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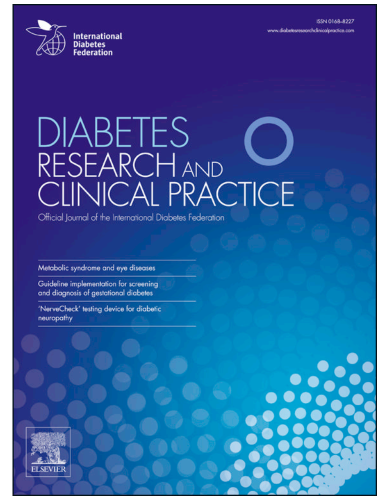

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Obesity, GDM and diabetes risk

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Effects of obesity and a history of gestational diabetes on the risk of postpartum diabetes and hyperglycemia in Chinese Women

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Abstract:

Objective: To evaluate the independent or combined effects of gestational diabetes (GDM) and pre-pregnancy and postpartum BMI on the odds of postpartum diabetes and hyperglycemia.

Methods: The study samples included 1,263 women with prior GDM and 705 women without GDM. Postpartum 1-7 years diabetes was diagnosed by the standard oral glucose tolerance test.

Results: The multivariable-adjusted odds ratios among women with prior GDM, compared with those without it, were 7.52 for diabetes and 2.27 for hyperglycemia. The multivariable-adjusted odds ratios at different postpartum BMI levels (<24, 24-27.9, and ≥28 kg/m^2) were 1.00, 2.80, and 8.08 for diabetes (P_{trend}<0.001), and 1.00, 2.10, and 4.42 for hyperglycemia (P_{trend}<0.001), respectively. Women with high body fat (≥31.9%) or abdominal obesity (≥85 cm) had a 2.7-6.9-fold higher odds ratio for diabetes or hyperglycemia. Women with both obesity and prior GDM had the highest risk of diabetes or hyperglycemia compared with non-obese women without GDM. Non-obese women with prior GDM had the same risk of diabetes and hyperglycemia as non-GDM women with obesity. When using Cox regression models, the results were very close to those using logistic regression models.

Conclusions: Maternal prior GDM and pre-pregnancy or postpartum obesity contribute equally to postpartum diabetes and hyperglycemia risk.

Keywords: BMI, gestational diabetes, diabetes risks

Introduction

Gestational diabetes mellitus (GDM) is defined as any degree of glucose intolerance with onset or first recognition during pregnancy according to the WHO 1999 definition [1]. In China, the prevalence of GDM increased rapidly from 2.4% to 8.2% during 1999-2012 [2, 3] similar to the level of women (~8%) in the U.S.[4]. Epidemiological evidence suggests that women with a history of GDM have a 7.4-fold higher risk of developing postpartum diabetes than those who have the normal glucose tolerance during pregnancy [5]. GDM women have a higher risk of major cardiovascular events, which first manifest within the first decade after the index pregnancy [6, 7]. Asian Americans with GDM are more likely to develop type 2 diabetes than non-Hispanic whites despite their generally lower body mass index (BMI)[8-10].

Evidence from epidemiological studies has also indicated that overweight and obesity are associated with the development of type 2 diabetes [11, 12]. A recent meta-analysis showed that the absolute risk for type 2 diabetes for obese adults was high with an estimated cumulative incidence of diabetes exceeding 3% over 10 years [13], and when BMI increases per unit, the risk of diabetes increases 18% [14]. Meanwhile, several studies have reported that body fat distribution, based on ethnicity, was a better predictor of diabetes risk than general obesity [15, 16]. Asians have smaller figures and lower overall body fat than white Europeans at the same BMI level [17]. However, abdominal adipose tissue is higher, especially visceral adipose tissue in Chinese and South Asians [18]. In this regard, waist circumference is more sensitive for Asians as a measure of abdominal fat and also a predictor of type 2 diabetes [19, 20].

It is universally acknowledged that women with higher BMI or with a history of GDM may have a further risk of adverse maternal and perinatal outcomes and a higher risk of developing diabetes after delivery [21-23]. However, previous studies usually investigated the effects of BMI, body fat, and waist circumference on the risk of type 2 diabetes among the general population or the independent effect of pre-pregnancy BMI or waist circumference on the risk of GDM among pregnant women [24]. Very few studies have evaluated combined effects of a history of GDM, pre-pregnancy BMI, postpartum BMI, body fat and waist circumference on subsequent type 2 diabetes and prediabetes after pregnancy. Thus, it still remains unclear whether a history of GDM and pre-pregnancy obesity or postpartum obesity, two important risk factors for postpartum type 2 diabetes, might play a same important role on postpartum diabetes. The aim of the present study was to assess the independent and combined effects of a history of GDM and different indicators of obesity (pre-pregnancy BMI, postpartum BMI, postpartum body fat and postpartum waist circumference) on the risk of postpartum diabetes and hyperglycemia among Chinese women with and without a history of GDM.

Methods

Tianjin GDM screening project

Tianjin is the fourth largest city in Northern China, which is a municipality directly adjacent to the sea. There are 4.3 million residents living in six central urban districts. Since 1999, the pregnant women living in the urban regions in Tianjin have participated in a two-step GDM screening program, which was launched by the Tianjin's Women and Children Health Center. The screening rate was reported to be more than 91% from 1999 to 2008 [3]. The center conducted a 1-h 50 g glucose screening test at 26-30 gestational weeks and the gestational women who had a 1-h glucose level over 7.8 mmol/L would experience another 2-h 75 g oral glucose tolerance test (OGTT). According to the 1999 WHO criteria, women were diagnosed with GDM when the 2-h 75g OGTT result confirmed either diabetes (fasting glucose ≥7 mmol/L or 2-h glucose ≥11.1 mmol/L) or impaired glucose tolerance (IGT) (2-h glucose ≥7.8 and <11.1 mmol/L).

Study samples

A total of 76,325 women participated in the Tianjin GDM screening project between 2005 and 2009, and 4,644 women were diagnosed as GDM (6.1%) with 71,681 women free of GDM. During 1-5 years after delivery, all 4,644 GDM women were invited to participate in a baseline survey for the Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMPP) between August 2009 and July 2011 [23, 25, 26]. Finally, 1,263 women with GDM completed the baseline survey, 83 women were newly diagnosed as type 2 diabetes after a 75g OGTT. Meanwhile, we recruited 705 non-GDM women who were matched to the 1,263 GDM women (Supplementary Figure 1). The program was approved by the Human Subjects Committee of the Tianjin Women's and Children's Health Center. Each participant signed the informed consent.

Questionnaires and examinations

All participants filled in a questionnaire about their social-demographics (age, education, marital status, family income, and occupation), history of GDM (values of fasting and 2-h glucose in the OGTT and treatment of GDM during the pregnancy), family history of diabetes, medical history (hypertension, diabetes, and hypercholesterolemia), pregnancy outcomes (pre-pregnancy weight, weight gain in pregnancy, and number of children), dietary habits (a self-administered food frequency questionnaire (FFQ) [27] to measure the frequency and quantity of intake of 33 major food groups and beverages during the past year) [27], alcohol intake, smoking habits, passive smoking, and physical activity (the frequency and duration of leisure time and sedentary activities) at the postpartum baseline survey. They also completed the 3-day 24-h food records using methods for dietary record collections taught by a dietician. The performance of 3-day 24-h food records, the FFQ [27] and the above questionnaire on assessing physical activity [28], were validated in the China National Nutrition and Health Survey in 2002.

Anthropometric variables such as body weight, height and waist circumference were measured for all women using the standardized protocol by specially trained research doctors. Waist circumference was obtained using a cloth tape. The waist circumference was defined as the midpoint between the peak of the iliac crest and the nadir of the costal margin in the mid-axillary line. Waist circumference was divided into two categories: normal (<85 cm) and central obesity (≥85 cm) by the Chinese standard [29]. Pre-pregnancy and postpartum baseline BMI were calculated by dividing pre-pregnancy or current weight in kilograms by the square of height in meters. According to the Chinese BMI classification standard [30], BMI was classified to three categories: normal weight (<24 kg/m^2), overweight (24-27.9 kg/m^2) and obesity (≥28 kg/m^2). Body fat was measured by a Body Composition Analyser (SC-240, Tanita, Tokyo, Japan). Body fat was divided into two categories by median. Blood samples were collected in all participants after an overnight fast of at least 12 hours. Participants were given a standard 75-g glucose solution, and plasma glucose was measured on an automatic analyzer (Toshiba TBA120FR, Japan) at time 0 and 2 h after administration during the OGTT.

Definition of postpartum type 2 diabetes and prediabetes

Based on the WHO's criteria, diabetes should be defined as fasting plasma glucose ≥7.0 mmol/l and/or 2–h plasma glucose ≥11.1 mmol/l and prediabetes was defined as either impaired fasting glucose (fasting plasma glucose ≥6.1 mmol/L and <7.0 mmol/L) or IGT (2-h plasma glucose ≥7.8 mmol/L and <11.1 mmol/L) [1]. We defined hyperglycemia as having both diabetes and prediabetes.

Statistical analyses

Means and SDs or proportions were used for the analysis among women with and without GDM. We used the standard *t* test and chi-square test to compare the two groups for the continuous variables and categorical variables, respectively (Table 1). Logistic regression was used to estimate independent and combined effects of a history of GDM, postpartum BMI, body fat, and waist circumference on the risks of diabetes and hyperglycemia (cross-sectional study design). Cox proportional hazards regression was used to estimate independent and combined effects of a history of GDM and pre-pregnancy BMI on the risks of diabetes and hyperglycemia (cohort study design). The number of study samples was the same between the cross-sectional study and cohort study, and there were no drop-outs in the cohort study. BMI was assessed as three categories: <24 kg/m^2 (reference group), 24-27.9 kg/m^2, and ≥28 kg/m^2; body fat was estimated as two categories: <31.9% (reference group), and ≥31.9%; and waist circumference was assessed as two categories: <85 cm (reference group), and ≥85 cm. BMI, body fat and waist circumference were also evaluated as continuous variables. All analyses were adjusted for age (Model 1) and further for education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, energy intake, fiber, fat, protein and carbohydrate consumption, sweetened beverage drinking, weight gain during pregnancy, postpartum time, GDM status, and BMI, other than the variables for stratification (Model 2). All analyses were performed with IBM SPSS Statistics 25.0 (IBM SPSS, Chicago, IL).

Results

Descriptive characteristics of the study population at baseline are presented in Table 1. During a mean follow-up of 4.22 years postpartum, 124 and 776 women were diagnosed as having type 2 diabetes and hyperglycemia. Compared with women without GDM, women with prior GDM were slightly older at the delivery but younger at the baseline survey, and had less weight gain during pregnancy. Women with prior GDM had higher pre-pregnancy BMI, postpartum baseline BMI, body fat, waist circumference, HbA1c, fasting and 2-h glucose, lower education levels and family income compared with women without GDM.

Multivariable-adjusted (age, education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, energy consumption, fiber, fat, protein and carbohydrate consumption, sweetened beverage drinking, weight gain during pregnancy, postpartum time, and BMI - Model 2) odds ratios among women with GDM, compared with those without it, were 7.52 (95% confidence interval [CI] 2.65-21.3) for diabetes and 2.27 (95% CI 1.50-3.44) for hyperglycemia, respectively (Table 2). The multivariate-adjusted odds ratios among normal weight (BMI <24), overweight (BMI 24-27.9), and obese (BMI ≥ 28 kg/m^2) women were 1.00, 2.80, and 8.08 for diabetes ($P < 0.001$ for trend), and 1.00, 2.10, and 4.42 for hyperglycemia ($P < 0.001$ for trend), respectively. The multivariable-adjusted odd ratios of women with body fat < 31.9% vs. ≥ 31.9% were 4.25 (95% CI 2.59-7.00) for diabetes, and 2.69 (95% CI 2.21-3.27) for hyperglycemia. Abdominal obesity, defined as waist circumference ≥85 cm, was associated with greater risks of diabetes (odd ratio 6.85; 95% CI 4.45-10.5) and hyperglycemia (odd ratio 3.20; 95% CI 2.54-4.02). When BMI, body fat, and waist circumference were considered as continuous variables, the multivariable-adjusted odds ratios of diabetes and hyperglycemia were 1.22 (95% CI 1.16-1.28) and 1.18 (95% CI 1.15-1.22) for each 1 kg/m^2 increase in postpartum BMI, 1.16 (95% CI 1.12-1.21) and 1.12 (95% CI 1.10-1.14) for each 1% increase in body fat, 1.10 (95% CI 1.08-1.12) and 1.07 (95% CI 1.06.1.08) for each 1 cm increase in waist circumference, respectively.

We also examined the effect of a history of GDM and pre-pregnancy BMI on the risk of diabetes and hyperglycemia using Cox regression models (Table 3). The observed results were very close to those using logistic regression models. The multivariate-adjusted hazards ratios (Model 2) among women with prior GDM, compared with women without GDM, were 7.73 (95% CI 3.84-15.5) for diabetes and 2.83 (95% CI 2.34-3.41) for hyperglycemia, respectively. The multivariate-adjusted hazards ratios at different pre-pregnancy BMI levels (<24, 24-27.9, and ≥28 kg/m^2) were 1.00, 2.78, and 4.90 for diabetes (P <0.001 for trend), and 1.00, 1.30, and 2.16 for hyperglycemia (P <0.001 for trend), respectively. When pre-pregnancy BMI was considered as a continuous variable, the multivariable-adjusted hazard ratios of diabetes and hyperglycemia were 1.18 (95% CI 1.13-1.23) and 1.08 (95% CI 1.07-1.11) for each 1 kg/m^2 increase in pre-pregnancy BMI.

The combined effects of a history of GDM and different levels of pre-pregnancy BMI, postpartum BMI, body fat and waist circumference on the risks of diabetes and hyperglycemia are presented in Table 4 and Figure 1. A positive association of a history of GDM with the risks of diabetes and hyperglycemia was persistent in pre-pregnancy or postpartum non-obese and general obese women, in women with different levels of body fat, and in non-obese and abdominal obese women. In comparison with non-obese women without GDM, non-GDM women with either general obesity, high body fat or abdominal obesity showed a 1.6-7.2-fold risk of diabetes or hyperglycemia, non-obese women with prior GDM showed a 1.7-8.7-fold risk of diabetes or hyperglycemia, and women with both obesity and prior GDM had a 5.4-51.4-fold risk of diabetes or hyperglycemia. The multivariable-adjusted relative risks among non-GDM women with pre-pregnancy general obesity (BMI ≥28 kg/m^2), postpartum general obesity (BMI ≥28 kg/m^2), high body fat (≥31.9%), and abdominal obesity (waist circumference ≥85 cm), compared with non-obese women with prior GDM, were 0.36 (95% CI 0.05-2.62), 0.73 (95% CI 0.16-3.28), 0.25 (95% CI 0.04-1.78), and 1.06 (0.19-5.81) for diabetes, and 0.59 (95% CI 0.33-1.06), 1.28 (95% CI 0.60-2.74), 0.75 (95% CI 0.39-1.46), and 1.54 (95% CI 0.74-3.18) for hyperglycemia, respectively. There were no significant interactions of BMI, body fat, waist circumference and a history of GDM with the risk of diabetes (all P for interaction >0.1).

Conclusions

In the present study, we found that women with a history of GDM had an increased risk of postpartum diabetes and hyperglycemia. Women with pre-pregnancy overweight, postpartum overweight, postpartum high body fat or postpartum abdominal obesity also had an increased risk of postpartum diabetes and hyperglycemia. The positive association of a history of GDM with the risk of postpartum diabetes and hyperglycemia was consistent in women with different levels of pre-pregnancy BMI, postpartum BMI, body fat and waist circumference. GDM and pre-pregnancy or postpartum obesity contributed equally to postpartum diabetes and hyperglycemia risk.

GDM now affects about 8% of pregnancies in the U.S. and China [2-4, 31]. About 30-50% of women with prior GDM will develop type 2 diabetes within 5 years after pregnancy [32, 33]. In the SWIFT (Study of Women, Infant Feeding and Type 2 Diabetes after GDM Pregnancy) study, 10.2% of Asian women with GDM in the U.S. developed incident type 2 diabetes within two years after delivery [34]. Our previous study indicated that women with prior GDM had significantly increased risks for postpartum diabetes and prediabetes, with the highest risk at the first 3-4 years after delivery [35]. Several recent studies have also indicated that Asian Americans are more likely to develop type 2 diabetes than non-Hispanic whites. It has been hypothesized that Asians have higher adiposity per unit BMI compared with other racial/ethnic groups, leading to an increased risk of type 2 diabetes at a lower BMI [36].

Emerging evidence from epidemiological studies has demonstrated that general obesity measured by BMI is a known risk factor for diabetes. A recent Chinese study has also shown that high pre-pregnancy and postpartum BMI increases the risk of postpartum diabetes and prediabetes among women with prior GDM [23]. However, some studies have indicated that BMI does not reflect the distribution of body fat exactly. Asian women are more sensitive to metabolic derangement at a lower BMI level [37]. Increased BMI is associated with an elevated fasting glucose level and diminished insulin sensitivity [38]. Compared to Europeans, Chinese and other Asians have more abdominal adipose tissue, thus waist circumference as a simple indicator to assess abdominal fat has been proven to be a predictor of type 2 diabetes, especially for Asians [19]. A recent Korean study has shown that waist circumference is a key risk factor for postpartum diabetes in women with prior GDM [39]. The present study found that higher pre-pregnancy BMI, postpartum BMI, postpartum body fat, and postpartum waist circumference were all associated with an increased risk of type 2 diabetes and hyperglycemia.

While a history of GDM, pre-pregnancy or postpartum obesity contributes to the development of postpartum type 2 diabetes among women, very few studies have compared the magnitude of a history of GDM and different indicators of obesity with the risk of postpartum type 2 diabetes. The long-term follow-up of the HAPO (Hyperglycemia and Adverse Pregnancy Outcomes) study demonstrated that women with prior GDM showed a 3.44-fold higher risk of postpartum type 2 diabetes compared with women without GDM [40]. However, the HAPO study did not assess the combined effects of a history of GDM and obesity on the risk of postpartum type 2 diabetes [40]. Meanwhile, some studies have found that women with a history of GDM are more likely to be overweight or obese before pregnancy and after delivery compared with women with normal glucose during pregnancy [25]. The present study was one of the first to find that non-obese women with prior GDM had the same risk of postpartum diabetes and hyperglycemia as non-GDM women with pre-pregnancy or postpartum general obesity, high body fat or abdominal obesity. Women with both a history of GDM and pre-pregnancy or postpartum obesity showed the highest (5.4-51.4-fold) odds of postpartum diabetes and hyperglycemia, while non-GDM women with obesity or non-obese women with a history of GDM showed higher (1.6-7.2-fold and 1.7-8.7-fold) odds of postpartum diabetes and hyperglycemia compared with non-obese women without GDM.

Several putative mechanisms of prior GDM and obesity with postpartum type 2 diabetes may be proposed. In GDM women, defective β-cell function and insulin hypersecretion cannot compensate insulin resistance during pregnancy and increasing insulin resistance and subsequent insulin hypersecretion may worsen β-cell function [41, 42]. Both a history of GDM and pre-pregnancy or postpartum overweight or obesity can lead to insulin resistance and reduce the insulin sensitivity, which may explain why they contribute equally to postpartum diabetes and prediabetes. As a history of GDM and pre-pregnancy or postpartum obesity are both great risk factors for postpartum diabetes and prediabetes, GDM prevention and pre-pregnancy or early postpartum lifestyle intervention including increasing physical activity and modifying diet among obese women could delay and reduce the development of postpartum diabetes.

An advantage of our study was that diagnoses of GDM at 26–30 gestational weeks were based on the whole population's GDM universal screening by using the 1999 WHO's criteria after a 2 h 75 g OGTT. The diagnosed postpartum diabetes and prediabetes were based on the WHO's criteria after a 2-h 75g OGTT. Furthermore, our study included a large sample size of 1,263 women with GDM and 705 women without GDM. Thus, the present study provided a comprehensive and accurate assessment on the risk factors of postpartum diabetes and prediabetes among women with and without a history of GDM. Several limitations existed in the present study. First, the study had a combined cross-sectional study and a retrospective cohort study design, and we had no data available on the follow-up of the GDM and therapeutic information of obese women during follow-up, which might produce recall bias. Second, these women were not screened immediately postpartum (1-3 months), thus the time to diabetes after GDM was not systematic but encompassed a wide variation in testing rather than natural progression with interval specific testing. Third, the return rate of the initial invitation was only 27% among women with a history of GDM. Although no differences existed in age, 2-h glucose, fasting glucose, the prevalence of IGT and diabetes at 26–30 gestational weeks and OGTT tests between those returned and those not returned, other differences between the postpartum outcomes cannot be identified. Fourth, the samples of women who developed postpartum diabetes or hyperglycemia from women without GDM were small, which might influence the results. Fifth, our study was conducted only in Chinese women, which limited the generalizability of this study.

In conclusion, a history of GDM, pre-pregnancy general overweight, and early postpartum general overweight, high body fat and abdominal obesity were all associated with an increased risk of postpartum type 2 diabetes. Non-obese women with a history of GDM had the same risks of postpartum type 2 diabetes and hyperglycemia as women with pre-pregnancy general obesity, early postpartum general obesity, high body fat or abdominal obesity. In women with both prior GDM and postpartum obesity there was a synergistic effect on the progression to diabetes.

Figure legend

Supplementary Figure 1: Flow chart

Figure 1. The cumulative incidence curve of type 2 diabetes (A) and hyperglycemia (B) according to combined effects of maternal GDM and obesity status. Adjusted for age, education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, dietary fiber, sweetened beverage drinking, energy intakes of fat, protein, and carbohydrate. GDM, gestational diabetes mellitus.

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Duality of interest

The authors have no competing interests in this article.

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Table 1. Characteristics of women with and without gestational diabetes

	Non-GDM	GDM	*P* Value
No. of participants	705	1,263	
Age at delivery, years	29.7 ± 2.83	30.1 ± 3.50	0.008
Age at baseline, years	35.4 ± 3.23	32.4 ± 3.52	<0.001
Duration after delivery, years	5.74 ± 1.19	3.36 ± 2.07	<0.001
Pre-pregnancy weight, kg	55.8 ± 8.21	59.4 ± 9.14	<0.001
Weight gain during pregnancy, kg	18.3 ± 6.67	16.8 ± 5.99	<0.001
Pre-pregnancy body mass index, km/m^2	21.4 ± 2.97	23.1 ± 3.32	<0.001
Postpartum body mass index, kg/m^2	22.9 ± 3.68	24.3 ± 3.96	<0.001
Waist circumference, cm	75.8 ± 8.26	80.6 ± 9.48	<0.001
Body fat, %	30.8 ± 5.84	33.1 ± 5.82	<0.001
Fasting glucose, mmol/l	5.23 ± 0.52	5.43 ± 0.99	<0.001
2 hour glucose, mmol/l	6.14 ± 1.41	7.24 ± 2.65	<0.001
HbA1c, mmol/mol	35 ±3	38 ± 8	<0.001
HbA1c, %	5.3 ± 0.2	5.6 ± 0.7	<0.001
Education, %			<0.001
<13 years	10.4	22.5	
13-16 years	75.5	70.1	
≥16 years	14.2	7.4	

Income, %			<0.001
<5000 yuan per month	5.4	27.5	
5000-8000 yuan per month	15.5	36.9	
≥8000 yuan per month	79.1	35.6	
Family history of diabetes, %	27.1	35.7	<0.001
Current smoking, %	4.0	2.5	0.355
Passive smoking, %	55.2	58.0	0.572
Current alcohol drinker, %	32.1	26.9	<0.001
Leisure time physical activity, %			<0.001
0 minute/day	61.7	71.7	
1-29 minutes/day	33.8	25.3	
≥30 minutes/day	4.5	3.0	
Sleeping time, hours/day	7.48 ± 0.95	7.70 ± 1.02	<0.01
Energy consumption, kcal/day*	1627 ± 381	1704 ± 432	0.01
Fiber, g/day	11.6 ± 4.42	12.3 ± 4.62	0.01
Fat, % of energy	31.1 ± 5.65	33.1 ± 6.12	<0.001
Carbohydrate, % of energy	52.3 ± 6.81	50.2 ± 7.04	<0.001
Protein, % of energy	16.6 ± 2.62	16.7 ± 2.68	0.006
Sweetened beverage drink, %	77.9	78.1	0.223

GDM, gestational diabetes.

* Dietary intakes were assessed by 3-day 24-h food records.

Table 2. Odds ratios of diabetes and hyperglycemia among women by different status of gestational diabetes, postpartum body mass index, body fat and waist circumference

	No. of participants	No. of cases	Odds ratios (95% confidence intervals)	
			Model 1	Model 2
Diabetes as outcomes				
Gestational diabetes				
No	705	10	1	1
Yes	1,263	114	6.98 (3.63-13.4)	7.52 (2.65-21.3)
Body mass index, kg/m^2				
<24	1,176	30	1	1
24-27.9	537	44	3.42 (2.12-5.50)	2.80 (1.71-4.61)
≥28	255	50	9.29 (5.77-15.0)	8.08 (4.80-13.6)
P for trend			<0.001	<0.001
Body fat, %				
<31.9	982	21	1	1
>=31.9	986	103	5.35 (3.32-8.64)	4.25 (2.59-7.00)
Waist circumference, cm				
<85	1,493	39	1	1
≥85	475	85	8.16 (5.50-12.1)	6.85 (4.45-10.5)

Hyperglycemia as outcomes				
Gestational diabetes				
No	705	205	1	1
Yes	1,263	571	2.00 (1.64-2.43)	2.27 (1.50-3.44)
Body mass index, kg/m^2				
<24	1,176	346	1	1
24-27.9	537	260	2.24 (1.81-2.77)	2.10 (1.69-2.62)
≥28	255	170	4.87 (3.65-6.51)	4.42 (3.26-5.99)
P for trend			<0.001	<0.001
Body fat, %				
<31.9	982	264	1	1
≥31.9	986	512	2.93 (2.43-3.54)	2.69 (2.21-3.27)
Waist circumference, cm				
<85	1,493	478	1	1
≥85	475	298	3.57 (2.88-4.43)	3.20 (2.54-4.02)

Model 1 adjusted for age; Model 2 adjusted for age, education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, energy consumption, fiber, fat, protein and carbohydrate consumption, sweetened beverage drinking, weight gain during pregnancy, postpartum time, gestational diabetes status, and body mass index, other than the variables for stratification.

Table 3. Hazards ratios of diabetes and hyperglycemia among women by different status of gestational diabetes and pre-pregnancy body mass index

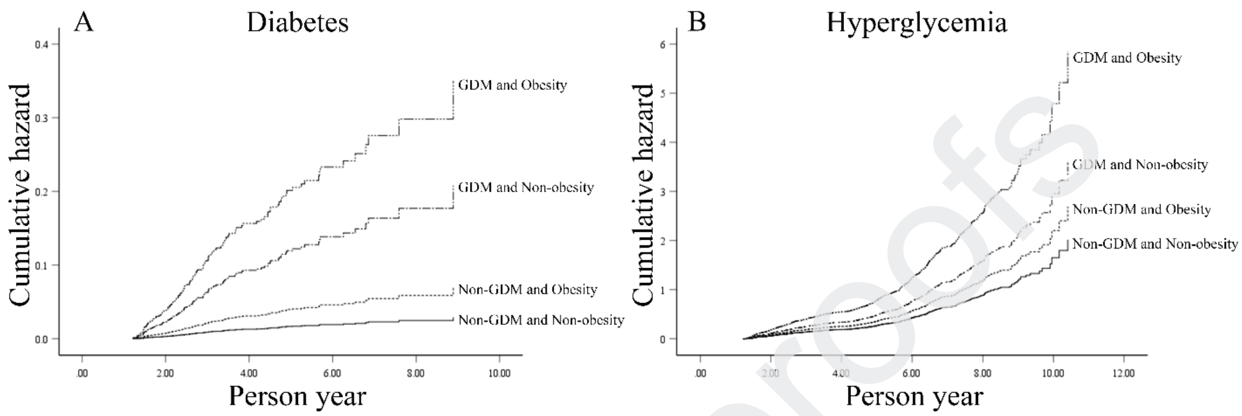
	No. of participants	No. of cases	Person-years	Hazards ratios (95% confidence intervals)	
				Model 1	Model 2
Diabetes as outcomes					
Gestational diabetes					
No	705	10	4,052	1	1
Yes	1,263	114	4,246	13.1 (6.82-25.1)	7.73 (3.84-15.5)
Body mass index, kg/m^2					
<24	1,422	46	6,206	1	1
24-27.9	416	50	1,634	4.30 (2.88-6.42)	2.78 (1.83-4.21)
≥28	130	28	457	8.72 (5.44-14.0)	4.90 (2.94-8.14)
P for trend				<0.001	<0.001
Hyperglycemia as outcomes					
Gestational diabetes					
No	705	205	4,052	1	1
Yes	1,263	571	4,246	3.16 (2.69-3.72)	2.83 (2.34-3.41)
Body mass index, kg/m^2					
<24	1,422	473	6,206	1	1
24-27.9	416	215	1,634	1.71 (1.45-2.01)	1.30 (1.10-1.54)
≥28	130	88	457	2.76 (2.20-3.47)	2.16 (1.70-2.74)
P for trend				<0.001	<0.001

Model 1 adjusted for age; Model 2 adjusted for age, education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, energy consumption, fiber, fat, protein and carbohydrate consumption, sweetened beverage drinking, weight gain during pregnancy, postpartum time, gestational diabetes status, and body mass index, other than the variables for stratification.

Table 4. Odds ratios or hazards ratios of diabetes and hyperglycemia according to joint status of gestational diabetes, pre-pregnancy body mass index, postpartum body mass index, body fat, and waist circumference

	Diabetes		Hyperglycemia	
	Non-GDM	GDM	Non-GDM	GDM
Pre-pregnancy body mass index, kg/m^2				
<28	1	8.68 (4.19-18.0)	1	2.88 (2.38-3.50)
≥28	2.56 (0.32-20.4)	28.2 (12.3-64.5)	1.56 (0.87-2.81)	6.04 (4.48-8.14)
Postpartum body mass index, kg/m^2				
<28	1	8.14 (2.55-25.9)	1	2.24 (1.47-3.40)
≥28	6.57 (1.75-24.6)	38.7 (11.8-127)	3.00 (1.71-5.27)	7.91 (4.75-13.1)
Body fat, %				
<31.9	1	4.35 (1.12-16.9)	1	1.70 (1.07-2.71)
≥31.9	2.18 (0.60-7.93)	20.6 (5.66-74.8)	1.93 (1.38-2.70)	5.42 (3.44-8.54)
Waist circumference, cm				
<85	1	7.55 (2.15-26.5)	1	2.13 (1.40-3.26)
≥85	7.17 (1.97-26.1)	51.4 (14.5-182)	3.21 (1.98-5.20)	6.80 (4.28-10.8)

All analyses adjusted for age, education, family income, family history of diabetes, current smoking, passive smoking, current alcohol drinking, leisure-time physical activity, sleeping time, energy consumption, fiber, fat, protein and carbohydrate consumption, sweetened beverage drinking, weight gain during pregnancy, and postpartum time. All *P* for interaction >0.1.


A
Diabetes
Cumulative hazard
0.0
0.1
0.2
0.3
0.4
GDM and Obesity
GDM and Non-obesity
Non-GDM and Obesity
Non-GDM and Non-obesity
.00
2.00
4.00
6.00
8.00
10.00
Person year
B
Hyperglycemia
Cumulative hazard
0
1
2
3
4
5
6
GDM and Obesity
GDM and Non-obesity
Non-GDM and Obesity
Non-GDM and Non-obesity
.00
2.00
4.00
6.00
8.00
10.00
12.00
Person year