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Does frank diabetes in first-degree relatives of a pregnant woman affect the likelihood of her developing gestational diabetes mellitus or non-gestational diabetes?

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Abstract

Objective—To examine the associations between patterns of family histories of diabetes and a history of gestational diabetes (hGDM).

Study Design—Parous women participating in the Third National Health and Nutrition Examination Survey (n=4566) were classified as having hGDM only, diagnosed diabetes, or neither. Family history of diabetes was categorized as: maternal-only, paternal-only, biparental, and sibling-only. The covariate-adjusted prevalence and odds of having hGDM were estimated.

Results—Compared to women without a family history of diabetes, women with a maternal history of diabetes (odds ratio 3.0, 95% CI 1.2-7.3), paternal history of diabetes (odds ratio 3.3, 95% CI 1.1-10.2), or a sibling history of diabetes (odds ratio 7.1, 95% CI 1.6-30.9) had greater odds of hGDM, after adjustment for age and race/ethnicity.

Conclusions—Women with a sibling history of diabetes were more likely to have hGDM than women with other family history patterns.

Keywords

gestational diabetes; family history; sibling

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Introduction

Gestational diabetes mellitus (GDM) is defined as glucose intolerance first identified during pregnancy.¹ Women with GDM are at increased risk for future diabetes,² but not all women with GDM eventually develop diabetes.² Women who have isolated GDM, or GDM without subsequent frank diabetes, could have different familial transmission patterns than women who develop permanent glucose intolerance. However, studies of familial transmission of GDM are relatively few, small, and the results conflict.³⁻⁷

In comparison, a family history of diabetes increases the risk of diabetes in a dose-response manner: the risk is higher when both parents are affected than when only one is.⁸⁻¹³ Moreover, maternal diabetes may^{9, 12} or may not^{8, 11} confer greater risk of diabetes in the offspring than paternal diabetes. Studies documenting greater maternal risk may have had greater rates of maternal glucose intolerance during pregnancy; such excess risk may be partially incurred in-utero or during early childhood development.¹⁴

Using the National Health and Nutrition Examination Survey (NHANES) III, a population-based survey, we examined the patterns of a family history of diabetes among parous, non-pregnant women. We compared family histories of diabetes in women with a history of isolated GDM (hGDM) vs. women with diagnosed diabetes vs. unaffected women. We wished to answer the following questions: 1) does a maternal-only history of diabetes increase risk of hGDM compared to paternal-only history of diabetes? 2) does a biparental history of diabetes increase risk of hGDM beyond having a single parent affected by diabetes? 3) does a sibling-only history of diabetes increase risk of hGDM? 4) do these associations differ from familial transmission patterns in women with diagnosed diabetes?

Materials and Methods

Study Population

The study population was obtained from NHANES III, a survey conducted using a multistage sampling design to make the sample representative of the non-institutionalized civilian population in the U.S. between 1988 and 1994. A detailed description of the objectives and data collection procedures of the NHANES III has been reported previously.¹⁵ Briefly, each NHANES wave consists of a detailed standardized medical examination in a mobile examination unit and an interview to obtain information on sociodemographic characteristics and other variables. For this report, we excluded women who were nulliparous, pregnant at the time of data collection, or had missing data regarding pregnancy status or previous diabetes or hGDM diagnoses or family history of diabetes, for a total sample of 4566 parous women. As we analyzed a public-use de-identified dataset, this study was declared institutional review board exempt by the University of Michigan.

Main Outcome Measures

Women were classified as having diagnosed diabetes, isolated hGDM, or neither condition. At the time of the NHANES interview, women were asked, “1) Have you ever been told by a doctor that you have diabetes or sugar diabetes? 2) Were you pregnant when you were told you had diabetes? 3) Other than during pregnancy, has a doctor ever told you that you have diabetes or sugar diabetes?” Based on these questions, women were classified as having diagnosed diabetes if they reported a diagnosis of diabetes outside of pregnancy (n=214).¹⁶ Women were classified as having isolated hGDM (hGDM without a diagnosis of diabetes) if they reported having a diagnosis of diabetes during pregnancy but not at the time of interview (n=84). Women were classified as unaffected if they had neither hGDM nor diagnosed diabetes (n=4268). Since we were focused on the women with hGDM only without current diagnosed

diabetes, women who had both diabetes and hGDM (n=29) were classified as having diagnosed diabetes. In the NHANES III, it is not possible to combine participants with diagnosed and undiagnosed diabetes for risk analysis, since the denominator to estimate undiagnosed diabetes is different from the one to estimate diagnosed diabetes; undiagnosed diabetes was assessed in a subsample of nondiabetic persons who were randomly assigned to a morning fasting examination, whereas diagnosed diabetes was assessed for the entire sample. Therefore, we did not use fasting glucose levels to assess diabetes status. Information on the tests used to make the original diagnosis of GDM were not available in the NHANES.

Exposure Assessment

Family history of diabetes was obtained from the NHANES question, "Including living and deceased, were any of your biological relatives, that is, blood relatives, including grandparents, parents, brothers, and sisters, ever told by a health professional that they had diabetes? Which family member?" Maternal-only history of diabetes (n=713), paternal-only history of diabetes (n=393), both parents affected (biparental) (n=139), and sibling-only history of diabetes (one or more siblings affected but neither parent affected) (n=214) are mutually exclusive categories. Women who had a parent and a sibling affected were classified according to their parental history; thus, women with a mother and a sibling affected were classified as "maternal-only," women with a father and a sibling affected were classified as "paternal-only," and women with two parents and a sibling affected were classified as having a "biparental" family history.

Information on age, sex, race/ethnicity, education, and household income were collected by interview.¹⁵ The poverty-income-ratio (PIR) was calculated using self-reported family income, family size, and the poverty threshold value produced annually by the U.S. Census Bureau.

¹⁷ Measurements of height, weight, and waist circumference were performed in a standardized manner, and body mass index (BMI) was calculated as weight in kilograms divided height in meters, squared.

Statistical analysis

All analyses accounted for the complex, multistage, stratified, cluster-sampling design of NHANES III by using sample weights, strata, and primary sampling units provided by the survey manual as part of the public dataset. First, we compared family history patterns between women with diabetes, hGDM, and neither condition. For continuous variables, we conducted ANOVA, and for categorical variables, we conducted chi-square tests. Second, using multivariable logistic regression models, we calculated the odds ratios and 95% confidence intervals for hGDM and diagnosed diabetes. Finally, we used the models to calculate the adjusted prevalence for hGDM and diagnosed diabetes.¹⁸ Multivariable models were constructed in consecutive stages. The first sets of models adjusted for age (Model 1) and age and race/ethnicity (Model 2). Next, we added BMI and waist circumference, measures of central obesity (Model 3). The final set of models also adjusted for education and PIR (Model 4). Statistical analyses were conducted using SUDAAN 9.0 (Research Triangle Institute, North Carolina) software.

Results

The characteristics of women in our sample are illustrated in Table 1. The majority of women reported not having any first-degree relative with diabetes. Compared to women with a family history of diabetes, women without a family history were younger, more likely to be non-Hispanic white, better educated, and thinner, and less likely to be impoverished. Among women with hGDM, 50% reported no family history of diabetes, 21% reported a maternal history only, 14% reported a paternal history only, 2% reported a biparental history, and 13% reported a

sibling history ($p<0.001$). Among women with diabetes, 43% reported no family history, 23% reported a maternal history only, 15% reported a paternal history only, 11% reported a biparental history, and 8% reported a sibling history ($p<0.001$). Among women with neither condition, 74% reported no family history, 13% reported maternal history only, 8% reported a biparental history, and 2% reported a sibling history ($p<0.001$).

In unadjusted analyses, women with maternal-only and paternal-only histories reported similar prevalences of hGDM and diagnosed diabetes, which were higher than those for women without any family history (Table 1). Women who reported a biparental history of diabetes did not have an increased prevalence of hGDM compared to women without such a history; however, women with a biparental history had a prevalence of diagnosed diabetes that was 2-8 times that of women in the other groups. Women who reported a sibling-only history of diabetes had a significantly higher prevalence of hGDM and diagnosed diabetes than those without a family history.

Maternal-Only and Paternal-Only Diabetes

After adjustment for age and race/ethnicity (Table 2), women with a maternal-only history had a 3-fold increased odds of hGDM and women with a paternal-only history had a similar increased odds of hGDM compared to women without a family history. The odds of hGDM were somewhat attenuated after adjustment, with the association between paternal-only history and hGDM losing significance in models including BMI and waist circumference. Similarly, women with a maternal-only history had a 2.6-fold increased odds of diagnosed diabetes compared to women without family history, and women with a paternal-only history had similar increased odds of diagnosed diabetes (Table 3). The odds of diagnosed diabetes were also somewhat attenuated after adjustment, most notably after adjustment for BMI and waist circumference, and less so additional adjustment for education and PIR.

Biparental Diabetes

After adjustment for age and race/ethnicity (Table 2), women with a biparental history did not have a marked increase in odds of hGDM either before or after adjustment for other factors. In contrast, women with a biparental history had a 9.6 increased odds of diagnosed diabetes compared to women without any family history, more than double the odds of maternal-only history (Table 3). The odds of diagnosed diabetes were again attenuated most notably by adjustment for BMI and waist circumference.

Sibling-Only Diabetes

After adjustment for age and race/ethnicity (Table 2), women with a sibling-only history had markedly increased odds of hGDM compared to women without any family history, more than double the odds of maternal-only history. These associations were attenuated after adjustment for BMI and waist circumference, but actually strengthened with further adjustment for education and PIR. Women with a sibling-only history had increased odds of diagnosed diabetes compared to women without any family history (Table 3). These associations were most attenuated by adjustment for BMI and waist circumference.

Comment

In this cross-sectional study of parous women in the U.S., we found that a family history of diabetes was associated with increased odds of hGDM. More specifically, we found that a maternal-only history of diabetes and a paternal-only history of diabetes similarly doubled or tripled the odds of hGDM compared to no family history. Having both parents affected with diabetes did not seem to increase the odds of hGDM compared to having one parent affected with diabetes, although it increased the odds of diabetes. We also found that sibling-only history

of diabetes conferred much greater odds of hGDM than having a parent affected. Finally, maternal-only history did not seem to confer excess risk for either hGDM or diagnosed diabetes beyond paternal risk.

Maternal-Only and Paternal-Only Diabetes History

Other reports examining hGDM have also found that both maternal-only and paternal-only diabetes histories confer greater hGDM risk.³⁻⁶ In these other reports, the degree of excess risk with maternal-only history compared to paternal-only history ranges from little to none,^{4, 6} as in our report, to mildly increased,⁵ to double.³ Excess risk with a maternal-only history would imply intrauterine, mitochondrial, or other epigenetic influences. Reports may conflict for several reasons. First, one feature of our report is that women with hGDM did not also have diagnosed diabetes; our previous reports show that few had elevated glucose levels.¹⁹ Women with diabetes may have excess maternal risk,^{9, 12} so it is possible that other reports also including women with hGDM who later developed diabetes as well as women with hGDM who actually had undiagnosed preconception diabetes might have shown increased maternal risk for this reason. Another possibility is that maternal risk may be mediated differently than paternal risk. We found that the association between paternal-only history and hGDM was no longer significant after adjustment for body mass, but the association between maternal-only history and hGDM remained robust, suggesting maternal-only history may affect glucose metabolism through alternate pathways aside from body mass. Finally, maternal history may be more important if the mother had dysglycemia during her pregnancy; maternal glucose intolerance occurring after the pregnancy should not lead to in-utero changes, and reports may have had mothers with differing ages of onset of diabetes.

Maternal-only history may be more likely to be ascertained than paternal-only history, due to biases such as longer life span in women, reduced healthcare utilization among fathers, incidence of diabetes at a later age in fathers compared to mothers, or greater awareness of mother's history than father's history.⁹ As we did not find evidence of excess maternal transmission in the current report, these biases may be of less importance, but could possibly explain the contrast with other reports.

Biparental History of Diabetes

As in other reports of family history of diabetes and risk for diabetes (as opposed to hGDM), we found that biparental history significantly increases offspring risk of diabetes compared to a single parent.^{8-10, 12, 13} In the Framingham Offspring Study, biparental diabetes was associated with a six-fold increase in odds of diabetes, almost double the odds of either parent alone (OR 6.1, 95% CI 2.9-13.0). In contrast, we found that biparental history of diabetes was not associated with hGDM beyond a maternal-only history, consistent with a report by McLean and colleagues³ but different from a report by Williams and colleagues.⁴ Again, since our report examined women with hGDM only, it is possible that the excess risk associated with biparental history was due to inclusion of women with previously undiagnosed diabetes or hGDM who were at excess risk for diabetes. In addition, due to the definition of hGDM, the prevalence of hGDM and diabetes exist in equilibrium. Women with a biparental history might have greater risk of earlier onset diabetes compared to women with other types of family history, and thus the odds of hGDM with a biparental history were relatively decreased.

Sibling History of Diabetes

As in our report, others have found that maternal history and paternal history of diabetes were associated with similar odds of hGDM, but the odds of hGDM increased most markedly when a sibling was affected.⁴ In addition, we found that the odds of hGDM with a sibling-only history actually increased with adjustment for measures of current and early-life influences such as education and PIR. This suggests that these environmental factors obscure the association

between sibling-only history and hGDM diagnosis, and that sibling-only history may be a greater risk factor than previously documented.

Strengths and Limitations—Strengths of this report include a large number of participants, a nationally representative population-based sample, information on multiple potential confounders including body mass and central adiposity, and comparison with familial transmission patterns of diabetes. However, NHANES is cross-sectional, and we were unable to calculate relative risks (as opposed to odds ratios) of diabetes and hGDM, which would have required a much larger number of subjects. We deliberately distinguished between women with hGDM only and women with diagnosed diabetes, so our results do not apply to the women with hGDM who later developed diabetes. GDM history and family history of diabetes were ascertained by participant self-report. If GDM screening were associated with self-report of family history of diabetes, this would artificially increase association with family history. Similarly, if diagnosed diabetes were associated with family history of diabetes, this would artificially increase association with family history. We did not have more specific information about the timing and criteria used to diagnose GDM and postpartum testing, which may have resulted in misclassification, although it is difficult to state how this affected the estimates of association.

These biases may be less important for this study as the odds ratios we obtained were similar to other reports that directly validated family history for diabetes as well as the diagnosis of GDM. It is possible that the estimate of maternal transmission for diagnosed diabetes was biased to the null by the inclusion of adults with type 1 diabetes, for whom maternal in-utero transmission may be less influential.²⁰ Optimally, we would have determined whether the mother had glucose intolerance at the time of the pregnancy to more exactly pinpoint the degree of maternal risk. To our knowledge, no reports of GDM and only two reports examining diabetes have been able to examine age of onset.^{8, 20} Thus, our estimates of excess maternal transmission may have been biased toward the null.

We conclude that family history of diabetes increases the odds of hGDM. Maternal-only family history of diabetes and paternal-only family history diabetes both increase risk of diagnosed diabetes and hGDM, but the odds of hGDM did not increase with the number of affected family members. In particular, women with a sibling history of diabetes were more likely to have hGDM compared to other family history patterns. These results suggest that women who develop GDM but not diabetes may have different family history transmission patterns than women with diabetes. Further research distinguishing genetic transmission among these two groups of women, with particular focus on sibling history, may help risk stratify GDM women at high risk for developing future diabetes, and thus target them for prevention interventions.

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Unadjusted characteristics of women with no family history of diabetes, maternal history of diabetes, paternal history of diabetes, both parents affected with diabetes, a sibling-only history of diabetes. Means (standard errors) or percentages (standard errors) are shown

Table 1

Characteristics	Family history status					P-value
	No history (n=3107)	Maternal only (n=713)	Paternal only (n=393)	Biparental (n=139)	Sibling-only (n=214)	
Age (years)	38.7 (0.3)	41.4 (0.6)	41.2 (0.7)	40.5 (1.1)	42.6 (1.1)	<0.001
Race/Ethnicity (%)						<0.001
Non-Hispanic White	74.1 (1.5)	62.3 (2.8)	70.0 (3.5)	68.4 (4.6)	60.0 (4.1)	
Non-Hispanic Black	13.1 (1.0)	17.1 (1.4)	12.6 (1.4)	18.0 (3.6)	20.3 (2.9)	
Mexican American	5.2 (0.6)	8.3 (1.1)	6.6 (0.8)	10.6 (2.3)	6.5 (1.1)	
Other	7.6 (1.0)	12.3 (2.8)	10.8 (3.5)	2.9 (2.0)	13.2 (3.7)	
Education (%)						0.003
Less than high school	20.9 (1.1)	29.3 (3.1)	22.1 (4.0)	29.1 (4.4)	37.9 (6.2)	
High school	40.6 (1.3)	36.7 (2.6)	38.3 (4.8)	48.5 (5.8)	36.1 (6.0)	
More than high school	37.9 (1.5)	33.8 (2.9)	39.3 (4.0)	22.1 (6.4)	25.9 (5.5)	
Unknown	0.6 (0.3)	0.1 (0.1)	0.3 (0.2)	0.3 (0.2)	0.1 (0.1)	
Poverty income ratio quartiles (%) (n=4177)						0.003
< 1.49	24.7 (1.3)	32.9 (3.4)	23.5 (3.3)	33.9 (7.3)	37.1 (5.3)	
1.49 to < 2.72	25.9 (1.5)	24.8 (3.5)	33.9 (4.0)	35.9 (8.1)	23.2 (4.7)	
2.72 to < 4.20	25.7 (1.6)	23.4 (2.6)	25.8 (3.5)	17.9 (5.7)	26.6 (5.4)	
≥ 4.20	23.7 (2.0)	18.9 (2.5)	16.8 (2.7)	12.2 (4.7)	13.1 (4.3)	
Body mass index (kg/m ²) (%)						<0.001
< 25	52.9 (1.4)	35.7 (2.7)	42.4 (3.9)	25.9 (5.9)	32.6 (4.3)	
25 to 29.9	24.6 (1.1)	25.6 (2.3)	23.7 (3.8)	32.4 (5.6)	27.4 (3.7)	
≥ 30	22.6 (1.2)	38.7 (3.0)	33.9 (4.3)	41.8 (7.2)	40.0 (5.0)	
Waist circumference (cm)	86.8 (0.4)	93.8 (1.0)	91.4 (1.4)	96.5 (2.1)	95.0 (1.4)	<0.001
Diabetes status						
Neither hGDM or DM	97.1 (0.4)	92.0 (1.5)	91.7 (1.7)	81.8 (5.3)	88.6 (3.3)	
History of GDM (hGDM) only	0.8 (0.2)	1.8 (0.5)	1.9 (0.8)	1.1 (0.6)	3.9 (2.6)	
Diagnosed Diabetes	2.1 (0.4)	6.2 (1.5)	6.4 (1.4)	17.1 (5.0)	7.5 (3.0)	<0.001

Table 2
Estimated odds ratios (95% CI)* and prevalences (standard errors) for history of gestational diabetes (hGDM) according to category of family history of diabetes, adjusted for covariates

Models and adjustments	No history (n=3107)	Maternal-only (n=713)	Paternal-only (n=393)	Biparental (n=139)	Sibling-only (n=214)
Model 1: Adjusted for age					
Odds ratio, 95% CI	1.0	3.1 (1.3 - 7.6)	3.3 (1.1 - 10.5)	2.1 (0.5 - 8.6)	7.2 (1.8 - 29.0)
Prevalence of hGDM (standard error)	0.7 (0.2)	2.2 (0.7)	2.3 (1.0)	1.4 (0.8)	4.7 (3.1)
Model 2: Adjusted for age, race/ethnicity					
Odds ratio, 95% CI	1.0	3.0 (1.2 - 7.3)	3.3 (1.1 - 10.2)	1.9 (0.5 - 7.6)	7.1 (1.6 - 30.9)
Prevalence of hGDM (standard error)	0.7 (0.2)	2.0 (0.7)	2.3 (1.0)	1.2 (0.7)	4.7 (3.2)
Model 3: Adjusted for age, race/ethnicity, body mass index (BMI), waist circumference					
Odds ratio, 95% CI	1.0	2.8 (1.1 - 7.0)	2.9 (0.8 - 10.3)	1.6 (0.4 - 6.6)	6.9 (1.6 - 29.4)
Prevalence of hGDM (standard error)	0.7 (0.2)	1.9 (0.7)	2.0 (1.0)	1.0 (0.6)	4.6 (3.1)
Model 4: Adjusted for age, race/ethnicity, BMI, waist circumference, education, poverty-income ratio (PIR)					
Odds ratio, 95% CI	1.0	2.7 (1.0 - 7.3)	2.8 (0.8 - 10.0)	1.8 (0.4 - 7.6)	7.3 (1.9 - 28.0)
Prevalence of hGDM (standard error)	0.7 (0.2)	2.0 (0.7)	2.0 (1.0)	1.2 (0.8)	4.9 (3.1)

* Reference group: No family history of diabetes among first degree relatives.

Table 3

Estimated odds ratios (95% CI)* and prevalences (standard errors) for diabetes mellitus (DM) according to category of family history of diabetes, adjusted for covariates

Models and adjustments	No history (n=3107)	Maternal-only (n=713)	Paternal-only (n=393)	Biparental (n=139)	Sibling-only (n=214)
Model 1: Adjusted for age					
Odds ratio, 95% CI	1.0	2.7 (1.6 - 4.7)	2.9 (1.6 - 5.2)	10.0 (4.4 - 22.7)	3.0 (1.3 - 7.0)
Prevalence of DM (standard error)	2.2 (0.4)	5.6 (1.2)	5.9 (1.3)	16.9 (4.9)	6.0 (2.4)
Model 2: Adjusted for age, race/ethnicity					
Odds ratio, 95% CI	1.0	2.6 (1.5 - 4.5)	2.9 (1.6 - 5.2)	9.6 (4.1 - 22.1)	2.7 (1.1 - 6.2)
Prevalence of DM (standard error)	2.2 (0.4)	5.4 (1.2)	6.0 (1.3)	16.4 (4.9)	5.4 (2.2)
Model 3: Adjusted for age, race/ethnicity, body mass index (BMI), waist circumference					
Odds ratio, 95% CI	1.0	2.1 (1.1 - 3.9)	2.6 (1.4 - 4.7)	8.0 (3.1 - 20.5)	1.7 (0.6 - 4.7)
Prevalence of DM (standard error)	2.4 (0.4)	4.7 (1.1)	5.7 (1.1)	14.1 (4.2)	3.8 (1.8)
Model 4: Adjusted for age, race/ethnicity, BMI, waist circumference, education, poverty-income ratio (PIR)					
Odds ratio, 95% CI	1.0	2.1 (1.1 - 3.8)	2.3 (1.3 - 4.3)	7.8 (3.0 - 20.1)	1.5 (0.5 - 4.5)
Prevalence of DM (standard error)	2.5 (0.5)	4.8 (1.2)	5.4 (1.1)	14.1 (4.2)	3.5 (1.8)

* Reference group: No family history of diabetes among first degree relatives.