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Association between gestational diabetes and 6-year incident diabetes: results from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL)

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ABSTRACT

Objective Type 2 diabetes and gestational diabetes (GDM) disproportionately affect those of Hispanic/Latino heritage. This study examined the association between GDM and prevalent and incident diabetes in a community-based study of Hispanic/Latina women living in the USA.

Methods Participants were women aged 18–74 years in the Hispanic Community Health Study/Study of Latinos who had at least one pregnancy and had information on self-reported history of GDM at baseline (n=6389). Logistic regression was used to determine the association between GDM and prevalent (2008–2011) and incident (2014–2017) diabetes and interactions between GDM and risk factors for incident diabetes.

Results At baseline, 8.7% of participants reported a history of GDM and 18.6% had prevalent diabetes. Women with Mexican heritage had the highest prevalence of GDM history (11.3%) vs women of Cuban (5.0%), Central American (4.9%), and South American (3.8%) heritage (p<0.001 for each comparison to Mexican heritage). Women with self-reported GDM were four times more likely to have prevalent diabetes compared with women without GDM, after adjusting for sociodemographic characteristics and cardiometabolic risk factors (adjusted OR (aOR)=3.94, 95% CI 2.75 to 5.64). Overall incidence of diabetes was 14.3/100 women. Women with GDM at baseline increased their odds of incident diabetes by threefold compared with women without GDM (aOR=3.25, 95% CI 2.09 to 5.05). Women with Cuban or Puerto Rican heritage and GDM had significantly higher odds of incident diabetes compared with women with Mexican heritage (aOR=2.15, 95% CI 1.17 to 3.95; aOR=1.95, 95% CI 1.07 to 3.55, respectively).

Conclusion Self-reported GDM was significantly associated with a threefold higher risk of incident diabetes among Hispanic/Latino women in the USA even after adjusting for several significant predictors of diabetes.

WHAT IS ALREADY KNOWN

⇒ Women with a history of gestational diabetes (GDM) are more likely to develop type 2 diabetes in their lifetime but there are limited data on this burden among US Hispanic/Latino women.

WHAT THIS STUDY ADDS

⇒ Hispanic/Latino women with GDM at baseline increased their odds of incident diabetes by threefold compared with women without GDM.

⇒ Women with Cuban or Puerto Rican heritage and GDM had significantly higher odds of incident diabetes compared with women with Mexican heritage.

⇒ Hispanic women with less than a high school education and self-reported history of GDM were at a substantially elevated odds of incident diabetes compared with those without GDM.

HOW THIS STUDY MIGHT AFFECT RESEARCH

⇒ Given that women with Hispanic/Latino heritage are already at a higher risk of developing diabetes, future interventions should be tailored to women of childbearing age to prevent underlying risk factors for GDM, or focused on women who have recently been diagnosed with GDM.

Gestational diabetes (GDM), defined as glucose intolerance first identified during pregnancy, has increased substantially over the past several decades.[1–3] Previous research using the 2007–2014 National Health and Nutrition Examination Surveys (NHANES) indicated that the prevalence of self-reported GDM is 7.6% among a nationally representative sample of US parous women.[4] GDM is more common in women with risk factors for diabetes such as obesity, advanced maternal age, family history of diabetes, and non-white race.[5 6] Studies have reported significant differences in GDM risk by race/ethnicity, with Mexican American women having a

higher risk of GDM than non-Hispanic white and black women.[7 8] In addition, national data from the 2007–2014 NHANES showed that prevalence of a history of GDM was higher in Mexican American (9.9%) and all Hispanic women (9.3%) than non-Hispanic white and black women (7.0% and 6.9%, respectively).[4]

In addition to the potential pregnancy complications from GDM (eg, macrosomia, cesarean delivery),[9 10] women with a history of GDM are more likely to develop type 2 diabetes in their lifetime. Two systematic reviews found that the relative risk of developing type 2 diabetes was 7-fold to 10-fold higher for women with a history of GDM compared with women who had not developed GDM during their pregnancies.[11 12] A 20-year prospective study found that women with one or more births with GDM were more likely to develop diabetes compared with nulliparous women.[13] Cross-sectional national data from the 2007–2014 NHANES determined that the crude prevalence of subsequent diabetes after a diagnosis of GDM, both of which were determined at the time of interview, was 19.7% among parous women.[4] In these analyses from NHANES, the prevalence of subsequent diabetes was higher for Hispanic women (22.8%), most of whom were Mexican American, compared with non-Hispanic white women (18.8%), although this difference was not statistically significant. However, there are limited data on the risk of diabetes after a GDM diagnosis among US Hispanic/Latino women where their Hispanic/Latino heritages can be disaggregated.

The objective of this study was to determine the prevalence of self-reported GDM, predictors of incident diabetes, and explore whether a history of GDM was associated with future diabetes over 6 years in a community-based study of Hispanic/Latino women from diverse heritages living in the USA.

RESEARCH DESIGN AND METHODS

The HCHS/SOL is a probability sample and community-based cohort study of 16 415 self-identified Hispanic/Latino persons aged 18–74 years from randomly selected households in four US field centers (Chicago, Illinois; Miami, Florida; Bronx, New York; San Diego, California). Sample design and cohort selection have been described previously.[14] Participants were enrolled in 2008–2011 (baseline) and a second clinic visit was conducted in 2014–2017, on average 6 years after baseline examination. Annual follow-up interviews were conducted by telephone to collect basic health and healthcare information, including a diagnosis of diabetes.

Study participants

At baseline, 9835 participants of the cohort were women of which 6661 (68%) had at least 1 pregnancy. We additionally excluded 272 because of missing GDM history information resulting in an analytic sample of 6389 women for the cross-sectional analyses. Sociodemographic characteristics and medical history of participants were obtained at baseline through an interviewer-administered questionnaire in their language of preference (www.cscc.unc.edu/hchs). Participants were asked to report their current age, number of pregnancies, and which of the following best describes their Hispanic/Latino heritage: Central American, Cuban, Dominican, Mexican, Puerto Rican, South American, other, or more than one heritage. Participants self-reported the following sociodemographic and access to care characteristics: language preference, age of immigration among those not born in the US mainland, highest level of education, household income, employment status, occupation, access to care (health insurance, number of physician visits in past year), years living in the USA, and smoking status (current, former, never).

Gestational diabetes

Self-reported history of GDM, defined as any degree of glucose intolerance with onset or first recognition during pregnancy, was determined by answering 'yes' to (1) a physician diagnosis of diabetes only during pregnancy at the baseline visit or (2) asked again at visit 2 for diabetes first diagnosed during pregnancy before the baseline visit (80% of women participated at both baseline and visit 2).

Diabetes

Prevalent diabetes at baseline was defined by self-report of a physician diagnosis of diabetes to the question "Has a doctor ever said that you have diabetes?" and no report of GDM to the follow-up question of 'Was this during pregnancy only?', fasting plasma glucose (FPG) ≥126 mg/dL, 2-hour postoral glucose tolerance test (OGTT) ≥200 mg/dL, or A1c ≥6.5%. Incident diabetes was defined by self-report at any annual follow-up telephone interview or by self-report or laboratory measures (FPG, OGTT, A1c) at visit 2. The methods for the OGTT, FPG, and A1c were the same for the baseline and follow-up visits. For the OGTT, participants were instructed to drink a serving of glucola within 5 min; a 2-hour blood sample was obtained 2 hours after the participants initiated with glucola drink.[15] Venipunctures for the OGTT, FPG, and A1c were performed similarly with technicians applying a tourniquet, identifying a vein, cleansing the site, inserting the needle, and appropriating 10 tubes of blood.

Cardiometabolic risk factors

Cardiometabolic risk factors were measured at baseline. Height and weight were measured by trained examiners to determine body mass index (BMI (kg/m^2)). Waist circumference was measured and a circumference of >88 cm was considered high risk for cardiovascular disease.[16] Hypertension was defined as self-report of antihypertensive medication or a blood pressure reading of ≥140/90 mm Hg. Elevated low-density lipoprotein (LDL) cholesterol was defined as use of lipid-lowering medication or LDL cholesterol ≥100 mg/dL. Low high-density lipoprotein (HDL) was defined as HDL cholesterol <50 mg/dL and elevated triglycerides were defined as ≥150 mg/

dL. Statin use was self-reported and verified by scanning medication bottles. Albuminuria was defined as an albumin-to-creatinine ratio ≥30 mg/g.

Statistical analysis

Women's baseline demographic, behavioral, and health characteristics (per cent, SE) were estimated and stratified by self-reported GDM status. All baseline analyses included all women regardless of prevalent diabetes status. For cross-sectional analyses at baseline, we estimated the prevalence (per cent, SE) of a history of GDM overall and by heritage group and other characteristics of the HCHS/SOL study population. We used logistic regression to estimate the OR (95% CI) for the association between GDM and diabetes at baseline. Estimates were determined overall and stratified by participant characteristics (study center, current age, number of pregnancies, Hispanic/Latino heritage, sociodemographic characteristics, health insurance, number of physician visits, and cardiometabolic risk factors). For stratified analyses, no correction factors (eg, Bonferroni) were used. In addition, OR estimates from logistic regression models were (1) unadjusted, (2) adjusted for study center, age, and number of pregnancies, (3) additionally adjusted for Hispanic/Latino heritage, (4) additionally adjusted for sociodemographic characteristics and access to care, and (5) additionally adjusted for cardiometabolic risk factors.

For prospective analyses, among women without prevalent diabetes at baseline, the overall cumulative incidence of diabetes (per 100 persons) was determined by whether or not women reported history of GDM at baseline and additionally stratified by women's characteristics. To do this, we used predictive marginals from logistic regression, which allows for inference for internal comparisons of subgroups (GDM vs no GDM) within the target population from which the sample is drawn. Second, bivariate interactions between GDM and women's characteristics were assessed for incident diabetes. Third, we used logistic regression to estimate the OR for the association between history of GDM at baseline and incident diabetes at visit 2 (~6 years after baseline) overall and stratified by participant characteristics. In addition, OR estimates from logistic regression models were adjusted sequentially as was done for the prevalent models. Lastly, for incident diabetes analyses, manual backwards stepwise selection, starting with all variables included in the stratified analyses and any significant interactions, was used to define the most parsimonious model with variables having a statistical significance level of $p<0.10$ at each model selection step and $p<0.05$ in the final model.

All statistical analyses used sampling weights and accounted for clustering and stratification in the HCHS/SOL sampling design using SUDAAN (SUDAAN User's Manual, Release 11, 2012; Research Triangle Institute). The HCHS/SOL baseline sampling weights are a product of a base weight (reciprocal of the probability of selection) and three adjustments: (1) non-response adjustments made relative to the sampling frame, (2) trimming to handle extreme values, and (3) calibration of weights to the 2010 US Census according to age, sex, and Hispanic heritage. Visit 2 sampling weights accounted for visit 2 non-response.

RESULTS

Characteristics of study population

Women with a self-reported history of GDM were younger (60.7% vs 47.5% age 18–44 years, respectively), were more often of Mexican heritage (51.7% vs 38.8%) and had a greater number of pregnancies (74.8% with ≥3 pregnancies vs 63.0%) ($p<0.001$ for all) compared with women without a history of GDM (online supplemental table S1). Women with a history of GDM more often immigrated at younger ages compared with those without a history of GDM (76.8% vs 55.2% at age <30 years, $p<0.001$). Family history of diabetes, obesity, high-risk waist circumference, low HDL, elevated triglycerides, and albuminuria were all higher for women with versus without a history of GDM ($p<0.05$ for all). The prevalence of diabetes at baseline was 18.6%.

Prevalence of GDM

At baseline, the overall prevalence of a history of self-reported GDM was 8.7% (table 1). The prevalence of self-reported GDM was greater for those aged 18–44 years versus older ages. Women with Mexican heritage had the highest prevalence of GDM (11.3%) followed by women of Puerto Rican (10.1%) and Dominican (9.4%) heritage. Women with Cuban (5.0%), Central American (4.9%), and South American (3.8%) heritage had a significantly lower prevalence of GDM compared with those with Mexican heritage ($p<0.001$ for all). GDM was lower for women who immigrated at age 30–49 years or ≥50 years versus those who immigrated at age ≤18 years (5.1% and 2.4% vs 9.9%, respectively, $p<0.001$ for both). Prevalence of GDM was greater for those with ≥3 pregnancies vs 1–2, those who were obese versus normal weight, those with a high-risk waist circumference, those with low HDL, elevated triglycerides, and albuminuria ($p<0.03$ for all).

Association of GDM with prevalent diabetes

Women with a self-reported history of GDM were significantly more likely to have prevalent diabetes at their baseline visit compared with women without a history of GDM (OR=2.63, 95% CI 2.01 to 3.44) (online supplemental table S2). When the analysis was stratified by sociodemographic characteristics, access to care characteristics, and cardiometabolic risk factors, self-reported history of GDM was significantly associated with prevalent diabetes for most subgroups.

The overall association between self-reported history of GDM and prevalent diabetes remained after full adjustment for sociodemographic characteristics, access to care, and cardiometabolic risk factors (adjusted OR (aOR)=3.94, 95% CI 2.75 to 5.64) (figure 1).

Table 1 Prevalence of a self-reported history of GDM prior to baseline visit by women's characteristics, Hispanic Community Health Study/Study of Latinos 2008–2011

	N (denominator)	GDM prevalence (SE)	P value
Overall	6389	8.7 (0.54)	
Center			
Bronx	1559	10.1 (1.22)	Ref
Chicago	1652	11.2 (1.12)	0.48
Miami	1628	4.7 (0.57)	**<0.001**
San Diego	1829	10.1 (1.13)	0.98
Age at baseline visit, years			
18–44	2130	10.9 (0.89)	Ref
45–64	3952	7.3 (0.56)	**<0.001**
65–74	586	4.2 (1.22)	**<0.001**
Hispanic/Latino heritage group			
Central American	726	4.9 (0.96)	**<0.001**
Cuban	874	5.0 (0.81)	**<0.001**
Dominican	650	9.4 (1.54)	0.32
Mexican	2828	11.3 (1.02)	Ref
Puerto Rican	1018	10.1 (1.30)	0.47
South American	422	3.8 (1.13)	**<0.001**
Language preference			
Spanish	5690	8.3 (0.58)	**Ref**
English	978	10.7 (1.47)	0.14
Years living in the USA			
Born in the USA	805	11.0 (1.57)	Ref
1–5	918	4.3 (0.77)	**<0.001**
6–15	1723	8.3 (0.97)	0.16
>15	3174	10.2 (0.87)	0.67
Age of immigration, years			
≤18	1149	9.9 (1.43)	**Ref**
19–29	1949	12.0 (1.04)	0.24
30–49	2184	5.1 (0.60)	**0.002**
>50	558	2.4 (0.79)	**<0.001**
Highest education			
<High school	2661	9.1 (0.95)	Ref
High school graduate	1587	9.0 (0.98)	0.94
>High school	2404	8.2 (0.82)	0.49
Household income, US$			
<20 000	3205	9.1 (0.80)	Ref
20 000–74 999	2669	8.7 (0.77)	0.72
≥75 000	172	8.3 (2.87)	0.79
Not reported	622	7.3 (1.38)	0.25
Current employment			
Retired, not currently employed	666	4.9 (1.06)	Ref
Not retired and not currently employed	2895	9.7 (0.87)	<0.001
Employed part time, ≤35 hours/week	1224	9.5 (1.22)	0.005
Employed full time, >35 hours/week	1815	7.6 (0.86)	0.04
Type of occupation, longest held			

Continued

Table 1 Continued

	N (denominator)	GDM prevalence (SE)	P value
Non-skilled worker	1936	9.3 (1.07)	Ref
Service worker	1153	8.5 (1.04)	0.59
Skilled worker	1232	8.3 (0.95)	0.46
Professional/Technical/Other office worker	1098	7.9 (1.22)	0.37
Other	1187	9.0 (1.44)	0.85
Health insurance			
No	3134	7.7 (0.70)	Ref
Yes	3456	9.6 (0.78)	0.06
Number of physician visits, past 12 months			
0	1393	6.6 (0.92)	Ref
1	972	9.1 (1.34)	0.10
2–3 times	1735	9.3 (1.27)	0.09
>3 times	2463	9.4 (0.80)	0.02
Number of pregnancies			
1–2	2045	6.1 (0.63)	Ref
3–4	2860	10.4 (0.92)	**<0.001**
≥5	1756	9.9 (1.08)	**0.002**
Smoking status			
Never	969	9.4 (1.42)	Ref
Former	1094	6.5 (1.02)	0.12
Current	4599	9.1 (0.66)	0.82
Family history of diabetes			
No	3345	6.4 (0.72)	Ref
Yes	3284	11.5 (0.76)	**<0.001**
Body mass index, kg/m^2			
<25.0	1148	5.6 (0.91)	Ref
25.0–29.9	2386	6.7 (0.72)	0.34
≥30.0	3116	11.7 (0.95)	**<0.001**
Waist circumference			
Low risk (<88 cm)	1589	4.8 (0.66)	Ref
High risk (≥88 cm)	5063	10.2 (0.66)	**<0.001**
Hypertension			
No	4451	9.2 (0.68)	Ref
Yes	2216	7.6 (0.71)	0.11
Elevated LDL			
No	1538	8.1 (0.99)	Ref
Yes	5127	8.9 (0.64)	0.50
Low HDL			
No	3428	7.0 (0.66)	Ref
Yes	2935	10.6 (0.87)	**<0.001**
Elevated triglycerides			
No	4510	8.0 (0.61)	Ref
Yes	1853	11.0 (1.12)	**0.01**
Statin use, %			
No	5705	8.5 (0.58)	Ref
Yes	838	10.2 (1.48)	0.31

Continued

Table 1 Continued

	N (denominator)	GDM prevalence (SE)	P value
Albuminuria			
No	5581	8.2 (0.57)	Ref
Yes	703	12.4 (1.75)	**0.02**

GDM based on self-report at baseline or self-report at follow-up for pregnancies before baseline visit.
Bold text indicates statistical significance (p<0.05).
GDM, gestational diabetes; HDL, high-density lipoprotein; LDL, low-density lipoprotein; Ref, reference.

Cumulative incidence of diabetes

There were 859 cases of incident diabetes at visit 2 among the 4972 women without diabetes at baseline. The cumulative incidence of diabetes during the follow-up period was 31.0 per 100 persons for those with a history of GDM prior to baseline compared with 13.0 per 100 persons for those without a history of GDM (p<0.001) (online supplemental table S3).

Association of GDM with incident diabetes

Overall, women with a self-reported history of GDM at baseline were three times more likely to have incident diabetes between baseline and visit 2 compared with women without a history of GDM (OR=3.00, 95% CI 2.08 to 4.34) (table 2). When the analysis was stratified by sociodemographic characteristics, access to care, and cardiometabolic risk factors, the association between self-reported GDM and incident diabetes was significant for most subgroups. When assessing bivariate interactions between GDM and women's characteristics, the only significant interaction was for GDM and education (p=0.012, data not shown).

The overall association between self-reported GDM and incident diabetes remained significant after fully adjusting for sociodemographic characteristics, access to care, and cardiometabolic risk factors (OR=3.25, 95% CI 2.09 to 5.05) (figure 1).

Table 3 shows the significant predictors of incident diabetes determined using backwards model selection (ie, the most parsimonious model). The initial model included all participant characteristics and the significant interaction term for self-reported GDM and education. Among women without a self-reported history of GDM, there is minimal variation across education levels in the odds of incident diabetes. However, there is variation in the odds among those with self-reported GDM. Those with less than a high school education had a substantial and significant increased odds of incident diabetes compared with those with the same level of education but no self-reported GDM (OR=5.91, 95% CI 3.06 to 11.4). Several traditional risk factors for diabetes, including family history of diabetes, obesity, high waist circumference, hypertension, and elevated triglycerides, were significantly associated with incident diabetes while accounting for GDM status.

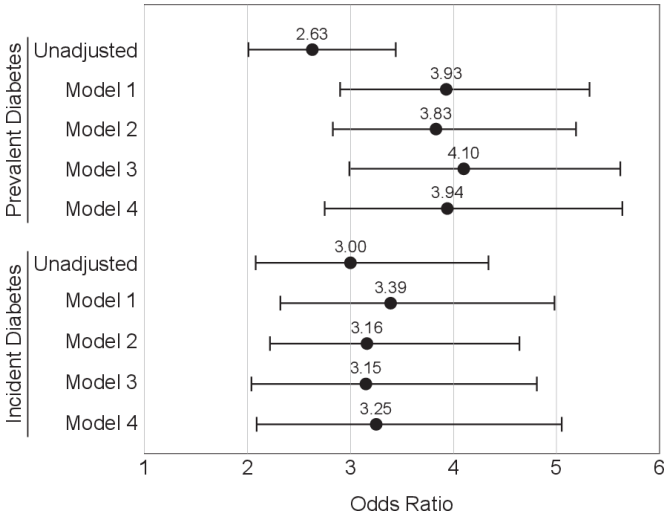

Figure 1 OR (95% CI) for prevalent and incident diabetes associated with self-reported history of gestational diabetes, Hispanic Community Health Study/Study of Latinos 2008–2011 and 2015–2017. Model 1: adjusted for center, age, and number of pregnancies. Model 2: additionally adjusted for Hispanic/Latino heritage. Model 3: additional adjusted for language preference, age of immigration, education, household income, employment, occupation, health insurance, number of physician visits in past 12 months, years living in the USA, smoking status. Model 4: additionally adjusted for family history of diabetes, body mass index, waist circumference, hypertension, elevated low-density lipoprotein, low high-density lipoprotein, elevated triglycerides, statin use, albuminuria.

DISCUSSION

Among a community-based cohort study of 6389 women with diverse Hispanic/Latino heritage from four centers in the USA, the prevalence of self-reported history of GDM was 8.7% at baseline (2008–2011). Over approximately 6 years, women with self-reported history of GDM increased their odds of developing incident diabetes by over threefold compared with those without a history of GDM, even after adjustment for sociodemographic characteristics, access to care, and cardiometabolic risk factors. For women with less than a high school education, having self-reported GDM significantly increased their odds of incident diabetes by nearly sixfold compared with those without GDM.

Women with Mexican, Puerto Rican, or Dominican heritage had the highest prevalence of self-reported GDM (9%–11%) while women with Central American,

Table 2 ORs (95% CI) of incident diabetes* associated with self-reported history of GDM prior to baseline visit by women's characteristics, Hispanic Community Health Study/Study of Latinos 2008–2017

	N (denominator)	Number of events	OR (95% CI)
Overall	4972	859	**3.00 (2.08 to 4.34)**
Center			
Bronx	1127	195	**3.93 (1.97 to 7.85)**
Chicago	1226	209	**2.03 (1.22 to 3.38)**
Miami	1213	146	**1.90 (0.76 to 4.73)**
San Diego	1406	309	**2.95 (1.51 to 5.78)**
Age, years			
18–44	1901	210	**4.34 (2.60 to 7.24)**
45–64	2776	586	**2.19 (1.41 to 3.38)**
65–74	295	63	**7.66 (0.96 to 61.11)**
Hispanic/Latino heritage			
Central American	552	74	2.09 (0.51 to 8.55)
Cuban	636	97	1.16 (0.40 to 3.39)
Dominican	488	76	**5.31 (1.96 to 14.36)**
Mexican	2153	415	**3.27 (1.94 to 5.49)**
Puerto Rican	690	143	2.12 (0.86 to 5.21)
South American	336	34	1.75 (0.31 to 9.82)
Language preference			
Spanish	4206	727	**2.73 (1.84 to 4.03)**
English	766	132	**4.14 (1.92 to 8.91)**
Years living in the USA			
Born in the USA	661	106	4.16 (1.82 to 9.51)
1–5	730	95	0.90 (0.30 to 2.77)
6–15	1370	213	2.40 (1.32 to 4.35)
>15	2178	442	**3.52 (2.12 to 5.83)**
Age of immigration, years			
≤18	864	139	**4.57 (2.07 to 10.10)**
19–29	1503	245	**3.43 (2.00 to 5.88)**
30–49	1598	299	**2.07 (1.06 to 4.05)**
>50	333	70	0.59 (0.09 to 3.87)
Education			
<High school	1840	374	**5.71 (3.35 to 9.73)**
High school graduate	1228	185	**2.32 (1.19 to 4.52)**
>High school	1895	299	**1.88 (1.02 to 3.48)**
Household income, US$			
<20 000	2322	419	**3.69 (2.19 to 6.19)**
20 000–74 999	2100	349	**2.36 (1.37 to 4.06)**
≥75 000	143	18	1.47 (0.26 to 8.28)
Not reported	407	73	3.75 (1.05 to 13.43)
Employment			
Retired, not currently employed	357	91	3.59 (0.69 to 18.65)
Not retired and not currently employed	2094	356	**3.07 (1.73 to 5.46)**
Employed part time, ≤35 hours/week	1005	172	**3.93 (1.93 to 8.01)**
Employed full time, >35 hours/week	1465	231	**3.13 (1.64 to 5.97)**
Type of occupation, longest held			
Non-skilled worker	1427	254	**3.79 (1.92 to 7.51)**
Service worker	836	140	**2.90 (1.34 to 6.27)**
Skilled worker	934	164	2.12 (1.00 to 4.52)

Continued

Table 2 Continued

	N (denominator)	Number of events	OR (95% CI)
Professional/Technical/Other office worker	856	137	2.15 (0.85 to 5.44)
Other	873	157	**5.62 (2.59 to 12.17)**
Health insurance			
No	2459	382	**2.70 (1.49 to 4.90)**
Yes	2456	466	**3.49 (2.18 to 5.59)**
Number of physician visits, past 12 months			
0	1162	151	1.75 (0.68 to 4.48)
1	816	124	**3.63 (1.57 to 8.41)**
2–3 times	1326	230	**4.68 (2.46 to 8.93)**
>3 times	1598	342	**2.83 (1.57 to 5.07)**
Number of pregnancies			
1–2	1602	216	**3.00 (1.41 to 6.37)**
3–4	2150	405	**3.44 (2.10 to 5.63)**
≥5	1213	238	**1.98 (1.02 to 3.87)**
Smoking status			
Never	743	123	**3.32 (1.36 to 8.09)**
Former	749	144	1.42 (0.59 to 3.39)
Current	3478	592	**3.27 (2.12 to 5.05)**
Family history of diabetes			
No	2717	371	**3.31 (1.79 to 6.14)**
Yes	2226	483	**2.51 (1.63 to 3.88)**
Body mass index, kg/m^2			
<25.0	967	67	**7.34 (2.60 to 20.71)**
25.0–29.9	1910	288	1.78 (0.95 to 3.34)
≥30.0	2087	504	**2.69 (1.65 to 4.38)**
Waist circumference			
Low risk (<88 cm)	1376	114	**3.24 (1.33 to 7.90)**
High risk (≥88 cm)	3588	743	**2.64 (1.76 to 3.96)**
Hypertension			
No	3588	524	**3.42 (2.21 to 5.32)**
Yes	1266	335	**3.16 (1.59 to 6.31)**
Elevated LDL			
No	1269	171	**3.49 (1.78 to 6.82)**
Yes	3701	688	**2.89 (1.90 to 4.40)**
Low HDL			
No	2662	408	**3.56 (2.11 to 6.01)**
Yes	2088	414	**2.92 (1.74 to 4.88)**
Elevated triglycerides			
No	3551	516	**3.38 (2.18 to 5.24)**
Yes	1199	306	**2.68 (1.40 to 5.11)**
Statin use, %			
No	4526	730	**3.23 (2.18 to 4.78)**
Yes	348	109	1.80 (0.45 to 7.12)
Albuminuria			
No	4263	718	**3.12 (2.06 to 4.73)**
Yes	390	91	**5.91 (2.28 to 15.33)**

GDM based on self-report at baseline or self-report at follow-up for pregnancies before baseline visit.
*Participants with prevalent diabetes at baseline were excluded.
GDM, gestational diabetes; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Table 3 ORs (95% CI) for predictors of incident diabetes at follow-up associated with self-reported history of GDM diagnosis prior to baseline, adjusting for all other significant predictors, Hispanic Community Health Study/Study of Latinos (n=4972)

	OR (95% CI)
GDM×education	
No GDM, <high school	1.00
No GDM, high school graduate	0.74 (0.51 to 1.07)
No GDM, >high school	0.85 (0.62 to 1.18)
GDM, <high school	**5.91 (3.06 to 11.4)**
GDM, high school graduate	1.60 (0.78 to 3.30)
GDM, >high school	1.47 (0.62 to 3.49)
Center	
Bronx	1.00
Chicago	1.06 (0.64 to 1.77)
Miami	**0.44 (0.26 to 0.75)**
San Diego	1.55 (0.85 to 2.84)
Age, years	
18–44	1.00
45–64	**1.52 (1.10 to 2.12)**
65–74	1.03 (0.56 to 1.90)
Hispanic/Latino heritage group	
Central American	1.10 (0.67 to 1.82)
Cuban	**2.15 (1.17 to 3.95)**
Dominican	1.15 (0.59 to 2.22)
Mexican	1.00
Puerto Rican	**1.95 (1.07 to 3.55)**
South American	1.02 (0.56 to 1.88)
Age of immigration, years	
≤18	1.00
19–29	1.37 (0.95 to 1.96)
30–49	**2.10 (1.42 to 3.11)**
>50	**2.36 (1.40 to 3.99)**
Family history of diabetes	
No	1.00
Yes	**1.47 (1.15 to 1.88)**
Body mass index, kg/m^2	
<25.0	**1.00**
25.0–29.9	1.57 (0.92 to 2.69)
≥30.0	**2.76 (1.55 to 4.93)**
Waist circumference	
Low risk (<88 cm)	1.00
High risk (≥88 cm)	**1.94 (1.30 to 2.91)**
Hypertension	
No	1.00
Yes	**1.53 (1.15 to 2.04)**
Elevated triglycerides	
No	1.00
Yes	**1.48 (1.13 to 1.95)**

Participants with prevalent diabetes at baseline were excluded.
GDM, gestational diabetes.

Cuban, or South American heritage had a lower prevalence (4%–5%). These estimates align with results from a 2007–2014 NHANES study, which showed that the prevalence of a history of GDM was 10.5% among all Hispanic and 11.5% among Mexican American women, the largest Hispanic/Latino heritage group in NHANES.[4] Our findings of disparity in GDM prevalence by heritage group are generally consistent with that found previously for diabetes in HCHS/SOL where prevalence was highest among those women with Central American, Dominican, Mexican, or Puerto Rican heritage (18%–20%).[17] A previous study from Florida's live birth certificate data showed that, among Hispanic/Latinos, prevalence of GDM was highest among those with Mexican or Puerto Rican heritage compared with those with Central/South American or Cuban heritage.[18] In 2019, a study among US women aged 15–44 years found that, among Hispanic/Latina participants, the age-standardized rate of GDM was highest among those with Puerto Rican heritage[19]; women with Puerto Rican heritage in our study also had a high prevalence of GDM. GDM often mirrors the underlying prevalence of diabetes in a population,[2] thus, it is not surprising to see such differences in GDM prevalence by heritage. However, we found no interaction of Hispanic/Latino heritage and self-reported GDM related to the incidence of diabetes.

While previous studies in the USA and Europe have found that foreign-born women have a higher prevalence of GDM,[20–22] we found that the prevalence of self-reported GDM was similar for women born in the USA and women who immigrated and have lived in the USA for >15 years in our analysis of HCHS/SOL participants. Data from a cross-sectional US national survey found that foreign-born women with longer duration of US residence (≥10 years) had a greater odds of GDM history than US born women, suggesting that foreign-born women may acculturate and develop unhealthy behaviors that increase the risk of GDM.[23] In our study of HCHS/SOL participants, women who immigrated at age ≥30 years had a lower prevalence of GDM compared with those who immigrated as children (≤18 years); this may reflect underdiagnosis of GDM in a foreign country or underdiagnosis in earlier time periods before the importance of GDM on fetal and maternal health were established; it may also reflect acculturation in women who immigrated at a younger age.[24] We also found that the prevalence of self-reported GDM was higher for women with health insurance, which may reflect proper prenatal care and awareness, resulting in a lower likelihood that GDM goes undiagnosed. In supplemental analysis, we found that health insurance was slightly higher for women who immigrated as children (aged ≤18 years). There was no interaction between place of birth or age of immigration and self-reported GDM for incident diabetes, suggesting a minimal effect of these variables on GDM and diabetes risk.

We found that women who were older at the age of the baseline interview had a lower prevalence of GDM. Younger women may remember a GDM diagnosis more

often if it occurred more recently compared with women who were diagnosed with diabetes decades ago. Indeed, a previous validation study found that women could accurately recall a history of GDM 4 years post partum on average.[25] In addition, awareness of GDM, knowing the risk factors, and screening has changed over time.[26]

An important finding of our analyses was that self-reported GDM was highly associated with both prevalent and incident diabetes, even after adjusting for other risk factors for diabetes. As expected, prevalence of GDM was higher for women with a family history of diabetes, obesity, high-risk waist circumference, and abnormal lipid profiles, which are strong risk factors for both GDM and diabetes.[2 27] However, we found that regardless of sociodemographic characteristics, access to care and cardiometabolic risk factors, self-reported history of GDM was associated with four times higher odds of prevalent diabetes at baseline (figure 1). Given that self-reported GDM may be under-reported, the real association between GDM and diabetes may be even stronger if misclassification is random (but weaker if misclassification is non-differential). Furthermore, women with self-reported history of GDM were three times more likely to develop diabetes at follow-up and this association remained after full adjustment. A previous systematic review found that the unadjusted risk of developing type 2 diabetes was sevenfold higher for those with GDM compared with those who had a pregnancy without GDM[11]; subpopulation analysis indicated that the risk remained when stratified by age, race (white, non-white, mixed), and BMI. In a clinical study of Latino women with GDM but no diabetes at their initial postpartum examination, the cumulative incidence rate of diabetes 5 years after delivery was 47%[28]; in the current study among HCHS/SOL women, cumulative incidence rate was about 30% over 6 years. Given the high risk of developing diabetes after a diagnosis of GDM, understanding predictors of future diabetes is important for tailored interventions. In our study, we found that Cuban or Puerto Rican heritage (vs Mexican), older age at immigration, family history of diabetes, obesity, high-risk waist circumference, hypertension, and elevated triglycerides at baseline were independently associated with 6-year incident diabetes along with the significant effect of GDM. We did not find an interaction between self-reported GDM and these independent predictors of GDM, which suggests that the effect of the predictors was not dependent on GDM status. Women with Hispanic/Latino heritage who have had a diagnosis of GDM and/or have several traditional risk factors are especially vulnerable to develop diabetes.

Given the strong association between GDM and the development of diabetes, screening and prevention measures for diabetes following a GDM diagnosis are important. However, in a 2005–2010 NHANES study among adults without diabetes, the prevalence of having a diabetes screening test in the past 3 years was significantly lower for adults with Hispanic ethnicity compared with non-Hispanic whites.[29] In a 2007–2016 NHANES study, Hispanic/Latina women with GDM were more likely to have diabetes compared with non-Hispanic white women, but were not more likely to be screened for diabetes.[30] Evidence from a retrospective study that analyzed data from 11 825 women who gave birth in Kaiser Permanente Southern California hospitals found that half of Hispanic/Latina women were tested for diabetes 1 week to 6 months post partum, which was significantly greater than non-Hispanic white women (48%) after adjustment for a variety of factors.[31] Similarly, a secondary analysis in 2009–2010 from the Pregnancy Risk Assessment Monitoring Systems found that 43% of Hispanic/Latina women with GDM reported being tested for diabetes post partum compared with 51% of non-Hispanic white women and 55% of non-Hispanic black women.[32] Diabetes prevention efforts after a GDM diagnosis may need to be intense and long term. A previous clinical trial showed that women with mild GDM (elevated glucose levels that did not exceed established GDM thresholds) who received nutritional counseling and diet therapy (with insulin if needed), in addition to routine prenatal care, had similar maternal outcomes (diabetes, metabolic syndrome, obesity) to those without intervention 7 years after their GDM pregnancy.[33] However, a Diabetes Prevention Program study among women with impaired fasting glucose found that both intensive lifestyle intervention and metformin were highly effective in reducing incident diabetes in those with a history of GDM.[34] Thus, future work on diabetes prevention and screening rates post partum are needed, with special attention to racial/ethnic disparities.

A limitation of this study was that history of GDM status was self-reported, thus subject to recall bias resulting in misclassification. Previous work verifying self-reported GDM is varied with one study finding good agreement between self-reported GDM and birth certificates,[35] although the sensitivity for identifying GDM by birth certificate is marginally lower compared with hospital discharge data.[36] While self-reported history of GDM differed by age at baseline (potential recall bias), we could not stratify further by country of origin or years living in the USA. We did not have information on the country where GDM was diagnosed and, as such, there may be heterogeneity in the diagnostic criteria used to diagnose GDM in the different heritage groups of the HCHS/SOL study[37]; similarly, age of GDM diagnosis was not collected, thus changes in diagnostic criteria could not be controlled. Additionally, the date of a GDM diagnosis relative to the baseline interview was unknown and, thus, we do not know the time elapsed between a GDM diagnosis and an incident diagnosis of diabetes; it is also unknown whether a woman had more than one diagnosis of GDM or if any treatments were used during pregnancy. We also assume that women who do not report diabetes were screened for GDM during pregnancy and did not have it and not that the GDM went unrecognized and thus undiagnosed. In addition to the criterion of self-reported diabetes, only one laboratory test was used to

determine diabetes status; in clinical settings, the American Diabetes Association recommends using two tests from the same sample or two separate tests to diagnose diabetes.[38] Finally, women with a history of GDM were slightly less likely to be followed up at visit 2 compared with women without a history of GDM. However, adjustment for social and metabolic factors that may account for this difference in follow-up should reduce any bias.

The strengths of the study were that laboratory measures in the HCHS/SOL were available to determine diabetes status, lipid levels, blood pressure, and kidney function. In addition, the HCHS/SOL constitutes a large and diverse sample that includes women from multiple Hispanic/Latina heritage groups for which both their ancestry and timing of immigration to the USA are known for women not born in the USA.

In this large community-based study of women with Hispanic/Latino heritage from four centers in the USA, self-reported history of GDM was significantly associated with incident diabetes even after adjustment for sociodemographic characteristics, access to care, and cardiometabolic risk factors. In addition, Hispanic women with less than a high school education and self-reported history of GDM were at a substantially elevated odds of incident diabetes compared with those without GDM. Given that women with Hispanic/Latino heritage are already at a higher risk of developing diabetes, future interventions should be tailored to women of childbearing age to prevent underlying risk factors for GDM, or focused on women who have recently been diagnosed with GDM.

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