>P</i> for overall difference		0.24	0.11	0.037	< 0.001	0.23	< 0.001	0.37	0.69	0.002	0.13

Table 3

Prevalence of metabolic syndrome and its individual components across different categories of pre-pregnancy BMI and weight change from pre-pregnancy to 1–5 years post-partum

Weight change	No. subjects	Individual components of metabolic syndrome (%)					Metabolic syndrome (%)
		Waist circumference 80 cm	Triglycerides 1.7mmol/l	HDL-C < 1.3 mmol/l	Blood pressure 130/85 mmHg	Fasting glucose 5.6 mmol/l or 2-h glucose > 7.8 mmol/l	
All participants	1263	49.9	16.2	43.2	11.4	38.3	23.8
Loss of < 3 kg	132	31.8	5.3	34.1	6.8	27.3	12.1
Loss of < 3 kg – gain of < 3 kg	589	33.6	12.4	40.4	8.5	33.3	16.2
Gain of 3–7 kg	293	57.3	19.5	44.7	10.9	39.6	26.0
Gain of > 7 kg	249	89.2	26.9	53.0	21.3	54.6	44.3
<i>P</i> for overall difference		< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001
Stratified by pre-pregnancy BMI							
Pre-pregnancy BMI <24 kg/m ²	823	31.4	11.7	36.5	6.7	32.0	14.0
Loss of < 3 kg	54	7.4	0.0	25.9	1.9	14.8	0.0
Loss of < 3 kg – gain of < 3 kg	428	14.3	8.6	32.2	5.4	28.0	7.9
Gain of 3–7 kg	194	37.6	16.0	39.7	6.7	34.5	16.5
Gain of > 7 kg	147	81.6	19.1	48.3	12.2	46.3	33.3
<i>P</i> for overall difference		< 0.001	< 0.001	0.001	0.015	< 0.001	< 0.001
Pre-pregnancy BMI 24–27.9 kg/m ²	335	81.8	22.1	55.2	17.9	46.0	38.2
Loss of < 3 kg	49	32.7	4.1	34.7	8.2	26.5	8.2
Loss of < 3 kg – gain of < 3 kg	128	81.3	23.4	61.7	14.1	45.3	37.5
Gain of 3–7 kg	79	94.9	22.8	54.4	17.7	41.8	41.8
Gain of > 7 kg	79	100	30.4	58.2	30.4	63.3	54.4
<i>P</i> for overall difference		< 0.001	0.006	0.013	0.005	0.001	< 0.001
Pre-pregnancy BMI ≥ 28 kg/m ²	105	93.3	32.4	58.1	27.6	63.8	54.3
Loss of < 3 kg	29	75.9	17.2	48.3	13.8	51.7	41.4
Loss of < 3 kg – gain of < 3 kg	33	100	18.2	63.6	27.3	54.6	45.5
Gain of 3–7 kg	20	100	40.0	55.0	25.0	80.0	60.0
Gain of > 7 kg	23	100	65.2	65.2	47.8	78.3	78.3
<i>P</i> for overall difference		< 0.001	< 0.001	0.55	0.057	0.060	0.035

Metabolic syndrome was defined as any three of five constitutes. Adjusted for age, post-partum time, sitting time, dietary fibre, intakes of monounsaturated fat, polyunsaturated fat and saturated fat (continuous variables for above all variables), education, family history of diabetes, smoking, passive smoking, alcohol drinking, leisure-time physical activity (categorical variables for above all variables).

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