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 (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. Logistic regression indicated that the prevalence of self-reported GDM was 7.6% among a nationally representative sample of US parous women. GDM is 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.

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

Gestational diabetes (GDM), defined as glucose intolerance first identified during pregnancy, has increased substantially over the past several decades. 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. 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. 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.\textsuperscript{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).\textsuperscript{3}

In addition to the potential pregnancy complications from GDM (eg, macrosomia, cesarean delivery),\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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 6601 (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.cscce. 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) $\geq 126$ mg/dL, 2-hour postoral glucose tolerance test (OGTT) $\geq 200$ mg/dL, or A1c $\geq 6.5\%$. 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.\textsuperscript{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 $\geq 88$ cm was considered high risk for cardiovascular disease.\textsuperscript{16} Hypertension was defined as self-report of antihypertensive medication or a blood pressure reading of $\geq 140/90$ mm Hg. Elevated low-density lipoprotein (LDL) cholesterol was defined as use of lipid-lowering medication or LDL cholesterol $\geq 100$ mg/dL. Low-high-density lipoprotein (HDL) was defined as HDL cholesterol $<50$ mg/dL and elevated triglycerides were defined as $\geq 150$ mg/dL.
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).

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

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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/m²               |                 |                     |         |
| <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    |
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 1 shows the significant predictors of incident diabetes determined using backwards model selection (i.e., 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. 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.

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
Epidemiology/Health services research

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/m²         |                 |                  |                 |
| <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 4.86)  |
| 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.
Younger women may remember a GDM diagnosis more because of this practice, and the baseline interview had a lower prevalence of GDM. The results here are consistent with other studies showing that young women who immigrated to the USA at a younger age had a greater odds of GDM history than US born women who immigrated at age ≥10 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 undiagnosis 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. 

While previous studies in the USA and Europe have found that foreign-born women have a higher prevalence of GDM, 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 of GDM, 20–22 we found that the prevalence of self-reported GDM was highest among those with Puerto Rican heritage; 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, 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.

We found that women who were older at the age of immigration and maternal health were established; it may also reflect acculturation in women who immigrated at a younger age. 

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

### Table 3

| Predictor | 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 2.64) |
| 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 |          |
| 18–44 | 1.00 |
| 45–64 | 1.52 (1.10 to 2.12) |
| 65–74 | 1.03 (0.56 to 1.90) |
| Family history of diabetes |          |
| No | 1.00 |
| Yes | 1.47 (1.15 to 1.88) |
| Body mass index, kg/m² |          |
| <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.
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.\textsuperscript{25} In addition, awareness of GDM, knowing the risk factors, and screening has changed over time.\textsuperscript{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.\textsuperscript{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\textsuperscript{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%\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{31} Similarly, a secondary analysis in 2009–2010 from the Pregnancy Risk Assessment Monitoring System 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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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,\textsuperscript{35} although the sensitivity for identifying GDM by birth certificate is marginally lower compared with hospital discharge data.\textsuperscript{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\textsuperscript{37,38}, 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. 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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