How Close Are You to Gestational Diabetes Mellitus?

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ABSTRACT

The objective of this study is to evaluate if proximity to food sources, rather than density, is associated with gestational diabetes mellitus (GDM) risk. Rhode Island birth certificate data from 2015–2016 were utilized. A proximity analysis was used to determine the distance from each pregnant person's home address to the closest food source (fast food restaurant, supermarket, and farmers market/community garden). Multivariable logistic regression was used to examine the association between distance to food source and the risk of GDM. Of the 20,129 births meeting inclusion criteria, 7.2% (1,447) had GDM. Distance to food sources differed by insurance type, educational background, and race/ethnicity. There was no statistically significant association between distance to any of the food sources and GDM in the adjusted model. Other factors need to be examined to improve interventions, influence policy, and impact neonatal and maternal outcomes.

KEYWORDS: gestational diabetes mellitus, food environment, pregnancy, diet, food access

INTRODUCTION

Gestational diabetes mellitus (GDM) is defined as a glucose intolerance first detected during pregnancy.[1] Approximately 2–10% of all pregnancies are affected with GDM and 50–70% of pregnant persons with GDM go on to develop type 2 diabetes mellitus (T2DM).[1] Advanced maternal age, obesity, gestational weight gain, and family history are well-known risk factors of GDM.[1,2] Gestational weight gain is a particular focus of pregnancy counseling because it is the only GDM risk factor that is modifiable post-conception. Pregnant persons who gain more weight than recommended during pregnancy have an 50–80% increased risk of developing GDM compared to those who limit their gestational weight gain to within the IOM guidelines based on body mass index.[3]

Recently, data has suggested an association between living in neighborhoods with fewer supermarkets and increased gestational weight gain.[4] Studies have also suggested that poorer diet during pregnancy, specifically lower fruit and vegetable intake, is associated with gestational weight gain.[4-8] When GDM has been examined as a primary outcome, a few studies have also suggested that limited food resources in pregnancy increase risk.[9,10] A study in Texas recently found that pregnant persons who lived in environments with a high density of fast-food restaurants had a significantly increased risk of developing GDM.[9] Similarly, a study in Delaware found geospatial overlap between areas with poor-quality food and increased risk of requiring medication to achieve good glycemic control in patients with GDM.[11] While these findings underscore the potential that geospatial analyses may be used to better characterize what food environments are most associated with GDM, more studies are needed that examine all types of food resources collectively. Only by examining the entire food environment available to pregnant persons can we determine if shifting the type of food resources in a community is a potential intervention that might reduce GDM risk.

We therefore conducted a retrospective study to assess the relationship between the proximity to many types of food (fast-food restaurants (FFR), supermarkets (SM), and farmers markets and/or community gardens (FMCG)) and the occurrence of GDM in Rhode Island (RI). We hypothesized that GDM would be positively correlated with proximity to FFR and would be inversely related to the distance to SM and FMCG. Identifying specific food environments that are associated with GDM risk could allow for statewide public health initiatives to shift food resources in the hope of reducing GDM risk and ultimately improving maternal and neonatal health.

METHODS

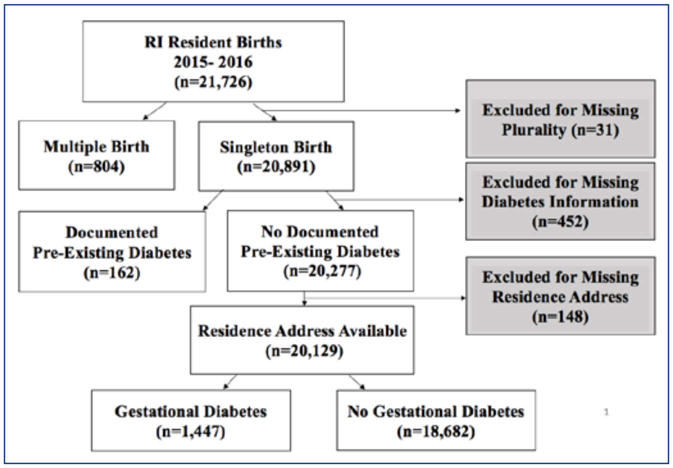
Study Population

We conducted a retrospective analysis of births in RI from January 1, 2015 to December 31, 2016 using Rhode Island Department of Health Vital Statistics data. Pregnant persons were excluded from the analysis if the birth certificate indicated pre-existing diabetes (type I or type II diabetes), multiple gestation, or were missing information for diabetes status, plurality, or residential address (**Figure 1**).

Measures

The primary outcome of interest was GDM defined by documentation on the birth certificate. Data on covariates

Figure 1. Study Sample Flow Chart



including maternal age, parity, insurance status, maternal education, marital status, race and ethnicity, cigarette smoking during pregnancy, gestational weight gain, hypertension, number of prenatal care visits, and body mass index (BMI) were also obtained from the birth certificate. Gestational weight gain was categorized as appropriate or excessive according to the Institute of Medicine (IOM) guidelines for appropriate weight gain based on prepregnancy BMI.[12] Hypertension was classified as chronic, pregnancy induced (gestational and preeclampsia), or none. While we fully acknowledge that race/ethnicity is a social construct, we included it as a covariate as many of the outcomes of interest for this study have previously been examined by race/ethnicity.

The residential address for each pregnant person was obtained from the birth certificate and was determined by the address given at the time of delivery. Unfortunately, longevity at this address was not available. A residence was classified to be in a "core city" if 25% or more children live below the poverty threshold according to the American Community Survey estimates (Rhode Island Department of Health, 2012).[13] In RI, core cities include Central Falls, Pawtucket, Providence, and Woonsocket.

For this investigation, we assessed three exposures relating to food environment. We examined distance from primary address to the closest 1) FFR 2) SM and 3) FMCG. FFR included places that sold quick, ready-to-eat food and required customers to order and pay before eating and whose primary business was take-out or had take-out or express in the name.[14] SM included both large corporate and smaller noncorporate grocery stores.[14] FMCG were operationalized as one variable to encompass healthier food sources. Food environment data on restaurants and supermarkets was downloaded in July–August 2019 from the Rhode Island Department of Health licensing website (https:// health.ri.gov/licenses/index.php). Information on farmers markets and community gardens was identified in July–August 2019 using website searches including the Rhode Island Community Food Bank, Southside Community Land Trust, Farm Fresh RI, Rhode Island Department of Human Services, and the U.S. Department of Agriculture.

Data Analysis

Pregnant persons address at the time of delivery, as listed on the birth certificate, was geocoded. Shapefiles containing the maternal residence address and the locations of each resource (FFR, SM, and FMCG separately) in Rhode Island were imported into the ArcGIS Network Analyst. A proximity analysis was then used to determine for each pregnant person, the distance from their home address to the closest of each of the three food sources. All analyses were done using ArcGIS Desktop 10.7.1 and SAS 9.4 (SAS Institute Inc, Cary, NC).[15]

Bivariate analyses were conducted to examine the association between maternal characteristics and GDM. The mean distance to each type of food source was calculated by GDM status and other maternal characteristics. Multivariable logistic regression was used to examine the association between distance to FFR, SM, and FMCG and the risk of GDM. Potential confounders were chosen on the basis of significance on bivariable analysis and biological plausibility. Regression modeling was also adjusted for clustering at the Census tract level. All analyses were performed using SAS software version 9.4 (SAS Institute Inc, Cary, NC).[15]

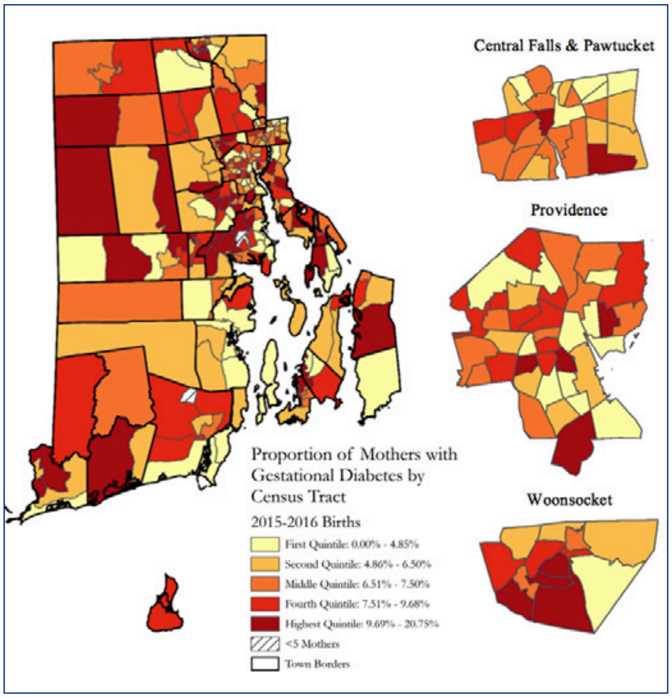
RESULTS

Of the 21,726 births in Rhode Island between January 1, 2015 and December 31, 2016, individuals with missing information for plurality (N=31), pre-existing diabetes (N=452), and residence address (N=148) were excluded. An additional 804 were excluded due to multiple gestation and 162 due to documented pre-existing diabetes. The final sample contained 20,129 individuals, of which 7.2% (N=1,447) were diagnosed with GDM (**Figure 1**). **Figure 2** is a geospatial representation of the proportion of pregnant persons with GDM by RI census tract.

Pregnant persons with GDM were slightly older (31.6 vs 29.0), had a higher BMI (29.4 vs 26.1 , and more likely to be married compared to being single (61.8% vs 33.8% $p < 0.01$) (**Table 1**). Pregnant persons with GDM were more likely to have chronic (4.9% vs 1.4% $p < 0.01$) or gestational hypertension (9.7% vs 6.1% $p<0.01$) compared to those without GDM. Of the forty percent of the study population that resided in core cities, only 38.1% had GDM, compared to 61.9% that did not reside in core cities.

On average, pregnant persons lived 0.66 of a mile from fast-food restaurants, 1.5 miles from supermarkets, and 2 miles from farmers markets or community gardens (**Table 2**). Distance to each food source varied significantly by race/ethnicity with Non-Hispanic white pregnant persons living the furthest from each food source (0.88 from FFR, 1.88 from SM, and 2.67 from FMCG) compared to Hispanic pregnant persons who lived the closest to each food source (0.31 from

Figure 2. Proportion of mothers with gestational diabetes by census tract, Rhode Island, 2015–2016



FFR, 0.90 from SM, and 0.90 from FMCG) (all p<0.01). Pregnant persons with private health insurance lived almost twice as far from each food source compared to their counterparts who were uninsured or had public medical insurance (0.88 vs 0.43 FFR; 1.76 vs 1.15 SM; 2.6 vs 1.36 FMCG) (all p<0.01). On average, pregnant persons with a graduate level of education lived the furthest from each food source compared to those with less than high school degree (0.90 vs 0.35 FRR; 1.76 vs 1.01 SM; 2.52 vs 1.05 FMCG) (all p <0.01). Pregnant persons who gained more weight than the recommended IOM guidelines lived slightly closer to every food source compared to those who were within the recommended IOM guidelines (0.65 vs 0.71 FFR; 1.44 vs 1.55 SM; 2.00 vs 2.09 FMCG) (p<0.01 FFR/SM and p=0.01 FMCG). Residents of core cities on average lived significantly closer to FFR (0.26 vs 0.92 p <0.01), SM (0.88 vs 1.85 p <0.01), and FMCG (0.65 vs 2.91 p <0.01).

After adjusting for age, race, marital status, and BMI, there was no association between distance to FFR and GDM (adjusted odds ratio [aOR] = 1.00; 95% Confidence Interval [CI] 0.94–1.07) (**Table 3**). There was also no association between distance to SM and GDM (aOR= 1.00; 95% CI 0.96–1.03) or FMCG and GDM (aOR = 1.00; 95% CI 0.98-1.03). For every one-year increase in maternal age there was a 1.09 increased risk of GDM (aOR = 1.09; 95% CI 1.07–1.10). Non-Hispanic Asian pregnant persons were 2.55 times more likely to have GDM compared to Non-Hispanic White pregnant persons (FFR aOR= 2.55; 95% CI 2.02–3.23; SM aOR= 2.54; 95% CI 2.01–3.2; FMCG aOR= 2.56; 95% CI 2.03-3.23).

Table 1. Characteristics of the study population by GDM status, Rhode Island, 2015–2016

	N	No GDM N (%) N=18,682	GDM N (%) N=1,447	P-Value
Maternal Age, years (mean, SD)	20,129	29.0 (5.7)	31.6 (5.5)	<0.01
Race/Ethnicity				<0.01
Hispanic	5,030	4,701 (25.4)	329 (22.9)	
Non-Hispanic White	11,540	10,724 (57.9)	816 (56.7)	
Non-Hispanic Black	1,728	1,625 (8.8)	103 (7.2)	
Non-Hispanic Asian	1,047	903 (4.9)	144 (10.0)	
Non-Hispanic Other	627	581 (3.1)	46 (3.2)	
Parity				<0.01
Nulliparous	8,167	7,638 (41.5)	529 (37.5)	
Multiparous	11,673	10,791 (58.6)	882 (62.5)	
Insurance Status				0.56
Public Insurance/ Uninsured	10,070	9,355 (50.5)	715 (49.7)	
Private Insurance	9,899	9,175 (49.5)	724 (50.3)	
Maternal Education				0.40
Less than High School	2,311	2,156 (13.1)	155 (12.4)	
High School	3,819	3,557 (21.7)	262 (21.0)	
Some College	5,309	4,903 (29.9)	406 (32.5)	
College Degree	3,808	3,551 (21.6)	257 (20.6)	
Graduate/ Professional Degree	2,425	2255 (13.7)	170 (13.6)	
Marital Status				<0.01
Married	10,989	10,096 (54.3)	893 (61.8)	
Divorced/Widowed/ Separated	646	583 (3.1)	63 (4.4)	
Single	8,407	7,919 (42.6)	488 (33.8)	
Cigarette Smoking During Pregnancy				0.46
Yes	1,434	1,324 (7.1)	110 (7.6)	
No	18,695	17,358 (92.9)	1,327 (92.4)	
Within IOM Weight Gain Guidelines				0.06
Yes	5,950	5,559 (32.5)	391 (30.0)	
No	12,434	11,523 (67.5)	911 (70.0)	
Maternal Hypertension				<0.01
Chronic	328	257 (1.4)	71 (4.9)	
Gestational	1,280	1,139 (6.1)	141 (9.7)	
None Documented	18,521	17,286 (92.5)	1,235 (85.5)	
BMI (mean, SD)	19,011	26.1 (6.1)	29.4 (7.4)	<0.01
Resident of Core City				0.04
Yes	8,181	7,630 (40.9)	551 (38.1)	
No	11,944	11,048 (59.1)	896 (61.9)	

*BMI= Body Mass Index; IOM=Institute of Medicine

Table 2. Distance, in Miles, to the Closest Fast-Food Restaurant (FFR), Supermarket (SM), and Farmers Market/Community Garden (FMCG) by Maternal Characteristics

	FFR Mean (SD)	P-Value	SM Mean (SD)	P-Value	FMCG Mean (SD)	P-Value
Gestational Diabetes		0.78		0.97		0.18
Yes	0.66 (0.93)		1.45 (1.57)		2.06 (2.02)	
No	0.66 (0.89)		1.45 (1.47)		1.99 (2.06)	
Race/Ethnicity		<0.01		<0.01		<0.01
Hispanic	0.31 (0.33)		0.90 (0.83)		0.90 (1.08)	
Non-Hispanic White	0.88 (1.06)		1.81 (1.85)		2.67 (2.27)	
Non-Hispanic Black	0.34 (0.51)		0.91 (0.73)		0.99 (1.01)	
Non-Hispanic Asian	0.51 (0.61)		1.21 (1.01)		1.84 (1.57)	
Non-Hispanic Other	0.40 (0.51)		1.06 (0.98)		1.23 (1.40)	
Parity		0.68		0.19		0.002
Nulliparous	0.65 (0.89)		1.43 (1.54)		1.94 (2.03)	
Multiparous	0.65 (0.89)		1.46 (1.58)		2.03 (2.03)	
Insurance Status		<0.01		<0.01		<0.01
Public Insurance/ Uninsured	0.43 (0.64)		1.15 (1.32)		1.36 (1.65)	
Private Insurance	0.88 (1.04)		1.76 (1.73)		2.6 (2.21)	
Maternal Education		<0.01		<0.01		<0.01
Less than High School	0.35 (0.52)		1.01 (0.95)		1.05 (1.33)	
High School	0.51 (0.78)		1.24 (1.29)		1.69 (1.88)	
Some College	0.65 (0.91)		1.46 (1.67)		2.07 (2.09)	
College Degree	0.89 (1.03)		1.81 (1.84)		2.61 (2.21)	
Graduate/ Professional Degree	0.90 (0.97)		1.76 (1.61)		2.52 (2.14)	
Marital Status		<0.01		<0.01		<0.01
Married	0.80 (1.00)		1.66 (1.76)		2.35 (2.19)	
Divorced/Widowed/ Separated	0.58 (0.76)		1.30 (1.21)		1.94 (1.97)	
Single	0.47 (0.70)		1.19 (1.26)		1.53 (1.77)	
Cigarette Smoking During Pregnancy		0.01		0.46		0.83
Yes	0.60 (0.89)		1.48 (1.64)		2.00 (1.99)	
No	0.66 (0.89)		1.45 (1.56)		1.99 (2.06)	
Within IOM Weight Gain Guidelines		<0.01		<0.01		0.01
Yes	0.71 (0.94)		1.55 (1.75)		2.09 (2.09)	
No	0.65 (0.89)		1.44 (1.51)		2.00 (2.06)	
Maternal Hypertension		0.01		0.04		0.21
Chronic	0.56 (0.83)		1.25 (1.24)		1.91 (2.14)	
Gestational	0.62 (0.89		1.37 (1.45)		1.90 (1.99)	
None Documented	0.66 (0.90)		1.46 (1.58)		2.00 (2.06)	
Resident of Core City		<0.01		<0.01		<0.01
Yes	0.26 (0.18)		0.88 (0.47)		0.65 (0.50)	
No	0.92 (1.07)		1.85 (1.90)		2.91 (2.20)	

*IOM= Institute of Medicine

Lastly, for every unit increase in BMI there was a 1.08 increased risk of GDM (aOR = 1.08; 95% CI 1.07–1.08).

DISCUSSION

In this retrospective study, we hypothesized that GDM risk would increase with proximity to FFR and decrease with proximity to SM and FMCG. Instead, we found no association between distance to FFR, SM, or FMCG and GDM risk. Distance to all food sources varied in the same direction when the population was compared by many variables associated with socioeconomic status. We found that the more resources (i.e., private insurance or higher education) a pregnant person had, the further away they lived to all food sources. A lack of significant variance between food sources may suggest that unmeasured confounders such as access to vehicles, bus routes, neighborhood safety, etc. should be assessed in future studies.

Prior studies assessing food environment have had conflicting results regarding GDM. For example, a study in Texas reported that patients who lived in the zip code quartile with the highest density of fast-food restaurants had a significantly increased risk of developing GDM.[9] Whereas a study in New York City did not detect an association between the number of healthy or unhealthy retail food outlets in the neighborhood and gestational diabetes.[10] Studies comparing distance rather than density were more likely to report an association between food environment and GDM most likely due to access and availability. A retrospective study in Chicago found a lower frequency of GDM in food deserts (low-income areas that were >0.5 miles away from a major food outlet) compared to areas with food outlets within a half mile radius.[16] Similarly, a study in Delaware calculated an index of healthy versus less healthy food sources based on 0.5-mile radius also found an association between areas of poor-quality food and a higher prevalence of GDM.[16] Given that we had the mother's full residential address at the

Table 3. Adjusted Odds Ratios of Gestational Diabetes Mellitus by Distance to Food Source

	FFR Adjusted OR (95% Cl)	SM Adjusted OR (95% Cl)	FMCG Adjusted OR (95% Cl)
Distance, miles	1.00 (0.94–1.07)	1.00 (0.96–1.03)	1.00 (0.98–1.03)
Maternal Age, years	**1.09 (1.07–1.10)**	**1.09 (1.07–1.10)**	**1.09 (1.07–1.10)**
Race/Ethnicity			
Hispanic	1.04 (0.87–1.24)	1.03 (0.86–1.23)	1.04 (0.87–1.25)
Non-Hispanic White	Reference	Reference	Reference
Non-Hispanic Black	0.86 (0.68–1.09)	0.86 (0.67–1.08)	0.86 (0.68–1.10)
Non-Hispanic Asian	**2.55 (2.02–3.23)**	**2.54 (2.01–3.21)**	**2.56 (2.03–3.23)**
Non-Hispanic Other	0.99 (0.74–1.33)	0.99 (0.74–1.32)	0.99 (0.74–1.33)
Marital Status			
Single	1.02 (0.88–1.17)	1.02 (0.88–1.17)	1.02 (0.88–1.17)
Married	Reference	Reference	Reference
Divorced/Widowed/ Separated	1.00 (0.74–1.36)	1.00 (0.74–1.36)	1.00 (0.74–1.36)
BMI	**1.08 (1.07–1.08)**	**1.08 (1.07–1.08)**	**1.08 (1.07–1.08)**

*BMI= Body Mass Index; FFR= Fast Food Restaurant; FMCG= Farmer's Market/Community Garden; OR= Odds Ratio; SM= Supermarket

time of delivery, we elected to use absolute distance in miles from each patient's home address to food source since this measure is more specific than neighborhood data and may be able to better account for the individual's surroundings. While our findings were inconsistent with the previously established relationship, it is important to note that RI is substantially geographically smaller than previously examined states which may explain some of the differences noted.

While food environment definitions are heterogeneous, many studies, including this one, have found inequities in food access.[16-20] Studies in New York, Texas, and Chicago have reported that women living in food deserts are more likely to be younger, non-Hispanic Black, low-income and have Medicaid insurance.[9-11] We found that distance to FFR, SM, and FMCG differed by insurance type, educational background, and race/ethnicity. Like prior studies, we also found that women who lived closer to each of the food sources gained more weight than is recommended by IOM guidelines during pregnancy. These differences should be interpreted through the lens of social determinants of health such as income and socioeconomic status which are often collinear with food environment. While we did not directly control for income, we clustered pregnant persons based on core cities (defined as 25% of children living below the poverty line) to account for the economic burden experienced in certain food environments. Interestingly, we found the opposite relationship that pregnant persons living in core cities were less likely to have GDM compared to their counterparts that did not live in core cities (6.8% vs 7.5% p <0.4). There are additional factors to consider such as income, differences in employment, access to prenatal care, shopping behaviors, etc., that is not readily available in birth certificate data, as we aim to understand the relationship between food environment and GDM risk.

The results of this study should be interpreted considering the following limitations. First, it was subjected to a temporal mismatch between our birth data (January 2015–December 2016) and our food environment data that was downloaded in July–August 2019 from the Rhode Island Department of Health licensing website as historical food environment data from 2015–2016 was not available. Another limitation is that we used the address listed on the birth certificate at the time of delivery as the home address for the entire duration of the pregnancy and did not have data on any previous addresses resided during pregnancy. Taken together it is plausible that our classification does not reflect the true food environment of pregnant persons throughout the course of their pregnancy. Secondly, there are unmeasured cofounders such as family history of GDM, patient-doctor-communication, transportation, safety, etc., that would be valuable to consider in our analyses. There are also several strengths of our study. Previous studies that have aimed to understand this relationship have targeted it at the neighborhood level, block level, and at the census level. Our study utilized two-step process to understand if a patient's individual risk of GDM increased or decreased given their absolute proximity to FFR, SM, and FMCG as well as clustering at the Census tract level.

In summary, understanding the role of social determinants of health is imperative to managing GDM patients. Until recently, preventative measures have largely focused on individual pregnant persons behaviors to reduce the risk of GDM. However, as GDM rates continue to climb, we must begin to evaluate specific social and environmental factors in order best support pregnant persons at risk for GDM. While the association between food access and GDM remains unclear, it is apparent that our current interventions are not effectively managing this high-risk population. Our study looks at the relationship between individual proximity to FFR, SM, and FMCG and individual GDM risk. While our data did not lend evidence that proximity to food sources is associated with GDM rates, other studies have found that a relationship does exist. Future studies should aim to better define and compare food environments so that the health consequences of food access and availability can be consistently evaluated.

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