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Racial differences of incident diabetes postpartum in women with a history of gestational diabetes

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ABSTRACT

Aims: The aim of the present study was to investigate the race-specific association between a history of gestational diabetes mellitus (GDM) and incidence of type 2 diabetes and evaluate how the risk changed over different years after delivery.
Methods: We performed two large cohorts - the Coronary Artery Risk Development in Young Adults (CARDIA) cohort and the Tianjin GDM Observational Study. The multivariate cox regression model was used to assess the risk of incident postpartum diabetes between women with and without prior GDM.
Results: During a mean follow-up of 13.8 years, 405 women developed type 2 diabetes. After adjustment for multiple confounding factors, Chinese women with GDM had a higher risk of incident diabetes within 5 years postpartum than African Americans with GDM compared with Chinese and African Americans without GDM (Hazard ratio 71.5 in Chinese vs. 9.29 in African Americans). When the risk of incident diabetes was analyzed within 10 years, white women with GDM seemed to have a higher hazard ratio than African American and Chinese women with GDM compared with non-GDM women of different races. In comparison to African American women without GDM, the highest risk of type 2 diabetes over 10 years postpartum appeared in Chinese women with GDM, followed by African American women with GDM, and the smallest risk was seen in white women with GDM.
Conclusions: Different genetic backgrounds and other risk factors among women of different races might contribute to the racial differences in the incidence of diabetes postpartum among women with GDM.

1. Introduction

Gestational diabetes mellitus (GDM) is a growing global epidemic in both the United States and China. The prevalence of GDM among pregnancies in the United States in 2010 was 9.2%,[1] while it was 9.3% in China in 2012.[2] Women with prior GDM will have much higher risks of postpartum diabetes, metabolic syndrome, and future cardiovascular diseases.[3] These findings have been confirmed in many individual studies among Chinese women,[4–6] Australian women,[7] European women[8–10] and North American women.[11–13] However, the underlying racial and geographical contribution of GDM to postpartum diabetes was less studied. Epidemiologic studies have revealed that there are racial differences in GDM prevalence.[14] Asian and Hispanic women have a higher risk of GDM when compared with women of other races in the US.[15] One study compared the risk of postpartum diabetes among Chinese, South Asian and Caucasian women with prior GDM, but it did not include black women.[16] This large population based study of over 1 million women with a follow up period up to 15 years in Canada found that although Chinese women had a higher prevalence of GDM, these GDM women instead had a lower risk of incident diabetes after delivery than white women.[16] Asian Americans represent 28% of all foreign-born people in the United States.[17] Mainland Chinese experiencing a lifestyle transition mimic Asians living in the United States.[18] The studies of native Chinese actually are a good reflection of Asian Americans. In addition, the prenatal care systems are almost similar between the United States and China. In the United States, socioeconomic disparities might prevent the equal adoption of prenatal care throughout the country. Various degrees of health care accessibility exist among different demographic characteristics, such as ethnicity/race and income-level, throughout the United States.[19] No study has directly compared the risk of postpartum diabetes among African American, white and Chinese women with and without GDM. Therefore, the aim of the present study was to investigate the race-specific association between a history of GDM and incidence of type 2

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diabetes and evaluate how the risk changed over different years after delivery.

2. Material and methods

Data of the study participants were composed of two different cohorts, the Tianjin GDM Observational Study and the Coronary Artery Risk Development Study in Young Adults (CARDIA) study.

2.1. The Tianjin GDM observational study

We screened 4644 women with GDM in Tianjin, China and finally 1263 of them finished the study survey including a questionnaire and an oral glucose tolerance test (OGTT) after August 2009, which has been described previously.[5] There were no differences 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. Among the 1263 women, 83 were newly diagnosed diabetes using an OGTT and 1180 GDM women received randomization into the intervention group ($n = 586$) and the "usual care" control group ($n = 594$) for another clinical trial. In parallel, we also enrolled in the Tianjin GDM observational study 705 non-GDM women and their children with birth dates and sex frequency-matched to the 594 children of GDM women in the "usual care" group and 83 children of GDM women who were newly diagnosed diabetes at the baseline survey. The study was approved by the Human Subjects Committee of the Tianjin Women's and Children's Health Center. All the participants provided written informed consent.

2.2. CARDIA

The multicenter CARDIA study examines the trends and correlates of cardiovascular disease risk in young black and white men and women.[20] The CARDIA study enrolled 5115 adults aged 18 to 30 years from 1985 to 1986 (2787 women; 52% black and 48% white) using community-based sampling from 4 geographic areas in the United States: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. The study design, recruitment, methodology, and characteristics have been described elsewhere.[20] Retentions were 81%, 79%, 74%, 72%, 72% and 71% of the surviving cohort at 7, 10, 15, 20, 25, and 30 years since baseline, respectively. There were totally 2787 women enrolled in the CARDIA study, and we excluded 838 women who had no birth ever, 12 women who had overt diabetes before pregnancy, and 36 women who reported GDM before baseline. Of the remaining 1901 women, we also excluded women with no follow-up data on any of the variables that we used in this analysis ($n = 115$). Finally, 1786 women with 161 who had GDM were included in the analysis. Women excluded were more likely to be black with higher body mass index and lower educated level when compared with those included. Institutional review boards at each participating study center (University of Alabama at Birmingham, Northwestern University, University of Minnesota, and Kaiser Permanente Northern California) approved the study. Written informed consent was obtained from participants for all study procedures.

2.3. Questionnaires and measurements

For the Tianjin GDM observational study, all study participants filled in a standard questionnaire, which had also been described previously.[5] They also completed the 3-day 24-hour food records using methods for dietary record collections taught by a dietician. Specially trained research doctors measured body weight and height using the standardized protocol. Body mass index (BMI) was calculated as the body weight in kilograms divided by the square of the height in meters. Waist circumference was measured at the horizontal level between the inferior costal margin and the iliac crest on the mid-axillary line with women in their standing position. Blood samples were collected in all participants after an overnight fast of at least 12 h. Participants without a self-reported history of diabetes were given a standard 75-g glucose OGTT test. Plasma glucose was measured on an automatic analyzer (Toshiba TBA-120FR, Japan).

For CARDIA, data included trained and certified staff-assessed medical and clinical attributes; socio-demographics and lifestyle behaviors at in-person examinations using standardized methodologies; calibrated equipment; and interviewer and self-administered questionnaires. The information on diet was assessed at years 0, 7, and 20 by using an interviewer-administered CARDIA Diet History questionnaire. Interviewers asked open-ended questions about dietary consumption in the past month within 100 food categories that referenced 1609 separate food items during years 0 and 7 and many more at year 20.[21] Detailed information on venipuncture, laboratory quality control, and biochemical assays has been reported previously.[22] Glucose was analyzed by American Bioscience Laboratories (Van Nuys, CA). Tests were run on a Sequential Multiple Analyzer Computer (SMAC) except for glucose, which was measured on a COBAS.

Leisure time activity with 1–29 min per day was defined as moderate intensity and activity with >30 min per day was defined as heavy intensity. We categorized the family income according to the tertiles into low, medium and high categories.

2.4. GDM definition

For the Tianjin GDM observational study, we used a 1-hour glucose screening test with 50 g glucose load at 26–30 gestational weeks. If the 1-hour glucose level was over 7.8 mmol/L, another 2-h oral glucose tolerance test (OGTT) with 75 g glucose load would be performed at the Tianjin Women's and Children's Health Center. GDM diagnosis was made as per WHO criteria: a 75-g glucose 2-h OGTT result confirming either diabetes (fasting glucose ≥7 mmol/l or 2-hour glucose ≥11.1 mmol/l) or impaired glucose tolerance (IGT) (2-hour glucose ≥7.8 and <11.1 mmol/l).[23]

While in the CARDIA cohort, GDM status was all confirmed with self-reports. However, GDM history was validated by medical records among 165 women. Self-report of GDM status had high sensitivity (100%) and specificity (92%) confirmed by oral glucose tolerance laboratory results based on the Carpenter and Coustan criteria.[24] We distinguished GDM from overt diabetes based on the CARDIA Study questionnaires, dates of self-report of diabetes diagnosis with medication treatment, and biochemical test results at study examinations.[12]

2.5. Definition of incident diabetes

For TGDMPP, annual oral glucose tolerance test was performed in each participant. We used American Diabetes Association (ADA)'s criteria for the diagnosis of diabetes. Diabetes was defined as fasting glucose ≥7.0 mmol/L, and/or 2-h glucose ≥11.1 mmol/L.[25] Those using anti-diabetic drugs in the examination were also included into the type 2 diabetes cases.

For CARDIA, we defined incident diabetes as self-report of diabetes with medication treatment or elevated fasting or 2-hour postload serum glucose from the 75 g oral glucose tolerance tests and/or glycated hemoglobin consistent (fasting glucose measured at examinations in years 0, 7, 10, 15, 20, 25, or 30; oral glucose tolerance tests in years 15, 20, 25, or 30; and glycated hemoglobin in years 20, 25, or 30) based on the American Diabetes Association diagnostic criteria for diabetes: fasting glucose ≥126 mg/dL; 2-hour glucose ≥200 mg/dL; and/or glycated hemoglobin ≥6.5% (48 mmol/mol).[25]

2.6. Statistical analysis

Standard *t*-test and chi-square test were used in the comparison of continuous variables and categorical variables between women of different races with and without GDM. Multivariate cox proportional hazards regression analysis was used to assess the risk of postpartum diabetes between women with and without GDM. All analyses were adjusted for age (Model 1), and then for pre-pregnancy BMI, gestational weight gain, lactation duration, education, family income, family history of diabetes, smoking status, current alcohol drinking, leisure-time physical activity, fiber, fat, protein and carbohydrate consumption (Model 2). Analysis was performed at different time points postpartum. We calculated the hazards ratios of incident diabetes separately within 5 years, 10 years and over 10 years postpartum. $P < 0.05$ was considered statistically significant. All statistical analyses were performed by IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, N.Y., USA).

3. Results

The baseline characteristics of women with and without GDM by different races are presented in Table 1. Chinese women were the oldest when they got pregnant and had the lowest pre-pregnancy body mass index compared with African American and white women. Chinese women also had the highest gestational weight gain, while white women had the longest lactation duration. African American women reported the least education and had the lowest family income among the participants. Chinese women were the least likely to be current smokers and do physical activity, and they also drank the least alcohol.

Hazards ratios of postpartum diabetes among women with and without GDM by different races at different time points are listed in Table 2. The multivariable-adjusted hazard ratios of diabetes within postpartum 5 years among women with GDM, compared with those without it, were 9.29 (95% confidence interval [CI] 2.23–38.7) in African Americans, and 71.5 (95% CI 9.76–525) in Chinese. There were no incident diabetes events in white women without GDM within 5 years, so no hazard ratio was reported. When the time point extended to 10 years, the multivariable-adjusted hazard ratios for postpartum diabetes among women with GDM, compared with those without it, were 9.98 (95% CI 4.45–22.4) in African Americans, 52.6 (95% CI 5.73–462) in whites, and 8.96 (95% CI 4.39–18.3) in Chinese, respectively. When the time point further extended to over 10 years, the hazard ratios of postpartum diabetes among women with GDM, compared with those without it, were 5.95 (95% CI 4.03–8.77) in African Americans and 4.84 (95% CI 2.69–8.69) in whites, but the hazard ratio did not change in Chinese because no more events occurred over 10 years. For African American and white women in the CARDIA cohort, the multivariable-adjusted hazard ratios of postpartum diabetes within 5 years, 10 years and over 10 years among women with GDM, compared with those without it, were 12.5 (95% CI 3.42–45.4), 11.9 (95% CI 5.96–23.8), and 5.23 (95% CI 3.82–7.17) respectively.

In order to compare the risks of postpartum diabetes between women with different GDM status and different races, African American women without GDM were used as the reference group (Table 3). The highest risk of postpartum diabetes within postpartum 5 years, 10 years or over 10 years appeared in Chinese women with prior GDM (hazard ratios 23.6–103), followed by African American women with prior GDM (hazard ratios 5.72–8.25), white women with prior GDM (hazard ratios 3.62–10.7), and Chinese women without GDM (hazard ratios 1.41–5.06), whereas decreased risks of postpartum diabetes were found among white women without GDM (hazard ratios 0.23–0.70).

4. Discussion

In this pooled analysis using data from two large cohorts, we found a positive association between a history of GDM and the risk of postpartum diabetes. Chinese women with a history of GDM showed the highest risk of postpartum diabetes regardless of the follow-up period when compared with white or African American women with a history of GDM. White women without GDM had the lowest and Chinese women without GDM had the highest risk of postpartum diabetes when compared with African American women without GDM.

Table 1
Baseline characteristics in women with different races and GDM status in two large cohorts.

	CARDIA cohort				Tianjin GDM cohort	
	African American		White		Chinese	
	Non-GDM	GDM	Non-GDM	GDM	Non-GDM	GDM
No. of subjects	919	75	706	86	705	1263
Pregnant age, years old	27.5 ± 4.71	27.0 ± 4.75	27.7 ± 4.60	27.9 ± 4.46	29.7 ± 2.83	30.1 ± 3.50
Pre-pregnancy body mass index, kg/m^2	26.0 ± 6.48	29.8 ± 8.22	23.5 ± 4.48	25.6 ± 5.66	22.9 ± 3.68	24.3 ± 3.96
Weight gain during pregnancy, kg	15.8 ± 9.96	17.6 ± 15.0	16.5 ± 6.53	16.4 ± 6.81	18.3 ± 6.67	16.8 ± 5.99
Lactation duration, months	4.63 ± 9.41	5.26 ± 7.84	11.0 ± 13.4	15.6 ± 18.9	9.89 ± 7.05	8.72 ± 6.21
Education, %						
<13 years	61.8	50.7	32.6	23.3	10.4	22.5
13–16 years	34.9	40.0	45.3	50.0	75.5	70.1
>16 years	3.3	9.3	22.1	26.7	14.2	7.4
Income class, %						
Low	33.5	29.3	8.8	11.6	5.4	27.5
Medium	47.0	53.3	48.4	37.2	15.5	36.9
High	13.4	13.4	22.1	32.6	79.1	35.6
Not reported	6.1	4.0	20.7	18.6	0	0
Family history of diabetes, %	46.0	64.0	28.0	44.2	27.1	35.7
Smoking status, %						
Never	58.1	56.0	53.7	55.8	96.0	97.5
Past	9.5	10.7	23.9	29.1	0	0
Current	32.4	33.3	22.4	15.1	4.0	2.5
Alcohol drinker, %	43.2	28.0	57.1	45.3	32.1	26.9
Dietary intake						
Fiber, g/1000 kcal	12.4 ± 7.29	11.3 ± 5.59	14.6 ± 6.31	14.3 ± 6.31	11.6 ± 4.42	12.3 ± 4.62
Protein intake from energy, %	18.7 ± 4.98	18.3 ± 4.62	18.9 ± 4.54	19.6 ± 4.48	16.6 ± 2.62	16.7 ± 2.68
Fat intake from energy, %	21.1 ± 3.74	21.0 ± 3.93	19.8 ± 3.93	21.0 ± 3.81	31.1 ± 5.64	33.1 ± 6.12
Carbohydrates intake from energy, %	60.2 ± 6.17	60.7 ± 6.17	61.3 ± 6.08	59.4 ± 6.02	52.2 ± 6.80	50.2 ± 7.04
Physical activity intensity, %						
No	2.8	4.1	0.4	4.8	64.7	75.1
Moderate	78.4	80.6	71.7	66.3	30.5	21.8
Heavy	18.7	15.3	27.8	28.9	4.8	3.1

Table 2
Hazard ratios of incident diabetes in women with different races and GDM status at 5, 10 and over 10 years postpartum.

	CARDIA cohort						Tianjin GDM cohort	
	African American		White		CARDIA total		Chinese	
	Non-GDM	GDM	Non-GDM	GDM	Non-GDM	GDM	Non-GDM	GDM
<5 years								
No. of participants	919	75	706	86	1625	161	705	1263
No. of cases	4	5	0	2	4	7	1	102
Person-years	4565	357	3507	420	8072	777	3482	4039
Age-adjusted hazard ratios	1.00	15.6 (4.19–58.2)	–	–	1.00	18.2 (5.34–62.3)	1.00	105 (14.7–756)
Multiple-adjusted hazard ratios[a]	1.00	9.29 (2.23–38.7)	–	–	1.00	12.5 (3.42–45.4)	1.00	71.5 (9.76–525)
<10 years								
No. of participants	919	75	706	86	1625	161	705	1263
No. of cases	14	14	1	7	15	21	10	125
Person-years	8945	663	6874	810	15,819	1473	4847	5221
Age-adjusted hazard ratios	1.00	13.7 (6.53–28.8)	1.00	59.4 (7.31–483)	1.00	15.4 (7.92–29.8)	1.00	12.9 (6.76–24.6)
Multiple-adjusted hazard ratios[a]	1.00	9.98 (4.45–22.4)	1.00	52.6 (5.73–462)	1.00	11.9 (5.96–23.8)	1.00	8.96 (4.39–18.3)
≥10 years								
No. of participants	919	75	706	86	1625	161	–	–
No. of cases	169	37	45	19	214	56	–	–
Person-years	22,052	1228	16,918	1667	38,970	2895	–	–
Age-adjusted hazard ratios	1.00	6.65 (4.59–9.65)	1.00	6.16 (3.53–10.8)	1.00	5.54 (4.08–7.53)	–	–
Multiple-adjusted hazard ratios[a]	1.00	5.95 (4.03–8.77)	1.00	4.84 (2.69–8.69)	1.00	5.23 (3.82–7.17)	–	–

[a] Adjustments included pregnant age, pre-pregnancy BMI, weight gain during pregnancy, lactation duration, education, family income, family history of diabetes, smoking status, current alcohol drinking, leisure-time physical activity, fiber, fat, protein and carbohydrate consumption.

The overall prevalence of diabetes in China in 2013 was 10.9%[26] that are getting closer to the U.S level.[27] Gestational diabetes, pre-pregnancy overweight or obesity, excessive gestational weight gain or postpartum weight retention were all considered as significant risk factors for women in developing diabetes postpartum, among which GDM should be one of the most significant risk factors.[2] One early review has found that women with a history of GDM had a 7-fold higher risk of postpartum diabetes than women without GDM.[28] In addition, it was commonly acknowledged that women with prior GDM showed the highest risk of postpartum diabetes at the first 3–4 years after delivery.[29] To our knowledge, the racial and ethnic disparities between the association of a history of GDM and postpartum diabetes were less studied. A recent meta-analysis and systemic review concluded that European women with GDM compared to those without GDM had the highest relative risk (RR) for diabetes (RR 11.5) while South American women had the lowest relative risk (RR 2.02).[30] However, another study concluded that South Asian women had the highest risk of diabetes postpartum.[16] Although Chinese women would have a higher risk of developing GDM compared with other races, their risk of postpartum diabetes is lower than that of Caucasian and South Asian women.[16] Another retrospective cohort study of women who enrolled in the Kaiser Permanente Southern California health plan showed that racial and ethnic disparities did exist in the risk of diabetes after GDM. Black women with GDM had the highest risk of developing diabetes, while Hispanic women ranked second in the risk of diabetes postpartum.[31] However, this study did not differentiate among the Asian group while people from different parts of Asia may have disparities in the risk of diabetes.[32] These inconsistent findings may be explained by different study designs, data source and the self-reported diagnosis of GDM and diabetes. Our pooled analysis indicated that Chinese women with a history of GDM had the highest risk of postpartum diabetes when compared with white and African American women with a history of GDM, while white women without GDM showed the lowest and Chinese women without GDM showed a higher risk of GDM compared with African American women without GDM. This study was the first one to directly compare the relative and absolute risks of postpartum diabetes among African American, white and Chinese women with and without GDM.

The potential mechanism of these racial and ethnic disparities is so far unknown. Lifestyle and related behaviors including diet, physical activities and so on may vary among women of different races.[33] With rapid economic development in the past three decades, the Chinese population has been experiencing a rapid lifestyle change. According to a recent report, although the consumption of fruits, eggs, meat, and poultry increased significantly during 2004–2011 in China, the overconsumption of cereal, legumes and nuts, and salt, as well as underconsumption of vegetables, and meat and poultry, were associated with a higher risk of increasing BMI.[34] A high intake of carbohydrates was significantly associated with metabolic risk factors.[35,36] In addition, the prevalence of physical inactivity and sedentary behavior was

Table 3
Hazard ratios of incident diabetes in women with different races and GDM status at 5, 10 and over 10 years postpartum with reference to the African American non-GDM women group.

	CARDIA cohort				Tianjin GDM cohort	
	African American		White		Chinese	
	Non-GDM	GDM	Non-GDM	GDM	Non-GDM	GDM
<5 years						
Age-adjusted	1.00	16.0 (4.30–59.7)	–	5.49 (1.01–30.0)	0.34 (0.04–3.03)	35.3 (12.9–97.1)
Multiple-adjusted[a]	1.00	7.56 (1.94–29.4)	–	10.7 (1.91–60.3)	1.41 (0.14–14.7)	103 (28.9–366)
<10 years						
Age-adjusted	1.00	13.7 (6.54–28.8)	0.09 (0.01–0.71)	5.63 (2.27–13.9)	1.64 (0.72–3.76)	21.1 (11.8–37.7)
Multiple-adjusted[a]	1.00	8.25 (3.83–17.8)	0.23 (0.03–1.78)	9.72 (3.82–24.7)	5.06 (1.81–14.2)	54.0 (24.0–122)
≥10 years						
Age-adjusted	1.00	6.65 (4.60–9.60)	0.35 (0.26–0.49)	2.25 (1.39–3.63)	1.21 (0.58–2.50)	15.4 (10.2–23.4)
Multiple-adjusted[a]	1.00	5.72 (3.93–8.32)	0.70 (0.49–0.99)	3.62 (2.20–5.96)	2.04 (0.90–4.65)	23.6 (13.9–40.2)

[a] Adjustments included pregnant age, pre-pregnancy BMI, weight gain during pregnancy, lactation duration, education, family income, family history of diabetes, smoking status, current alcohol drinking, leisure-time physical activity, fiber, fat, protein and carbohydrate consumption.

reported to be high among both urban[37] and rural[38] Chinese women. All these lifestyle changes with time in China could partly explain the high risk of diabetes postpartum. Meanwhile, East Asian women including Chinese are more likely to have lower BMI but more visceral fat accumulation, thus causing higher susceptibility to glucose intolerance when compared with women of other races.[39] The heterogeneity in genetic variants associated with GDM may also contribute.[40] Studies in terms of the racial and ethnic disparities in risks of diabetes among women with GDM may help strategy and guideline makers to pay more attention on the certain population with the highest risk. Relevant intensive lifestyle interventions should also be made to prevent and slow down the development of diabetes postpartum among women with GDM. Moreover, we also suggest that studies examining the effect of lifestyle interventions on GDM women by different races can help make individualizations for the best results. As we have discussed before, mainland Chinese are experiencing a lifestyle transition who mimic Asians living in the United States. Thus the studies of native Chinese actually are a good reflection of Asian Americans. Recently, we have reported the encouraging results from Year 1 data of an ongoing trial among women with prior GDM, which was designed and conducted by our group.[41] Interventions include both dietary interventions and physical activity interventions. We found that the 1-year lifestyle intervention led to significant weight losses after delivery in women who had GDM, and the effect was more pronounced in women who were overweight at baseline. Based on the fact that the prenatal care systems are almost similar between the US and China including clinical visits, information on history of diseases, routine vital and lab measurements, GDM screening and GDM treatments, we are trying to translate this successful mode from native Chinese to Chinese Americans in the near future.

Important strengths of this pooled analysis include the large sample size of both women with and without a history of GDM, and the detailed longitudinal assessments including various risk factors after delivery. One limitation of this study is that while women with GDM in the TGDMPP were diagnosed according to the WHO's criteria after a 2 h 75 g OGTT, the GDM cases in the CARDIA were all based on self-reports. However, the accuracy of the maternal recall in the CARDIA cohort has been validated elsewhere.[42] Another limitation of the study is the application of the findings from potentially incomparable cohorts to populations in two countries. However, individualized interventions among different populations living in different environments are somehow of referential values. For example, the China Da Qing study was first launched in 1997 to investigate if lifestyle intervention was effective on the onset of later diabetes among people with impaired glucose tolerance.[43] Subsequently, the similar Diabetes Prevention Program in the United States[44] and the Finnish Diabetes Prevention Study in Finland[45] confirmed the findings from the Da Qing study. Finally, there are variations in terms of disease risk or outcomes in Asian subgroups in the United States. Our study may speak to Chinese Americans but less likely to other Asian groups such as south Asian decedents who have different dietary habits and other risk factors to diabetes.

5. Conclusions

In conclusion, we indicated that a history of GDM was a strong predictor of incident type 2 diabetes later in life. Chinese women with a history of GDM showed the highest risk of incident type 2 diabetes compared with African American and white women with a history of GDM. White women without GDM had a lower and Chinese women without GDM had a higher risk of incident type 2 diabetes than African Americans without GDM. Although lifestyles vary among women of different races living in different countries, race-specific lifestyle interventions should be made among women with and without GDM. A successful intervention during pregnancy and postpartum in Chinese women could be definitely disseminated to women in the US.

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Authors' contributions

Y.S. and G.H. designed the study, acquired data, performed statistical analyses, and drafted the manuscript. L.H., H.L., L.W., J.L. and W.L. acquired data, reviewed and edited the manuscript. GH is the guarantor of this work and, as such, has full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

Declaration of competing interest

The authors have declared that no competing interests exist.

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