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Nutritional Correlates of Women with a History of Gestational Diabetes and Insulin Resistance in the National Health and Nutrition Examination Survey (NHANES) 2000-2010*

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Abstract

Objective: To evaluate the associations of gestational diabetes (GDM) history with dietary intake, nutritional status, insulin resistance, demographic, and anthropometrical data. Materials & Methods: This cross-sectional study used data from the National Health and Nutrition Examination Survey for the years 2000-2010. Data analysis was based on 290 women who reported a history of GDM compared to 4239 women who denied a GDM history. Insulin resistance [HOMA_IR = (fasting insulin in mU/mL × fasting glucose in mmol/L)/405] was calculated. Pearson correlation, Wilcoxon rank sum tests, Student's t-tests, and chi-square analysis were used while linear regression assessed independent associations. Results: The median time-lapse from the diagnosis of GDM was 15 years. Women with a GDM history had significantly higher body mass index (BMI), other anthropometric measurements, diastolic blood pressures and insulin resistance. They were also more likely to be Hispanic, have delivered macrosomic infants, and delivered via cesarean. Previous GDM history compared to non-GDM subjects had significantly higher dietary intakes of energy calories, protein, total fat, saturated fatty acids, mono-saturated fatty acids, and cholesterol. Within the entire cohort, increasing insulin resistance was also associated with lower income, less college education, Hispanic or African American ethnicity, obesity, higher systolic and diastolic blood pressures, and with higher dietary cholesterol but lower intake of dietary fiber and micro-

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nutrients. Regression analyses showed that GDM history, Hispanic ethnicity, BMI, dietary intake of cholesterol and decreasing income were independently predictive of insulin resistance. Conclusion: The data confirm that even many years after a pregnancy associated with GDM, women with a history of GDM still report significantly higher dietary intakes of energy calories, protein, and fat with no corresponding increase in consumption of dietary fiber or minerals and vitamins. Consequently, the increased calorie and food consumption of women with previous GDM are associated with obesity, insulin resistance and higher blood pressures. These observations may suggest the need to target high-risk groups who may need more resources and awareness of the benefits of quality nutrition.

Keywords

Macrosomia, Gestational Diabetes, Insulin Resistance, Nutrition

1. Introduction

Gestational diabetes mellitus (GDM) is currently defined as carbohydrate intolerance with onset or recognition during pregnancy [1]. Insulin resistance in pregnancy is associated with GDM [2].

Women with a history of GDM have an increased risk for long-term morbidity. A recent large meta-analysis reported a composite 7-fold increase in risk for type 2 diabetes mellitus (T2DM) [3]. A higher incidence of metabolic syndrome, which includes features such as obesity, insulin resistance, dyslipidemia, and hypertension, has been found in women with previous GDM [4]-[6]. Previous studies have also shown that GDM is an independent risk factor for long-term cardiovascular morbidity [4].

Obesity is implicated in the progression of GDM to T2DM [7]. Programs focusing on the ability of lifestyle changes to facilitate weight loss, decrease insulin resistance, minimize gestational weight gain, control infant birth weight and limit the progression to T2DM have been implemented. These programs focus on the achievement of guidelines for physical activity and nutritional control by decreasing total energy consumption, saturated fat and increase dietary fiber [8]-[10]. Despite these interventions, little is known regarding long-term spontaneous dietary behaviors in women with a previous history of GDM.

The objective of this study is to utilize the NHANES database to identify a nationally representative cohort of women with previous GDM and to assess the associations with demographic factors, dietary intake, obesity, blood pressure measurements, and insulin resistance.

2. Materials & Methods

The National Health and Nutrition Examination Survey (NHANES) is a nationally representative survey conducted by the National Center for Health Statistics (NCHS), Center of Disease Control and Prevention (CDC) to assess the health and nutritional status among civilian, non-institutionalized US population. A complex, multistage, probability sampling strategy is used, with oversampling of subgroups of particular public health interest, including individuals of lower socioeconomic status and racial/ethnic minorities. Participants undergo a personal interview, standardized physical examination, diagnostic procedures, and laboratory tests. Participants are surveyed, measured and provide blood and urine samples. Data is obtained from the NHANES subjects by household interviews and the standardized examinations are done in mobile examination centers throughout the United States. Written informed consent is obtained from all NHANES participants. Data on the NHANES website is de-identified and publicly accessible.

This cross-sectional retrospective study used data from (NHANES) for the years 2000-2010 and is based on 290 women who self-reported a history of gestational diabetes (GDM) compared to 4238 women who denied a GDM history. We removed women whom had never been pregnant before.

Dietary intake data was obtained by a single in-person 24-h dietary recall interview using an automated multiple-pass method. Dietary intake in the database that we analyzed included total energy calories, fats, carbohydrate, sugars, protein, total fat, total saturated fatty acids, total monounsaturated fatty acids, total polyunsaturated fatty acids, cholesterol, dietary fiber intakes, fish intakes in past 30 days of clams, crabs, crayfish, lobsters,

mussels, oysters, scallops, shrimp, other shellfish, breaded fish products, tuna, mackerel, sea bass, shark, swordfish; vitamin intakes (A, B1, B12, B6, Folate, niacin, C, E, K), trace metals intakes (calcium, phosphorus, magnesium, zinc, iron, selenium, copper, potassium), alcohol, caffeine, and the obromine intakes.

Demographic factors included age, ethnicity, household size, educational level, marital status and country of origin. Anthropometrical measurements included weight, height, BMI; arm, waist, and thigh circumferences; arm and thigh lengths; triceps and subscapular skinfold, estimated fat-free mass, estimated fat mass (kg) and estimated percent body fat. Cardiovascular and biochemical markers include diastolic and systolic blood pressures, cotinine levels, estimated extracellular fluid volume, estimated total water body volume, estimated intracellular fluid volume, fasting plasma glucose and insulin levels.

The NHANES has strict protocols and approvals regarding human subjects. IRB exempt approval was obtained from Beaumont Hospital IRB.

Insulin resistance was estimated using Homeostasis model assessment-insulin resistance (HOMA-IR), which is equal to (fasting insulin in mU/mL × fasting glucose in mmol/L)/405 [11].

We compared women with a history of GDM to those without. Categorical variables were analyzed using Pearsons Chi-square tests and reported with Odds ratios (OR) and 95% confidence intervals (CIs). The continuous variables were tested for normality. Wilcoxon rank sum tests and Student T test were used as indicated. HOMA-IR was classified as follows: normal insulin resistance <3, 3 - 5 as moderate insulin resistance and >5 was severe insulin resistance [11]. Women categorized as severe insulin resistance were compared to all others. Regression multivariate analysis was employed to identify variables that were independently associated with increasing insulin resistance.

3. Results

NHANES data consisted of a total of 290 women who self-reported having a history of GDM and 4238 women who self-reported no history of GDM. Of those 290 GDM women, there were 54 (18.6%) African Americans, 105 (36.2%) Hispanics, 114 (39.3%) Non-Hispanic Whites, and 17 (5.9%) Asians & other races. In the self-reported no GDM group, there were 835 (19.7%) African Americans, 1291 (30.5%) Hispanics, 1956 (46.1%) Non-Hispanic Whites, and 157 (3.7%) Asians and others races. When asked their citizenship, 201 (69.3%) GDM women were US born, 89 (30.7%) were not born in the US and for those without GDM 3147 (74.3%) were American born and 1090 (25.7%) were not. Of women with GDM, 134 (46.2%) reported having a college education versus 1881 (44.5%) of women without GDM. Income levels were comparable in the GDM and no GDM groups, with 136/264 (51.5%) and 1966/3846 (51.1%), respectively, reporting an income ≥35,000 per year. Of the GDM group, 72 (24.8%) and 1048 (24.7%) of the no GDM group women were current smokers.

Subjects with previous GDM were significantly younger than those with no GDM history at the time of screening. The median time-lapse from the diagnosis of GDM to participation in the NHANES interview was 15 years. Those with previous GDM were significantly more likely to be Hispanic but less likely to be Non-Hispanic White and more likely to be married with a larger household. They were also on average obese (mean BMI of 32) with larger body circumferences, increased skinfolds with significantly higher mean diastolic blood pressures. They also had significantly more macrosomic births and cesarean deliveries. Fasting plasma glucose levels and HOMA IR values were significantly higher in those with previous GDM than in controls. Women with a history of GDM were also significantly more likely to be categorized as severe insulin resistance (**Table 1**).

Data regarding dietary intake is notable in that those with previous GDM had significantly higher dietary intakes of total energy calories, protein and fat (total fat, saturated fatty acids, monounsaturated fatty acids) cholesterol with no differences in sugar, carbohydrate, fiber intake or any type of fish consumption (**Table 2**). In the analysis of 27 Vitamin and mineral intakes, there were no significant differences between those with previous GDM versus others except for Selenium and niacin that were both significantly higher in the GDM group [Selenium mcg median (25^{th}, 75^{th}) = {89 (69, 116) versus 84 (63, 110); p = 0.018} and niacin mg = {19.6 (15, 26) versus 18.6 (14, 24); p = 0.041}].

Women within the severe insulin resistance as defined by HOMA IR > 5 tended to have lower income and less college education. They were more likely to be Hispanic or African American but less likely to be Non-Hispanic Whites. They were also on average obese (mean BMI of 35) with larger body circumferences, skinfolds and significantly higher systolic and diastolic blood pressures with past obstetrical history confirming more macrosomic births (**Table 3**). They also had higher dietary cholesterol but lower dietary fiber intakes. Women with severe insulin resistance also had decreased intake of all micronutrients measured, which reached statistical

Table 1. Significant demographic, biometric, cardiovascular, obstetrical and metabolic measurements in women with a history of Gestational Diabetes (GDM) compared to women with no GDM history.

Variable mean (SD)	GDM N = 290	No GDM N = 4238	P values OR** (95% CI)
Age at screening	45 (13)	53 (17)	<0.0001; 0.77 (0.71, 0.83)
Median years since GDM diagnosis	15 (0 to 26)	NA	NA
Hispanics	105 (36.2%)	1291 (30.5%)	0.040; 1.30 (1.01, 1.66)
Non-Hispanic Whites	114 (39.3%)	1956 (46.1%)	0.024; 0.825 (0.736, 0.986)
Married/living with partner	193 (66.8%)	2422 (57.2%)	0.001; 1.51 (1.17, 1.94)
Household members	3.9 (1.7)	3.2 (1.7)	<0.001; 1.25 (1.18, 1.34)
Weight (kg)	83 (2.2)	76 (2.0)	<0.001; 1.16 (1.10, 1.22)
Body mass index (kg/m^2)	32.0 (7.6)	29.5 (7.1)	<0.001; 1.05 (1.03, 1.06)
Waist circumference (cm)	102 (17)	97 (16)	<0.001; 1.02 (1.01, 1.03)
Arm circumference (cm)	34 (5.5)	32 (5.3)	<0.001; 1.07 (1.04, 1.09)
Triceps skinfold (mm)	27 (7.0)	24 (7.2)	<0.001; 1.05 (1.03, 1.07)
Scapular skinfold (mm)	27 (8.2)	23 (8.4)	<0.001; 1.06 (1.04, 1.08)
Diastolic blood pressure (mmHg)	70 (13)	68 (13)	0.005; 1.14 (1.03, 1.25)
Previous macrosomia delivery	80 (28.1%)	686 (17.2%)	<0.001; 1.15, (1.07, 1.24)
Previous cesarean delivery	112 (56.9%)	860 (39.7%)	<0.001; 1.40 (1.42, 2.45)
Glucose, plasma (mg/dL)	126 (65)	106 (33)	1.08 (1.05, 1.12) per increments of 10
Insulin mU/mL	15.98 (12.97)	13.7 (12.39)	0.06; 1.01 (1.00, 1.02)
HOMA IR*	5.2 (5.7)	3.8 (4.5)	0.002; 1.040 (1.014, 1.066)
Severe insulin resistance*!	41 (30.8%)	407 (20.7%)	0.008; 1.709 (1.26, 2.25)

There were no significant differences with systolic blood pressure, plasma insulin levels, smoking, income, education status, height or arms' length; Legend: *N for GDM = 133; N for No GDM = 1968; !Severe insulin resistance = HOMA-IR > 5; **Odds ratio calculated per 10 increments.

Table 2. Significant dietary intakes correlates of women with a history of gestational diabetes (GDM) compared to other women.

Dietary intakes mean (SD)	GDM N = 290	No GDM N = 4239	P values; (95% CI)
Energy (kcal)	1791 (681)	1695 (619)	0.022; 1.02 (1.005, 1.04)
Total fat (grams)	68 (33)	63 (30)	0.010; 1.06 (1.016, 1.094)
Total saturated fatty acids (grams)	22 (12)	20 (11)	0.018; 1.016 (1.006, 1.026)
Monounsaturated fatty acids(grams)	25 (13)	23 (11)	0.006; 1.014 (1.005, 1.024)
Cholesterol (mg)	246 (145)	230 (149)	0.0095; 1.07 (0.99, 1.15)
Protein (grams)	69 (26)	66 (26)	0.021; 1.05 (1.002, 1.09)

There were no significant differences with sugar, carbohydrate, fiber intake, and any type of fish consumption or vitamin and mineral intakes.

significance for Vitamin B1, riboflavin, total folate, calcium, magnesium, copper, and potassium (**Table 4**).

Linear regression analysis of insulin resistance (HOMA IR) categorized as normal <3, moderate 3 - 5, severe >5 as the dependent variable showed that a history of GDM, being Hispanic, increasing body mass index, higher dietary intake of cholesterol and decreasing income were independent predictors of severity of insulin resistance (**Table 5**).

Table 3. Significant demographic, biometric, cardiovascular, obstetrical and metabolic measurements in women with a severe Insulin Resistance* compared those with less insulin resistance.

Variable mean (SD)	Severe insulin resistance N = 448	Non-severe insulin resistance N = 1653	P values OR* (95% CI)
Mean systolic blood pressure	125.32 (19.5)	120.9 (20.06)	<0.001; 1.11 (1.06, 1.17)
Mean diastolic blood pressure	68.51 (13.6)	66.14 (13.07)	0.0009; 1.15 (1.06, 1.26)
Body mass index (kg/m^2)	35.48 (7.48)	27.71 (5.83)	<0.001; 1.19 (1.16, 1.21)
Weight (kg)	91.40 (21.39)	71.61 (16.45)	<0.001; 1.69 (1.59, 1.80)
Arm circumference (cm)	36.46 (5.59)	31.22 (4.56)	<0.001; 1.22 (1.19, 1.25)
Waist circumference (cm)	111.54 (15.27)	93.61 (13.3)	<0.001; 1.09 (1.08, 1.10)
Triceps skinfold (mm)	27.12 (6.92)	23.27 (7.09)	<0.001; 1.08 (1.06, 1.10)
Subscapular skinfold (mm)	27.71 (7.5)	21.76 (8.34)	<0.001; 1.09 (1.08, 1.11)
Income > $35,000	148 (37.4%)	811 (53.8%)	<0.001; 0.51 (0.41, 0.64)
Macrosomic infant delivery	95 (22.2%)	274 (17.8%)	0.038; 1.32 (1.02, 1.72)
College education	166 (37.2%)	783 (47.5%)	<0.001; 0.65 (0.53, 0.81)
Non-Hispanic Whites	171 (38.2%)	816 (49.4%)	<0.001; 0.63 (0.51, 0.78)
African American	98 (21.9%)	281 (17%)	0.017; 1.37 (1.06, 1.77)
Hispanics	166 (37.1%)	496 (30%)	0.004; 1.37 (1.10, 1.71)
Gestational diabetes	41 (9.2%)	92 (5.6%)	0.008; 1.71 (1.16, 2.51)

OR = odds ratio; *Severe insulin resistance = HOMA-IR > 5; there were no significant differences with age at screening, smoking, household size, country of birth, previous cesarean delivery, marital status and height.

Table 4. Significant dietary intakes correlates of women with a severe insulin resistance* compared to other women.

Variable mean (SD)	Severe insulin resistance N = 448	Non-severe insulin resistance N = 1653	P values OR* (95% CI)
Cholesterol intake (mg)	253.47 (157)	223.61 (141.87)	0.000; 1.14 (1.065, 1.22)
Dietary fiber intake (gm)	13.99 (6.47)	15.19 (7.67)	0.001; 0.977 (0.963, 0.992)
Thiamine (vitamin B1)	1.29 (0.52)	1.36 (0.61)	0.03; 0.814 (0.675, 0.981)
Riboflavin (mg)	1.68 (0.73)	1.83 (0.88)	0.01; 0.796 (0.693, 0.9105)
Total folate (mcg)	327 (154.78)	346.79 (170.01)	0.027; 0.928 (0.869, 0.992)
Calcium (mg)	776.47 (400.09)	823.95 (418.06)	0.033; 0.971 (0.946, 0.998)
Magnesium (mg)	239.21 (91.55)	258.11 (108.71)	0.001; 0.831 (0.745, 0.926)
Copper (mg)	1.06 (0.45)	1.13 (0.59)	0.034; 0.794 (0.641, 0.983)
Potassium (mg)	2224.8 (804.12)	2339.16 (16)	0.016; 0.861 (0.762, 0.973)

*Severe insulin resistance = HOMA-IR > 5; OR = odds ratio; per increments of 100; There were no significant differences with dietary intakes of total energy, protein, carbohydrate, total fat, total saturated fatty acids, total monounsaturated fatty acids, total polyunsaturated fatty acids, any fish intake nor any other vitamin and mineral intakes.

Table 5. Logistic regression analysis with severe insulin resistance* as the dependent variable.

Variable	Beta	S.E	P value	t	95% CI for B	
GDM history	0.047	0.066	0.017	2.39	0.028	0.286
Race/ethnicity	−0.047	0.066	0.021	−2.32	−0.066	−0.006
Dietary fiber	−0.002	0.003	0.947	−0.7	−0.005	0.005
Dietary cholesterol	0.053	0.000	0.020	2.34	0.000	0.001
Body mass index	0.496	0.002	0.000	24.74	0.052	0.061
Energy (kcal) intake	−0.027	0.000	0.301	−1.03	0.000	0.000
Income	−0.093	0.004	0.000	−4.37	−0.025	−0.01
College education	−0.030	0.035	0.156	−1.42	−0.117	0.019

*Severe insulin resistance = HOMA-IR > 5.

4. Discussion

A key finding of this study is that women with a history of GDM reported higher intake of calories, protein, and fat. Despite their increased calorie and food consumption there was no corresponding increase in consumption in dietary fiber, minerals and vitamins, suggesting that the higher food consumption was in foods of lower nutritional value. High-risk groups including women of Hispanic and African American ethnicity, women with lower incomes, and women with lower college education disproportionately predicted inclusion in those with severe insulin resistance. It is also important to point out that this study unlike many previous studies shows that the nutritional behavior and obesity associated with pregnancy may persist for many years, since the median time from the pregnancy associated with gestational diabetes was 15 years. This data confirms the need for consistent and continuous targeted intervention programs to high-risk groups who may lack financial resources to obtain "quality" nutrition, which may have limited awareness of beneficial health information and lack access to preventive health care programs.

The relationship between insulin resistance, B-cell function, and caloric intake in the pathogenesis of T2DM has been described [12]. Conversely, short-term severe caloric intake is known to reduce insulin resistance [13] [14]. Applying these concepts to women with a history of GDM and thus at risk for T2DM, Huopio *et al*. in a cohort of women with GDM and normoglycemic controls from Finland showed that post-delivery hyperglycemia resulted from increased insulin resistance and decreased insulin secretion [15]. A longitudinal study of 62 Hispanic women with previous GDM showed that high spontaneous caloric intake was associated with a decline in insulin sensitivity. The authors concluded that high calorie consumption contributes to obesity and high fasting glucose [13]. Similar studies evaluating the relationship between spontaneous caloric intake in those with previous GDM and insulin resistance ascertainment are needed. Our study documenting the association of increased insulin resistance with a history of GDM and spontaneous high dietary fat and caloric intake in an expanded population contributes to this literature. The associations of insulin resistance in this study with obesity and higher blood pressures further support previous noted correlations with metabolic syndrome and cardiovascular dysfunction [4]-[6].

Attendance of women with GDM for post-delivery glucose tolerance testing has been shown to be low [3]. It has been suggested that this may be because healthcare providers and patients are not fully aware of the increased risk of diabetes and the opportunity to promote health and prevent progression to type 2 DM [3]. Our study findings may provide supporting evidence to motivate mothers in keeping screening appointments and to support healthcare providers in providing exercise and nutrition preventive programs.

There are some limitations to this study. The history of GDM is self-reported and we have no information on the diagnostic criteria. We expect however that since these women all delivered in the United States that ACOG two-step process using either the O'Sullivan or Carpenter criteria were employed. Both insulin resistance and insulin secretion have been shown to be the components contributing to T2DM with their relationship mathematically described as a curvilinear relationship, however we did not have investigate insulin secretion [16].

There may have been subjects with undocumented diabetes in both groups; however, we feel that this may not necessarily change our results significantly since it is presumed that those with diabetes would have more insulin resistance. Even though we looked at dietary intake we did not have information on some confounding variables such as physical activity. It is also possible that the large sample size increased a tendency to type1 error. However we think that the strengths of this study include the large national cross sectional population, the prospective collection of the clinical and laboratory data, the detailed assessment of dietary intake, and the insulin resistance calculation and anthropometrical data on the same group of subjects.

5. Conclusion

In conclusion, we have shown that women with a past history of gestational diabetes seem to eat more, consume more calories and correspondingly have more insulin resistance and obesity.

Condensation

Women with history of gestational diabetes have a higher intake of calories and fat, increased rates of obesity, higher blood pressures, and more insulin resistance.

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