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Proportion of Gestational Diabetes Mellitus Attributable to Overweight and Obesity Among Non-Hispanic Black, Non-Hispanic White, and Hispanic Women in South Carolina

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Abstract Objective was to estimate race-specific proportions of gestational diabetes mellitus (GDM) attributable to overweight and obesity in South Carolina. South Carolina birth certificate and hospital discharge data were obtained from 2004 to 2006. Women who did not have type 2 diabetes mellitus before pregnancy were classified with GDM if a diagnosis was reported in at least one data source. Relative risks (RR) and 95 % confidence intervals were calculated using the log-binomial model. The modified Mokdad equation was used to calculate population attributable fractions for overweight body mass index (BMI: 25.0–29.9 kg/m^2), obese (30.0–34.9 kg/m^2), and extremely obese ($\geq$35 kg/m^2) women after adjusting for age, gestational weight gain, education, marital status, parity, tobacco use, pre-pregnancy hypertension, and pregnancy hypertension. Overall, the adjusted RR of GDM was 1.6, 2.3, and 2.9 times higher among the overweight, obese, and extremely obese women compared to normal-weight women in South Carolina. RR of GDM for extremely obese women was higher among White (3.1) and Hispanic (3.4) women than that for Black women (2.6). The fraction of GDM cases attributable to extreme obesity was 14.0 % among White, 18.1 % among Black, and 9.6 % among Hispanic women. The fraction of GDM cases attributable to obesity was about 12 % for all racial groups. Being overweight (BMI: 25.0–29.9) explained 8.8, 7.8, and 14.4 % of GDM cases among White, Black, and Hispanic women, respectively. Results indicate a significantly increased risk of GDM among overweight, obese, and extremely obese women. The strength of the association and the proportion of GDM cases explained by excessive weight categories vary by racial/ethnic group.

Keywords Health disparity · Racial difference · Population attributable fraction · Epidemiology

Abbreviations

BMI	Body mass index
CI	Confidence interval
GDM	Gestational diabetes mellitus
IOM	Institute of medicine
NHDS	National Hospital Discharge Survey
PAF	Population attributable fraction
RR	Relative risk

Introduction

Gestational diabetes mellitus (GDM) is the recognition of glucose intolerance during pregnancy among women without a previous diagnosis of diabetes [1]. The

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prevalence of GDM could range between 1 and 14 % depending on the diagnostic tests being used and the population being studied [2]. Results from the National Hospital Discharge Survey (NHDS) found that the prevalence of GDM more than doubled from 1989 (1.9 %) to 2004 (4.2 %) [3]. The prevalence of GDM among non-Hispanic Black (hereinafter abbreviated as Black) women increased by 172 % from 1990 to 2004 (1.5–4.1 %), while the prevalence of GDM among non-Hispanic White (hereinafter abbreviated as White) women only increased 80 % in this time period (2–3.6 %) [3]. In South Carolina, the prevalence of GDM has been shown to be 6.0 % among Black women and 6.3 % among White women [4].

A major risk factor for the development of GDM is being overweight or obese prior to pregnancy [5]. The prevalence of overweight and obesity in the US has risen dramatically in recent decades. In 2009/2010, 64.5 % of US women were overweight or obese and the prevalence was highest among Black (82.1 %), followed by Hispanic (74.4 %) and White (61.3 %) women [6]. In 2009, pre-pregnancy obesity among women in the US that delivered a live birth was 20.5 %, significantly higher in Black, White, and Hispanic women compared to 2003 [7]. Among women who delivered a live birth in South Carolina between 2004 and 2006, 21.3 % of White women without GDM and 42.2 % of White women with GDM were classified as obese [4]. Among Black women, 35.3 % without GDM and 56.7 % with GDM were classified as obese [4]. Previous studies have demonstrated an association between pre-pregnancy overweight/obesity and increased risk of GDM [5, 8–17]. A meta-analysis of pre-pregnancy body mass index [BMI = weight(kg)/height(m)^2] and GDM conducted by Torloni et al. found that overweight women were almost twice as likely and obese women nearly four times more likely to develop GDM compared to normal-weight women [12]. Also, underweight women (BMI <20 kg/m^2) had a 25 % lower risk for GDM than did normal-weight women [12]. A study published in 2010 corroborates a significant reduced risk of GDM for women who were underweight (relative risk (RR) = 0.4) before pregnancy and a significant increased risk among overweight (RR = 2.1), obese (RR = 2.4), and extremely obese (RR = 5.0) women compared to normal weight women [13].

One explanation for the link between obesity and GDM is inflammation [18]. Overweight and obesity are associated with increased levels of inflammation [19, 20]. It has been shown that an increase in inflammation, specifically Interleukin-6 (IL-6), among obese individuals is associated with insulin resistance [21]. Normal pregnancy is accompanied by alterations in glucose metabolism and insulin resistance [22]. Another explanation could be that pregnancy exacerbates the defects in insulin receptors and post-receptors associated with obesity [23]. Abdominal obesity, specifically visceral adipose tissue, which has been shown to be associated with several adverse health effects (e.g., insulin resistance, diabetes), differs by race and ethnicity [24, 25].

To guide prevention efforts for GDM, it is important to examine the population attributable fraction (PAF) of GDM due to overweight or obesity. To our knowledge, four studies have examined PAF for GDM for each BMI category [13, 15–17]. One study found that the overall PAF for overweight and obesity is 46.2 % and the PAF for overweight, obesity, and extreme obesity were 15.4, 9.7, and 21.1 %, respectively [13]. Using data from Florida, a study found that the PAF of GDM due to overweight and obesity was slightly lower (41.1 %), but it varied by race/ethnicity: 39.1 % among Hispanic women, 41.2 % among White women, and 50.4 % among Black women [15]. Hedderson et al. [16] found the PAF of GDM due to overweight and obesity to be 54 % among Hispanic women, 52 % among White women, and 65 % among Black women. Kim et al. [17] in a California study, found the PAF of GDM due to overweight and obesity to be 44.2 % among Hispanic Women, 41.2 % among White women, 51.2 % among Black women.

South Carolina, with its poor maternal and child health indicators, high racial/ethnic disparities, a large Black population, rapidly growing Hispanic population, and a high prevalence of obesity [26, 27], is a compelling state in which to examine the association. Thus, our objective is to assess the association between pre-pregnancy BMI and GDM among Hispanic, White, and Black women in South Carolina, and to estimate the race/ethnicity-specific PAFs of GDM attributable to overweight and obesity in South Carolina from 2004 to 2006.

Methods

Sample

The sample included data from South Carolina birth certificates from 2004 to 2006 linked to hospital discharge data. Birth certificate data collected in SC, consistent with US Standards and procedures, obtain information about the birth, the baby, mother demographics, and mother risk factors [28, 29]. Hospital discharge data included information about the patient and their visit, such as admission information, age, gender, procedures and diagnoses. Hospital discharge observations were determined to occur during pregnancy if it transpired within the weeks of gestation before delivery to 2 weeks after delivery. Thus, the final sample was limited to observations with information from birth certificates and hospital discharge data (N = 142,994). Of these, 2,362 women were excluded due to a previous diagnosis of type 2 diabetes (reported on birth certificate or ICD-9 codes 250.0-.9 in hospital discharge data), 2,680 women were missing BMI or had an extreme value (<12 or >68.9 kg/m^2), 1,087 women were missing race/ethnicity, 3,059 were classified as “other” race/ethnicity, 34 women were missing age or had an extreme value (<13 or >47 years), and 1,198 women had missing values for one of the potential confounding variables. Consequently, our final analytical sample consisted of 132,574 women.

GDM Classification

Since 2004, the reporting of GDM was added to South Carolina birth certificates. Thus, we classified women with GDM if it was reported on the birth certificate or hospital discharge record. In hospital discharge data, GDM was defined using the ICD-9 code 648.8. To reduce the number of false positive GDM cases, we excluded women with diabetes mellitus diagnosis (ICD-9 codes 250.0-.9) for the 2 years before pregnancy and during pregnancy based on the data from hospital discharges and a diabetes mellitus diagnosis on the birth certificate. Women diagnosed with non-pregnancy diabetes (type 1 or type 2) were excluded from the analysis.

BMI Classification

Pre-pregnancy height and weight were obtained from the birth certificates, which were abstracted from prenatal records, delivery charts, or, if unavailable in these sources, obtained by self report from the mother. BMI was calculated using the subjects’ pre-pregnancy height and weight. Categories of BMI were defined using the cut points from the National Heart, Lung, and Blood Institute [30]. Subjects were defined as: underweight if BMI <18.5 kg/m^2; normal weight if $18.5 \leq \text{BMI} < 25.0$; overweight if $25.0 \leq \text{BMI} < 30.0$; obese if $30.0 \leq \text{BMI} < 35.0$ (obesity Class I); and extremely obese if BMI ≥35.0 (obesity Class II & III).

Classification of Potential Confounders

Potential confounders were selected based on previous research. All variables included in the analysis, except GDM, were obtained from the birth certificates. Information about data collected on birth certificates can be found at the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCHS) website [31]. Age was categorized as <20 years, 20–34 years, and ≥35 years. Race/ethnicity was defined as Hispanic, non-Hispanic White, and non-Hispanic Black. Education was categorized into less than high school, high school/some college or associate degree, and bachelor degree or higher. Marital status, tobacco use during pregnancy, pregnancy and pre-pregnancy hypertension were dichotomized as “yes/no” variables. Pregnancy weight gain was categorized according to the institute of medicine (IOM) definitions of below recommendations, at recommendations, or above recommendations [32]. Parity was dichotomized as nulliparous and multiparous.

Analysis

Descriptive statistics of baseline characteristics by GDM status and race/ethnicity were assessed using χ^2 tests. RR and 95 % confidence intervals (CI) were calculated using a log-binomial model (PROC GENMOD in SAS) [33]. A log-link was used to estimate RR while adjusting for potential confounders. A model with an intercept = -4 has been shown to work well to be sure that the model will converge [33]. The final models adjusted for mother’s age, education, marital status, gestational weight gain, parity, tobacco use, pre-pregnancy hypertension, and pregnancy hypertension. All results were stratified by race/ethnicity. The unadjusted and adjusted PAFs for overweight, obese, and extremely obese women were calculated using the modified Mokdad equation [34]:

$$\text{PAF}_i = \frac{P_i[RR_i - 1]}{P_0 + \sum P_i RR_i + P_q RR_q}$$

P_i = percentage in separate exposure (BMI) categories of the risk factor, RR_i = relative risk of GDM for each separate exposure category, P_0 = percentage of individuals in the population who were not exposed (i.e., normal weight $18.5 \leq \text{BMI} < 25.0$), P_q = percentage in a neutral category, where PAF cannot be calculated (underweight).

A bootstrap method was used to calculate 95 % CI for PAFs [35]. Because the underweight category is neutral or protective, the PAF is not calculated for this category. The proportion of the population in each BMI category by race/ethnicity was obtained from all women who gave birth between 2004 and 2006 and had data from birth certificates. Because BMI is not an appropriate indicator of weight-for-height in children [36], we also conducted an analysis excluding those subjects <16 years old.

All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC). Institutional Review Board (IRB) approval was obtained from the University of South Carolina and the South Carolina Department of Health and Environmental Control.

Results

Characteristics of the sample are presented by GDM status in Table 1. Women diagnosed with GDM were older, more educated, obese, more likely to be married, gain less weight during pregnancy, be non-smokers, multiparous,

Table 1 Characteristics of women giving birth in SC from 2004 to 2006 by GDM status

	n (%)		P value†
	No GDM (n = 124,332)	GDM cases (n = 8,242)	
Age at delivery			<0.0001
< 20 years	18,780 (15.1)	412 (5.0)	
20–34 years	93,721 (75.4)	6,183 (75.0)	
≥35 years	11,831 (9.5)	1,647 (20.0)	
Race/ethnicity			0.25
Hispanic	10,839 (8.7)	710 (8.6)	
White	72,490 (58.3)	4,740 (57.5)	
Black	41,003 (32.0)	2,792 (33.9)	
Education			<0.0001
Less than high school	30,055 (24.2)	1,362 (16.5)	
High school/some college or Associate degree	69,072 (55.5)	4,985 (60.5)	
Bachelor degree or higher	25,205 (20.3)	1,895 (23.0)	
Married			<0.0001
No	56,408 (45.4)	2,921 (35.4)	
Yes	67,924 (54.6)	5,321 (64.6)	
Pre-pregnancy BMI			<0.0001
Underweight	5,778 (4.7)	167 (2.0)	
Normal weight	55,322 (44.5)	2,160 (26.2)	
Overweight	31,623 (25.4)	2,071 (25.1)	
Obese	17,319 (13.9)	1,768 (21.5)	
Extremely obese	14,290 (11.5)	2,076 (25.2)	
Adequacy of gestational weight gain			0.001
Inadequate	35,448 (28.5)	2,490 (30.2)	
Adequate	32,659 (26.3)	2,050 (24.9)	
Excessive	56,225 (45.2)	3,702 (44.9)	
Parity			<0.0001
Nulliparous	57,464 (46.2)	3,158 (38.3)	
Multiparous	66,868 (53.8)	5,084 (61.7)	
Tobacco use during pregnancy			0.004
No	106,583 (85.7)	7,159 (86.9)	
Yes	17,749 (14.3)	1,083 (13.1)	
Pregnancy hypertension			<0.0001
No	117,870 (94.8)	7,285 (88.4)	
Yes	6,462 (5.2)	957 (11.6)	
Pre-pregnancy hypertension			<0.0001
No	122,156 (98.3)	7,889 (95.7)	
Yes	2,176 (1.7)	353 (4.3)	

† Variables were assessed for significance using χ^2 tests

and hypertensive than women without a diagnosis of GDM. Also, from Table 2 we can see significant differences in overweight and obesity among the race/ethnicity categories. The prevalence of GDM was 6.1, 6.1, and 6.4 % among Hispanics, Whites, and Blacks, respectively. All characteristics differed significantly by race. White women were older, more educated, more likely to be married, and more likely to use tobacco during pregnancy.

Results for the unadjusted and adjusted regression models are displayed in Table 3. The final model adjusted for age, education, marital status, gestational weight gain, parity, tobacco use, pre-pregnancy hypertension, and pregnancy hypertension. Results reveal a difference in the association between BMI and GDM among different racial/ethnic groups (p value for interaction = 0.0007). Among Hispanic women, the adjusted risk of GDM in the extremely obese was 3.4 times higher compared to normal weight women. Among White and Black women the risk of GDM among extremely obese women was 3.1 and 2.6 times higher than their normal-weight counterparts, respectively.

The PAF's are displayed for each BMI category above normal weight in Table 3. Overweight among Hispanic women explains almost twice as much of the GDM cases compared to White and Black women (14.4, 8.8, and 7.8 %, respectively). The fraction of GDM cases attributable to obesity was about 12 % for all racial groups. Extreme obesity among Black women explains a greater proportion of the GDM cases compared to White and Hispanic women (18.1, 14.0, and 9.6 %, respectively). Although PAFs of GDM varied by race/ethnicity and BMI status, the total adjusted fraction of GDM cases attributable to overweight and obesity (BMI ≥25) was 36.4 % in all women, highest among Blacks (38.1 %), followed by Hispanics (36.3 %) and White women (33.7 %) (not shown in the table).

Discussion

Our results show a significantly increased risk of GDM among overweight, obese, and extremely obese women compared to normal weight women, regardless of race/ethnicity. Also, results indicate that this association is modified by race/ethnicity. The percentage of GDM attributable to overweight (BMI ≥25.0 and <30.0 kg/m^2) is greater among Hispanics compared to White and Black women, while the percentage of GDM attributable to extreme obesity is lower among Hispanics compared to White and Black women. Overall, the percentage of GDM attributable to overweight and obesity was slightly higher among Black, compared to White and Hispanic women in South Carolina.

Our results are consistent with a number of previous studies showing an increased risk of GDM among overweight and obese women [5, 8–13, 15–17]. Similar to our results, recent studies conducted by Kim et al. [13, 15] found a significantly elevated risk of GDM among overweight women, with higher risks among obese and extremely obese women. Our findings corroborate these results. Torloni et al., in a meta-analysis, found that underweight women, defined as BMI <20 kg/m^2, had a risk of GDM

Table 2 Characteristics of SC women giving birth in the period of 2004–2006 by race/ethnicity

	n (%)				*P* value[†]
	All (n = 132,574)	Hispanic (n = 11,549)	White (n = 77,230)	Black (n = 43,795)	
GDM					0.25
No	124,332 (93.8)	10,839 (93.9)	72,490 (93.9)	41,003 (93.6)	
Yes	8,242 (6.2)	710 (6.1)	4,740 (6.1)	2,792 (6.4)	
Pre-pregnancy BMI					<0.0001
Underweight	5,945 (4.5)	404 (3.5)	3,975 (5.1)	1,566 (3.6)	
Normal weight	57,482 (43.4)	5,305 (45.9)	37,428 (48.5)	14,749 (33.7)	
Overweight	33,694 (25.4)	3,613 (31.3)	18,571 (24.1)	11,510 (26.3)	
Obese	19,087 (14.4)	1,522 (13.2)	9,681 (12.5)	7,884 (18.0)	
Extremely Obese	16,366 (12.3)	705 (6.1)	7,575 (9.8)	8,086 (18.4)	
Age at delivery					<0.0001
< 20 years	19,192 (14.5)	1,665 (14.4)	8,418 (10.9)	9,109 (20.8)	
20–34 years	99,904 (75.3)	9,019 (78.1)	59,342 (76.8)	31,543 (72.0)	
≥35 years	13,478 (10.2)	865 (7.5)	9,470 (12.3)	3,143 (7.2)	
Education					<0.0001
Less than high school	31,417 (23.7)	7,317 (63.4)	12,430 (16.1)	11,670 (26.6)	
High school/some college or associate	74,057 (55.9)	3,471 (30.0)	42,652 (55.2)	27,934 (63.8)	
Bachelor degree or higher	27,100 (20.4)	761 (6.6)	22,148 (28.7)	4,191 (9.6)	
Married					<0.0001
No	59,329 (44.8)	5,140 (44.5)	21,315 (27.6)	32,874 (75.1)	
Yes	73,245 (55.2)	6,409 (55.5)	55,915 (72.4)	10,921 (24.9)	
Adequacy of gestational weight gain					<0.0001
Inadequate	37,938 (28.6)	4,117 (35.6)	18,539 (24.0)	15,282 (34.9)	
Adequate	34,709 (26.2)	3,347 (29.0)	20,822 (27.0)	10,540 (24.1)	
Excessive	59,927 (45.2)	4,085 (35.4)	37,869 (49.0)	17,973 (41.0)	
Parity					<0.0001
Nulliparous	60,622 (45.7)	4,697 (40.7)	36,607 (47.4)	19,318 (44.1)	
Multiparous	71,952 (54.3)	6,852 (59.3)	40,623 (52.6)	24,477 (55.9)	
Tobacco use					<0.0001
No	113,742 (85.8)	11,216 (97.1)	62,451 (80.9)	40,075 (91.5)	
Yes	18,832 (14.2)	333 (2.9)	14,779 (19.1)	3,720 (8.5)	
Pregnancy hypertension					<0.0001
No	125,155 (94.4)	11,153 (96.6)	72,838 (94.3)	41,164 (94.0)	
Yes	7,419 (5.6)	396 (3.4)	4,392 (5.7)	2,631 (6.0)	
Prepregnancy hypertension					<0.0001
No	130,045 (98.1)	11,460 (99.2)	76,046 (98.5)	42,539 (97.1)	
Yes	2,529 (1.9)	89 (0.8)	1,184 (1.5)	1,256 (2.9)	

[†] Variables were assessed for significance using χ^2 tests

that was 25 % lower compared to normal weight women [12]. In our study, we observed a similar association only among Whites (RR = 0.83, 95 % CI = 0.68, 1.00). Kim et al. found the highest RR for obesity and extreme obesity to be among Whites, while in our sample, Hispanics had the highest RR. Similar to our results, Kim et al. found that the PAF for extreme obesity was highest among Blacks compared to Whites and Hispanics [15]. The PAFs among the different race/ethnicity groups found in our study are smaller than what was found in the other studies [15–17]. A potential explanation for this could be the different methods used to calculate PAF. In our methods we used a modified Mokdad equation which takes into account underweight individuals, as well as the proportion of the population and strength of association in the other categories of BMI. Also, the distribution of BMI categories by race/ethnicity is slightly different in our sample compared to the samples used in other studies.

Table 3 Relative risk and population attributable fraction for GDM by BMI category and race/ethnicity among women giving birth in SC from 2004 to 2006

	RR (95 % CI)		PAF (95 % CI)	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[a]
All				
Underweight	0.7 (0.6,0.9)	0.9 (0.8,1.0)	N/A	N/A
Normal weight	Reference	Reference	Reference	Reference
Overweight	1.6 (1.5,1.7)	1.6 (1.5,1.7)	9.8 (8.6,11.0)	9.1 (7.8,10.4)
Obese	2.5 (2.3,2.6)	2.3 (2.1,2.4)	12.8 (11.7,13.8)	11.8 (10.7,12.8)
Extremely obese	3.4 (3.2,3.6)	2.9 (2.8,3.1)	17.9 (16.9,18.9)	15.5 (14.5,16.6)
Hispanic				
Underweight	0.8 (0.5,1.5)	0.9 (0.5,1.7)	N/A	N/A
Normal weight	Reference	Reference	Reference	Reference
Overweight	1.9 (1.6,2.3)	1.7 (1.4,2.1)	16.2 (11.1,20.9)	14.4 (9.1,19.4)
Obese	2.9 (2.4,3.6)	2.4 (2.0,3.0)	15.0 (11.5,18.4)	12.3 (8.6,15.5)
Extremely obese	4.4 (3.5,5.4)	3.4 (2.8,4.3)	11.9 (9.4,14.5)	9.6 (7.3,12.0)
White				
Underweight	0.7 (0.6,0.8)	0.8 (0.7,1.0)	N/A	N/A
Normal weight	Reference	Reference	Reference	Reference
Overweight	1.6 (1.5,1.7)	1.5 (1.4,1.7)	9.0 (7.4,10.4)	8.8 (7.2,10.3)
Obese	2.4 (2.2,2.6)	2.3 (2.1,2.5)	11.3 (10.0,12.6)	10.9 (9.6,12.1)
Extremely obese	3.6 (3.3,3.9)	3.1 (2.9,3.4)	16.5 (15.2,17.8)	14.0 (12.8,15.3)
Black				
Underweight	0.9 (0.6,1.2)	1.0 (0.7,1.3)	N/A	N/A
Normal weight	Reference	Reference	Reference	Reference
Overweight	1.7 (1.6,2.0)	1.5 (1.3,1.7)	10.3 (8.0,12.1)	7.8 (5.4,9.9)
Obese	2.6 (2.3,2.9)	2.1 (1.9,2.3)	15.4 (13.5,17.2)	12.2 (10.4,14.2)
Extremely obese	3.3 (3.0,3.7)	2.6 (2.3,2.9)	22.4 (20.4,24.4)	18.1 (16.0,20.2)

[a] Model adjusted for age, gestational weight gain, education, marital status, parity, tobacco use during pregnancy, pre-pregnancy hypertension, and pregnancy hypertension. Models were also adjusted for race when not stratified by race

Interestingly, when comparing RR for overweight among the different racial/ethnic groups, we can see that there is not much difference in the strength of the association. However, when looking at the PAF due to overweight we see that the PAF is higher among Hispanic women compared to White and Black women. This is related to the higher prevalence of overweight in Hispanic women compared to the prevalence in White and Black women. Also, the proportion of GDM attributable to extreme obesity is highest among Blacks; even though the risk of GDM among women with extreme obesity is lowest among Black women. This is a result of a larger proportion of Black women who are extremely obese compared to White and Hispanic women. We can see that the PAF is dependent on the strength of the association as well as the prevalence of overweight and obesity in the population. This is important to note when planning and implementing prevention efforts.

Strengths

There are several strengths that benefit our investigation. We had information available for women both during pregnancy and 2 years prior to pregnancy from hospital discharge data. This allowed for appropriate exclusions based on previous diabetes diagnosis. Another strength is the ability to stratify by racial/ethnic group. Because of the population distribution in South Carolina and the large proportion of minorities, especially Blacks, we had adequate sample size to stratify by race/ethnicity and assess differences in the association between BMI and GDM. Also, we had the ability to control for a number of potential confounders. Analysis was also carried out adjusting for start of prenatal care ($\leq$ 12 weeks or $>$ 12 weeks) to account for differences in access to health care. Although significant, this did not alter the association between BMI and GDM. Also, analysis was carried out excluding women < 16 years of age to determine the effect of differences in BMI calculation. This did not alter the association between BMI and GDM.

Limitations

Although we had the ability to estimate the proportion of GDM cases attributable to overweight and obesity among different racial/ethnic groups, there are some limitations to our study. First, it is possible that we underestimated GDM prevalence. We took a conservative approach in classifying GDM and assumed that all type 2 diabetes mellitus diagnoses during pregnancy were not misclassified GDM cases. On the other hand, we also acknowledge that women with less access to healthcare may have been diagnosed with diabetes for the first time during pregnancy. In this case, pre-existing diabetes may be misclassified as GDM. Second, we used BMI as a measure of overweight and obesity and understand that it is not a perfect measure of adiposity. Also, pre-pregnancy BMI may not be accurate if the data on birth certificates are based on women's self-report and if the women started prenatal care late. This has been a common problem for all population-based studies using data from birth certificates; although a study by Park et al. [37] revealed minimal differences between birth certificate BMI when validated against Woman, Infants, and Children (WIC) data. Also, we did not have information on diet, physical activity, or fitness, which are important modulators of diabetes and pre-diabetes.

Conclusions

Women who are overweight or obese are at a significantly elevated risk of developing GDM, regardless of race/ethnicity. The proportion of GDM cases that are attributable to overweight is the largest among Hispanic women compared to White and Black women. The proportion of GDM attributable to extreme obesity is the largest among Black women followed by White then Hispanic women. Overall, we can see that a large proportion of the GDM among all race/ethnicity groups can be explained by excessive pre-pregnancy weight. Public health programs should aim to raise awareness among women of child bearing age.

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Conflicts of interest The authors declare that they have no conflict of interest.

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