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ORIGINAL RESEARCH

Trends in Prepregnancy Obesity and Association With Adverse Pregnancy Outcomes in the United States, 2013 to 2018

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BACKGROUND: The prevalence of obesity in the population has increased in parallel with increasing rates of adverse pregnancy outcomes (APOs). Quantifying contemporary trends in prepregnancy obesity and associations with interrelated APOs (preterm birth, low birth weight, and pregnancy-associated hypertension) together and individually can inform prevention strategies to optimize cardiometabolic health in women and offspring.

METHODS AND RESULTS: We performed a serial, cross-sectional study using National Center for Health Statistics birth certificate data including women aged 15 to 44 years with live singleton births between 2013 and 2018, stratified by race and ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Asian). We quantified the annual prevalence of prepregnancy obesity (body mass index ≥30.0 kg/m^2; body mass index ≥27.5 kg/m^2 if non-Hispanic Asian). We then estimated adjusted associations using multivariable logistic regression (odds ratios and population attributable fractions) for obesity-related APOs compared with normal body mass index (18.5–24.9 kg/m^2; 18.5–22.9 kg/m^2 if non-Hispanic Asian). Among 20 139 891 women, the prevalence of prepregnancy obesity increased between 2013 and 2018: non-Hispanic White (21.6%–24.8%), non-Hispanic Black (32.5%–36.2%), Hispanic (26.0%–30.5%), and non-Hispanic Asian (15.3%–18.6%) women (*P*-trend < 0.001 for all). Adjusted odds ratios (95% CI) for APOs associated with obesity increased between 2013 and 2018, and by 2018, ranged from 1.27 (1.25–1.29) in non-Hispanic Black to 1.94 (1.92–1.96) in non-Hispanic White women. Obesity was most strongly associated with pregnancy-associated hypertension and inconsistently associated with preterm birth and low birth weight. Population attributable fractions of obesity-related APOs increased over the study period: non-Hispanic White (10.6%–14.7%), non-Hispanic Black (3.7%–6.9%), Hispanic (7.0%–10.4%), and non-Hispanic Asian (7.4%–9.7%) women (*P*-trend < 0.01 for all).

CONCLUSIONS: The prevalence of prepregnancy obesity and burden of obesity-related APOs have increased, driven primarily by pregnancy-associated hypertension, and vary across race and ethnicity subgroups.

Key Words: adverse pregnancy outcomes ■ obesity ■ primordial prevention ■ population attributable fraction ■ racial disparities

Adverse pregnancy outcomes (APOs), including preterm birth, low birth weight, gestational hypertension, and preeclampsia, are highly prevalent and complicate nearly 1 in every 5 pregnancies in the United States.[1] Although phenotypically different, these APOs appear to share a common pathogenesis related to defective placental vascular development.[2] The prevalence of APOs has been increasing in recent years,[1,3,4] and significant racial disparities exist, with higher rates of APOs among non-Hispanic Black women compared with non-Hispanic White women.[3,5] APOs are now an established risk factor for cardiovascular disease (CVD) in women, and emerging data suggest intergenerational transmission of CVD risk,

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CLINICAL PERSPECTIVE

What Is New?

- The prevalence of prepregnancy obesity increased between 2013 and 2018 across all major race and ethnicity groups in the United States, with a concurrent increase in the obesity-associated burden of adverse pregnancy outcomes (preterm birth, low birth weight, and pregnancy-associated hypertension).

What Are the Clinical Implications?

- These findings highlight maternal obesity as a growing major public health concern, with targeted efforts needed in women of reproductive age to reverse unfavorable trends in prepregnancy obesity and prevent the long-term consequences of obesity and adverse pregnancy outcomes.

Nonstandard Abbreviations and Acronyms

APO	adverse pregnancy outcome
HAPO	Hyperglycemia and Adverse Pregnancy Outcomes
PAF	population attributable fraction

with higher likelihood of premature CVD in offspring of women who experience APOs compared with offspring from uncomplicated pregnancies.[5–10] As a result, the American Heart Association and the American College of Obstetrics and Gynecology have issued a joint statement highlighting the importance of addressing cardiometabolic health across the reproductive life course, including optimization of a healthy body weight before conception.[11]

Prepregnancy obesity is a key modifiable risk factor for the development of APOs.[12,13] Given the increasing prevalence of obesity in the United States, especially among younger women of reproductive age and in race and ethnicity minority groups, it is important to determine race and ethnicity-specific trends in maternal obesity and its association with APOs. The population attributable fraction (PAF) is a useful public health metric that accounts for both the prevalence of maternal obesity and the excess risk of APOs associated with obesity. Trends in the PAF can assess the changing population health burden associated with obesity and help motivate changes in preventive strategies and public health policies to improve long-term cardiometabolic health. However, contemporary national estimates for, as well as recent patterns in prevalence of maternal obesity and the obesity-related burden of APOs, are lacking. Therefore, we sought to examine nationwide temporal trends and associations of prepregnancy obesity with APOs in the United States between 2013 and 2018, stratified by race and ethnicity.

METHODS

Data Source and Study Population

All data and materials are made publicly available by the National Center for Health Statistics and can be accessed at https://www.cdc.gov/nchs/nvss/births.htm.

We performed a serial, cross-sectional, national study using data from birth registration records released annually by the National Center for Health Statistics within the Centers for Disease Control and Prevention, which captures 100% of all live births in the United States (50 US states and the District of Columbia).[14] Birth certificates are completed by the medical professional present at delivery on the basis of established National Center for Health Statistics protocols. Specifically, prepregnancy body mass index (BMI) was incorporated in the 2003 standard birth certificate revision. States gradually phased in the new birth certificate; by 2013, the new birth certificate covered >90% of live births to US residents. Therefore, we chose 2013 as the starting year for our study. By 2016, the new birth certificate covered 100% of live births, making overall coverage of the birth certificate during the study period well over 90%. This study was exempt from review by the Institutional Review Board because of the deidentified nature of the publicly available data set, and no informed consent was required.

Figure 1 shows the selection of our analytic population. Of 23 550 072 live births between 2013 and 2018 in the United States, 22 961 760 (97.5%) used the revised birth certificate and thus recorded prepregnancy BMI. We included maternal data from all women aged 15 to 44 years who were US residents, had singleton births, and self-identified as 1 of 4 major race and ethnicity groups in the United States by population size: non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Asian. These 4 race and ethnicity groups covered 96.7% of births. For the primary analysis, we excluded women with diagnoses of prepregnancy hypertension (361 780; 1.7%) or prepregnancy diabetes mellitus (176 515; 0.8%) to focus on women without prominent prepregnancy risk factors other than obesity. We also excluded 716 112 (3.4%) observations missing data on the exposure (prepregnancy BMI) or outcome (gestational age, birth weight, and

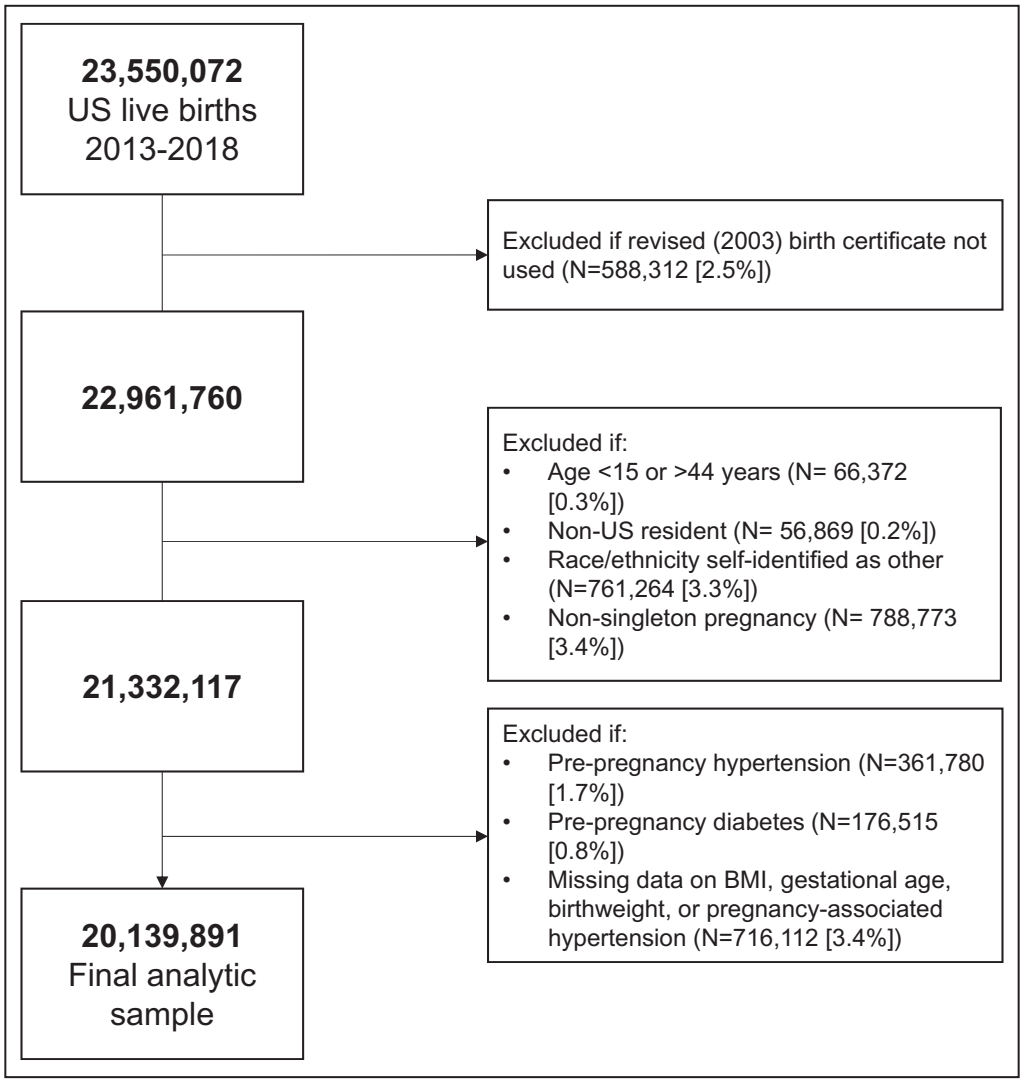

Figure 1. Flow diagram for the final analytic sample representing the study population.
From the initial population of all live births in the United States between 2013 and 2018 (N=23 550 072), we first excluded records using the unrevised (1989) birth certificate, which did not report prepregnancy body mass index. We then applied the following inclusion criteria: maternal age, 15–44 years; US resident; self-identified as non-Hispanic White, non-Hispanic Black, Hispanic, or non-Hispanic Asian; and singleton pregnancy. Finally, we applied the following exclusion criteria: prepregnancy hypertension; prepregnancy diabetes mellitus; or missing data on prepregnancy BMI, gestational age, birth weight, or pregnancy-associated hypertension. Our final analytic sample contained 20 139 891 live births. BMI indicates body mass index.

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Exposure and Outcome Defintions

The exposure for the analysis was prepregnancy obesity. For non-Hispanic White, non-Hispanic Black, and Hispanic women, we used standardized BMI categories according to the World Health Organization to classify maternal prepregnancy BMI into 4 categories: underweight (BMI <18.5 kg/m^2), normal or healthy weight (BMI between 18.5 and 24.9 kg/m^2), overweight (BMI between 25.0 and 29.9 kg/m^2), and obese (BMI ≥30.0 kg/m^2). For non-Hispanic Asian women, we used modified BMI categories as recommended by the World Health Organization for Asian populations,[15] with specific cutoffs that were used in a prior study of Asian Americans:[16] underweight (BMI <18.5 kg/m^2), normal or healthy weight (BMI between 18.5 and 22.9 kg/m^2), overweight (BMI between 23.0 and 27.4 kg/m^2), and obese (BMI ≥27.5 kg/m^2).

For the outcome, we defined APO a priori as a composite of preterm birth (defined as gestational age at delivery <37 weeks), low birth weight (defined

as birth weight <2500 g), or pregnancy-associated hypertension (defined as gestational hypertension or preeclampsia) based on National Center for Health Statistics definitions.[17,18] We used this definition, similar to prior publications,[19,20] based on the interrelated vascular nature of these complications that are theorized to share a common pathogenesis and have similar cardiometabolic risk implications for future maternal and offspring health.[2] Consistent with official tabulations of vital statistics, we used the obstetric estimate of gestational age, rather than the last menstrual period estimate, to determine preterm birth.[21] Hypertensive disorders of pregnancy are categorized in birth certificates as prepregnancy (chronic) hypertension, gestational hypertension (a categorization that also includes preeclampsia), and eclampsia. We included the gestational hypertension category in our outcome, with or without eclampsia, and excluded prepregnancy hypertension. We also investigated small for gestational age (SGA) as a secondary outcome. SGA was defined as a birth weight less than the 10th percentile for gestational age based on the Alexander curve.[22]

Covariates

We adjusted analyses for maternal age, maternal education level (less than high school, high school graduate, or greater than high school), receipt of prenatal care (versus no prenatal care), private insurance (versus other payment method), smoking during pregnancy (versus no smoking during pregnancy), and parity (nulliparous or multiparous). Approximately 5.0% of observations were missing data on any covariate. Because of the low level of missingness, we conducted a complete case analysis.

Statistical Analysis

Descriptive statistics were calculated. Given well-established race and ethnicity disparities in rates of obesity and APOs, we stratified by race and ethnicity a priori. Within each race and ethnicity group and for each year between 2013 and 2018, we calculated the percentage of women in each prepregnancy BMI category and annual unadjusted rates of APOs per 1000 live births stratified by BMI category. We tested for differences between race and ethnicity groups using χ^2 tests for BMI categories and single-factor ANOVA for APOs. We examined linear trends in rates of obesity and APOs using univariate linear regression with year as a continuous variable.

Next, we assessed associations between BMI (both continuous and categorical) and APOs. We visually assessed associations between continuous BMI and APOs over time using conditional expectation functions. For each race and ethnicity group, we plotted the conditional expectation of APO rate on BMI, adjusted for age, using 20 equal-sized bins, and superimposed separate linear fit lines within each BMI category in 2013 and 2018. To assess categorical associations between prepregnancy BMI and APOs for each year, we estimated odds ratios (ORs) and 95% CIs between prepregnancy BMI categories and APOs using multivariable logistic regression models with normal BMI (18.5–24.9 kg/m^2) as the referent and adjusted for age, education, prenatal care, private insurance, smoking during pregnancy, and parity. We calculated the PAFs (and 95% CIs) of each prepregnancy BMI category for APOs relative to normal BMI per year between 2013 and 2018. We used the Stata module *punaf* to calculate PAF, which has been previously described in detail (see also Data S1).[23] In brief, this statistical module uses the logistic regression results to estimate predicted population APO prevalences (termed *margins* or *marginal prevalences*) under 2 scenarios: the observed categorical BMI distribution in the population and a counterfactual scenario in which prepregnancy obesity is eliminated from the population. The ratio of these 2 predicted margins (subtracted from 1) is the PAF. The PAF ranges from 0 to 1, which we translated into percentages (0% to 100%). The formula used in the PAF calculations is valid for adjusted ORs, which are used in this study.[24] We tested for linear trends in PAFs using linear regression of the PAF point estimates on year as a continuous variable.

In secondary analyses, we repeated the logistic regression and PAF analysis for each APO separately, for women who had more than 1 APO, and for women who had an SGA birth. We performed sensitivity analyses reincluding women with prepregnancy hypertension and prepregnancy diabetes mellitus, who were excluded from the primary analysis, as well as nulliparous women. For all analyses, we used Stata 15.1, and we considered statistical significance for a P value <0.05.

RESULTS

Analytic Sample Demographics

Of the women aged 15 to 44 years who had 20 139 891 live births between 2013 and 2018, 54.6% were non-Hispanic White, 14.3% were non-Hispanic Black, 24.3% were Hispanic, and 6.8% were non-Hispanic Asian (Table 1). Mean age (SD) at delivery was 28.5 (5.8) years. Women with prepregnancy obesity were more likely to be non-Hispanic Black or Hispanic and multiparous than women who entered pregnancy with a normal BMI. Women who were underweight before pregnancy were younger on average than women with a normal BMI and more likely to report smoking during pregnancy.

Table 1. Maternal Characteristics in Analytic Sample Stratified by Prepregnancy BMI in the United States, 2013 to 2018

Prepregnancy BMI Category	Underweight*	Normal Weight*	Overweight*	Obese*
N	732 468	8 903 495	5 383 354	5 120 574
Age, y, mean (SD)	26.4 (5.8)	28.3 (5.8)	28.8 (5.7)	28.7 (5.6)
Race/ethnicity, n (%)				
Non-Hispanic White	395 028 (53.9%)	5 363 215 (60.2%)	2 706 005 (50.3%)	2 535 515 (49.5%)
Non-Hispanic Black	97 451 (13.3%)	1 010 951 (11.4%)	782 460 (14.5%)	987 985 (19.3%)
Hispanic	131 923 (18.0%)	1 913 003 (21.5%)	1 469 952 (27.3%)	1 371 293 (26.8%)
Non-Hispanic Asian	108 066 (14.8%)	616 326 (6.9%)	424 937 (7.9%)	225 781 (4.4%)
Education, n (%)				
Less than high school	130 615 (18.0%)	1 139 121 (12.9%)	796 783 (14.9%)	746 865 (14.7%)
High school graduate	213 258 (29.4%)	2 015 736 (22.8%)	1 331 614 (24.9%)	1 481 035 (29.1%)
Greater than high school	382 565 (52.7%)	5 687 683 (64.3%)	3 214 097 (60.2%)	2 858 679 (56.2%)
Private insurance, n (%)	292 319 (40.2%)	4 699 514 (53.2%)	2 595 779 (48.5%)	2 216 584 (43.6%)
Received prenatal care, n (%)	697 113 (98.0%)	8 559 030 (98.6%)	5 185 055 (98.6%)	4 942 637 (98.7%)
Smoked during pregnancy, n (%)	90 968 (12.6%)	613 630 (7.0%)	350 456 (6.6%)	407 057 (8.1%)
Multiparous, n (%)	374 068 (51.2%)	5 048 186 (56.9%)	3 389 703 (63.2%)	3 410 340 (66.8%)

BMI indicates body mass index.

*Underweight: <18.5 kg/m^2; normal weight: 18.5–24.9 kg/m^2, 18.5–22.9 kg/m^2 for non-Hispanic Asian women; overweight: 25.0–29.9 kg/m^2, 23.0–27.4 kg/m^2 for non-Hispanic Asian women; obese: ≥30.0 kg/m^2, ≥27.5 kg/m^2 for non-Hispanic Asian women.

Trends in Prepregnancy Obesity

Across all race and ethnicity groups, the proportion of prepregnancy normal BMI decreased, while the prevalence of prepregnancy obesity increased between 2013 and 2018 (Figure 2). For example, in Hispanic women, the percentage of normal prepregnancy BMI decreased from 41.4% in 2013 to 36.5% in 2018 (P<0.001), while the prevalence of obesity increased from 26.0% in 2013 to 30.5% in 2018 (P<0.001) (Table S1). There were large differences by race and ethnicity; in 2018, the percentage of women with normal prepregnancy BMI ranged from 33.3% in non-Hispanic Black women to 46.6% in non-Hispanic White women (P<0.001), while the prevalence of prepregnancy obesity ranged from 18.6% in non-Hispanic Asian women to 36.2% in non-Hispanic Black women (P<0.001). The prevalence of underweight prepregnancy BMI was low and slightly downtrended between 2013 and 2018; for example, in Hispanic women, the prevalence of underweight BMI was 2.9% in 2013 and 2.4% in 2018 (P<0.001).

Trends in Unadjusted APO Rates According to BMI Categories

The unadjusted rate of APOs in the United States increased between 2013 and 2018 across all race and ethnicity groups and for all BMI categories except underweight (Figure 3). This increase was greatest among women with prepregnancy obesity; for example, in Hispanic women, the rate of APOs per 1000 live births increased from 139.6 in 2013 to 170.7 in 2018 for women with prepregnancy obesity (P<0.001), a 22% increase, compared with 110.0 in 2013 to 125.4 in 2018 for women at normal BMI (P<0.001), a 14% increase (Table S2). Women with prepregnancy obesity consistently had a higher rate of APOs than those with overweight or normal BMIs. Unadjusted annual rates of APOs were consistently different by race and ethnicity; in 2018, APO rates per 1000 live births for women with prepregnancy obesity were 200.6 for non-Hispanic White, 231.4 for non-Hispanic Black, 170.7 for Hispanic, and 171.3 for non-Hispanic Asian women (P<0.001).

Association Between Prepregnancy BMI and APOs

The relationship between continuous prepregnancy BMI and APOs for all race and ethnicity groups was J-shaped in each year, with both underweight and obesity associated with higher risk of APOs compared with normal BMI (Figure 4). Within overweight and obesity strata, the association between continuous BMI and APO risk increased between 2013 and 2018; that is, the slopes of the linear splines for overweight and obesity increased between 2013 and 2018. In 2018, prepregnancy obesity had the strongest association with APOs in non-Hispanic White women (OR, 1.94; 95% CI, 1.92–1.96) and the weakest association with APOs in non-Hispanic Black women (OR, 1.27; 95% CI, 1.25–1.29) (Table 2). The OR of prepregnancy obesity increased for all race and ethnicity groups between 2013 and 2018; for example, in Hispanic women, OR for obesity increased from 1.35 (95% CI, 1.32–1.37) to 1.48 (95% CI, 1.45–1.50).

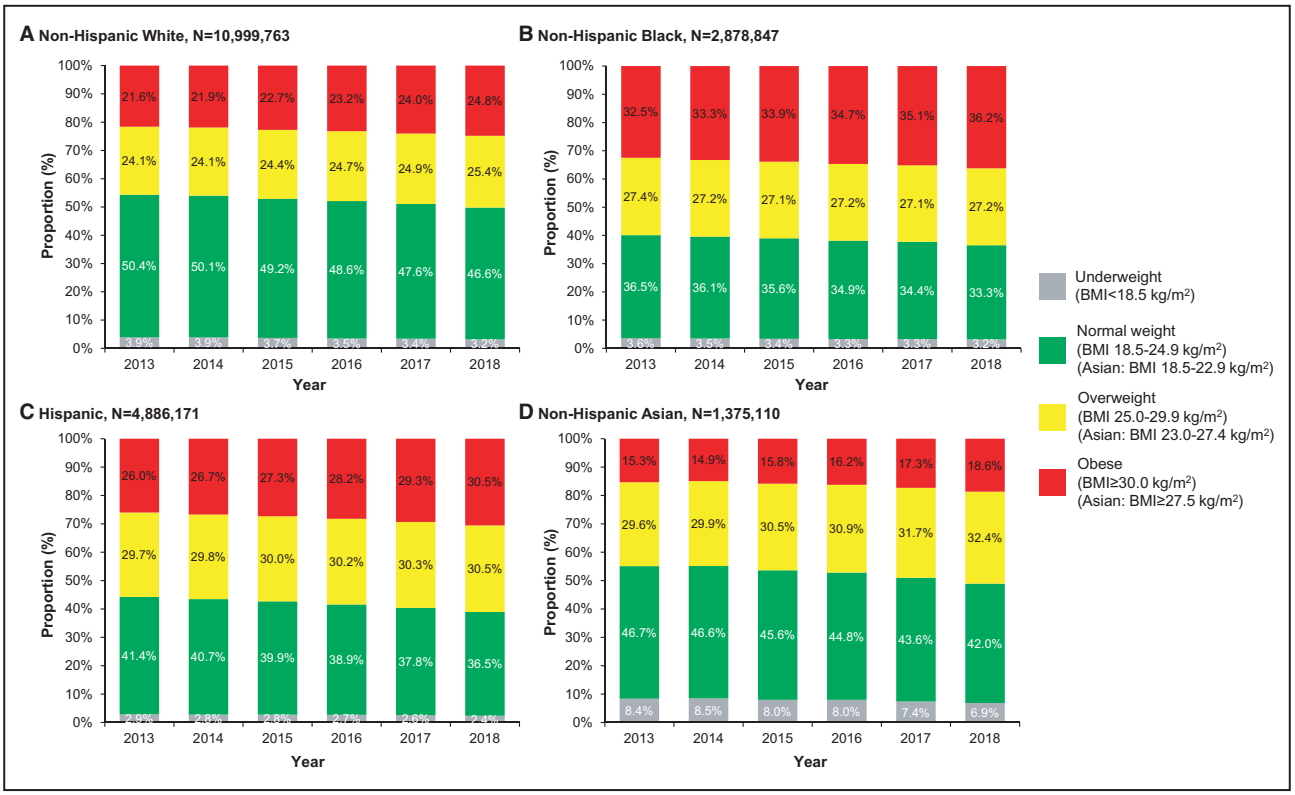

Figure 2. Trends in the percentage of women in each prepregnancy BMI category stratified by race and ethnicity in the United States, 2013 to 2018.

We examined annual trends in the categorical BMI distribution of pregnant women between 2013 and 2018 in (**A**) non-Hispanic White, (**B**) non-Hispanic Black, (**C**) Hispanic, and (**D**) non-Hispanic Asian women. Each year, the proportion of prepregnancy normal BMI decreased while the prevalence of prepregnancy obesity increased across all race and ethnicity groups. There were large differences in the prevalence of prepregnancy obesity by race and ethnicity. BMI indicates body mass index.

PAF for APOs Associated with Prepregnancy Obesity

PAFs for APOs associated with prepregnancy obesity increased between 2013 and 2018 in all race and ethnicity groups (Table 2). In 2018, the PAF for APOs associated with obesity was highest in non-Hispanic White women, 14.7% (95% CI, 14.5–15.0), and lowest in non-Hispanic Black women, 6.9% (95% CI, 6.4–7.4). This represents a potential reduction in APOs by 15% and 7% among non-Hispanic White and non-Hispanic Black women, respectively, if prepregnancy obesity was eliminated and all women began pregnancy with a normal BMI. The PAFs for APOs associated with obesity nearly doubled for non-Hispanic Black women from 3.7% (95% CI, 3.1–4.2) in 2013 to 6.9% (95% CI, 6.4–7.4) in 2018 (P=0.001), and increased in Hispanic women from 7.0% (95% CI, 6.5–7.4) in 2013 to 10.4% (95% CI, 10.0–10.8) in 2018 (P=0.009).

Secondary Analyses

Associations of prepregnancy obesity with individual APOs were strongest for pregnancy-associated hypertension and weakest for low birth weight (Table 2). Correspondingly, PAFs for obesity-related individual APOs were largest for pregnancy-associated hypertension and ranged from 26.5% (25.3–27.6) in non-Hispanic Asian women to 30.3% (30.0–30.7) in non-Hispanic White women in 2018. By contrast, associations of prepregnancy obesity with low birth weight were positive only for non-Hispanic Asian women, with a PAF of 2.4% (1.6–3.2) in 2018. Obesity was positively associated with preterm birth and experiencing >1 APO in all race and ethnicity groups except non-Hispanic Black women. No consistent statistically significant linear trends in PAF were noted for any individual APO across race and ethnicity groups. Obesity was inversely associated with SGA for all race and ethnicity groups (Table S3).

Sensitivity Analyses

In nulliparous women, temporal trends and race and ethnicity differences were similar to the overall population, but OR and PAF for APOs associated with obesity were larger (Table S4). In the sensitivity analysis including women with prepregnancy hypertension or diabetes mellitus, our main results did not change (Table S5).

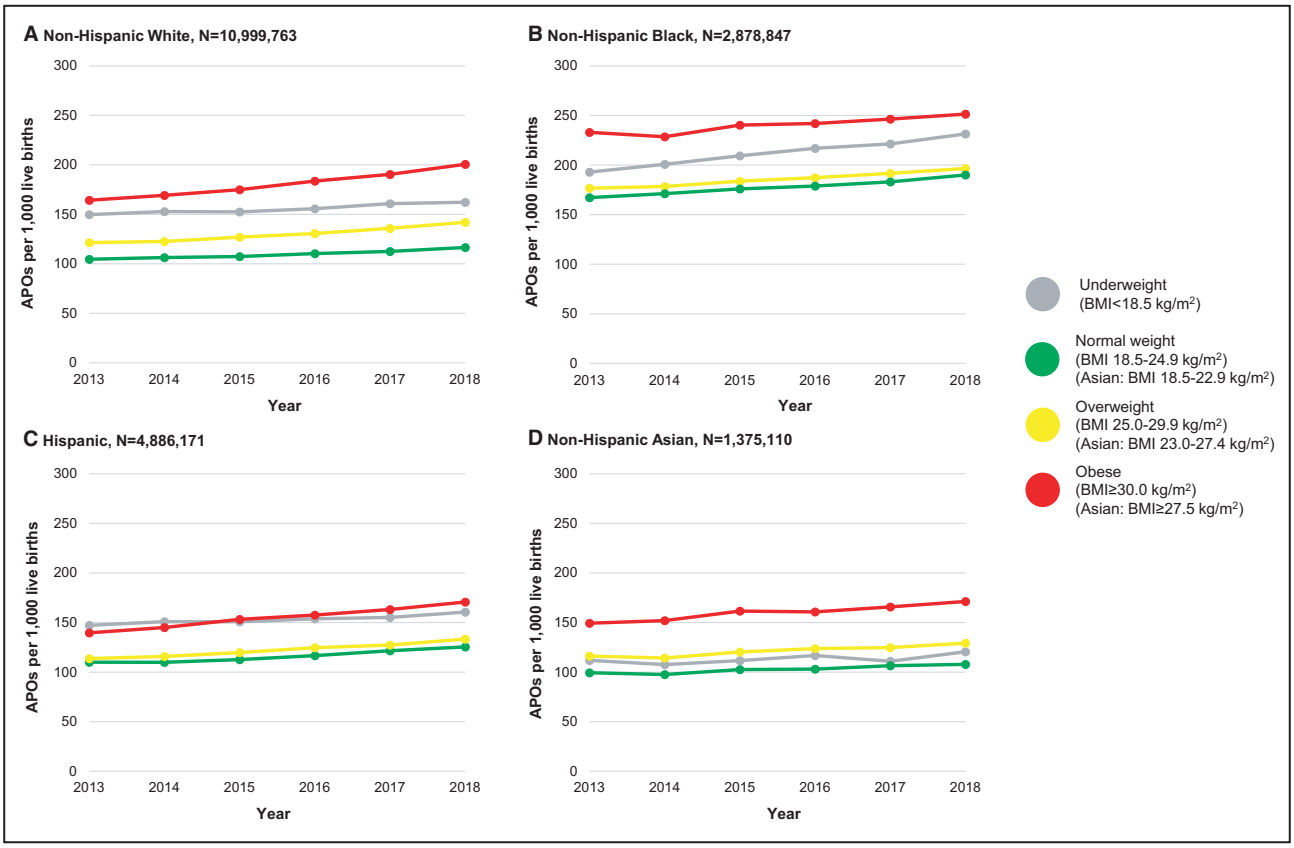

Figure 3. Trends in unadjusted rates of APOs stratified by race and ethnicity and prepregnancy BMI category in the United States, 2013 to 2018.

We examined annual trends in unadjusted APO rates between 2013 and 2018 in (**A**) non-Hispanic White, (**B**) non-Hispanic Black, (**C**) Hispanic, and (**D**) non-Hispanic Asian women stratified by prepregnancy BMI category. The rate of APOs increased between 2013 and 2018 across all race and ethnicity groups and for all BMI categories except underweight. This increase was greatest among women with prepregnancy obesity, who also experienced higher rates of APOs than women with overweight or normal BMI. However, annual rates were consistently different by race and ethnicity. APO indicates adverse pregnancy outcome; and BMI, body mass index.

DISCUSSION

In this national sample of maternal data linked to all live births between 2013 and 2018 in the United States, we identified several key findings regarding the population burden of APOs associated with obesity. First, we demonstrated that the prevalence of prepregnancy obesity increased significantly over this time frame. Second, the greatest increases in rates of APOs occurred among women with prepregnancy obesity. Third, the ORs estimating the risk of APOs associated with obesity compared with a normal BMI increased during the study period. Fourth, the association of prepregnancy obesity with APOs is primarily driven by pregnancy-associated hypertension. Fifth, the relative contribution of maternal obesity toward APOs approximately doubled in non-Hispanic Black and Hispanic women and increased by about 50% in non-Hispanic White and non-Hispanic Asian women. Finally, race and ethnicity disparities in prevalence of obesity and APOs persisted over time.

The absolute values of PAFs for APOs associated with obesity that we observed are within the range of several prior studies (1.0%–36.2%); however, these prior estimates were based on varying APO definitions, derivation cohorts, and BMI categories.[25–29] In the largest previous study to date, Santos et al pooled and analyzed 265 270 births between 1989 and 2014 from 39 cohorts across the United States, Europe, and Oceania and found a composite PAF of 12.5%.[26] We also confirm prior studies noting a strong association between prepregnancy obesity and pregnancy-associated hypertension,[25,26,28] and weaker as well as inconsistent associations between prepregnancy obesity and preterm birth and low birth weight across races/ethnicities when the APO subtypes are examined separately.[26,27] These APO subtypes are hypothesized to arise from a shared pathogenesis related to placental vascular dysfunction, local ischemia, and a resultant systemic proinflammatory and antiangiogenic state, reflected in elevated levels of biomarkers such as soluble

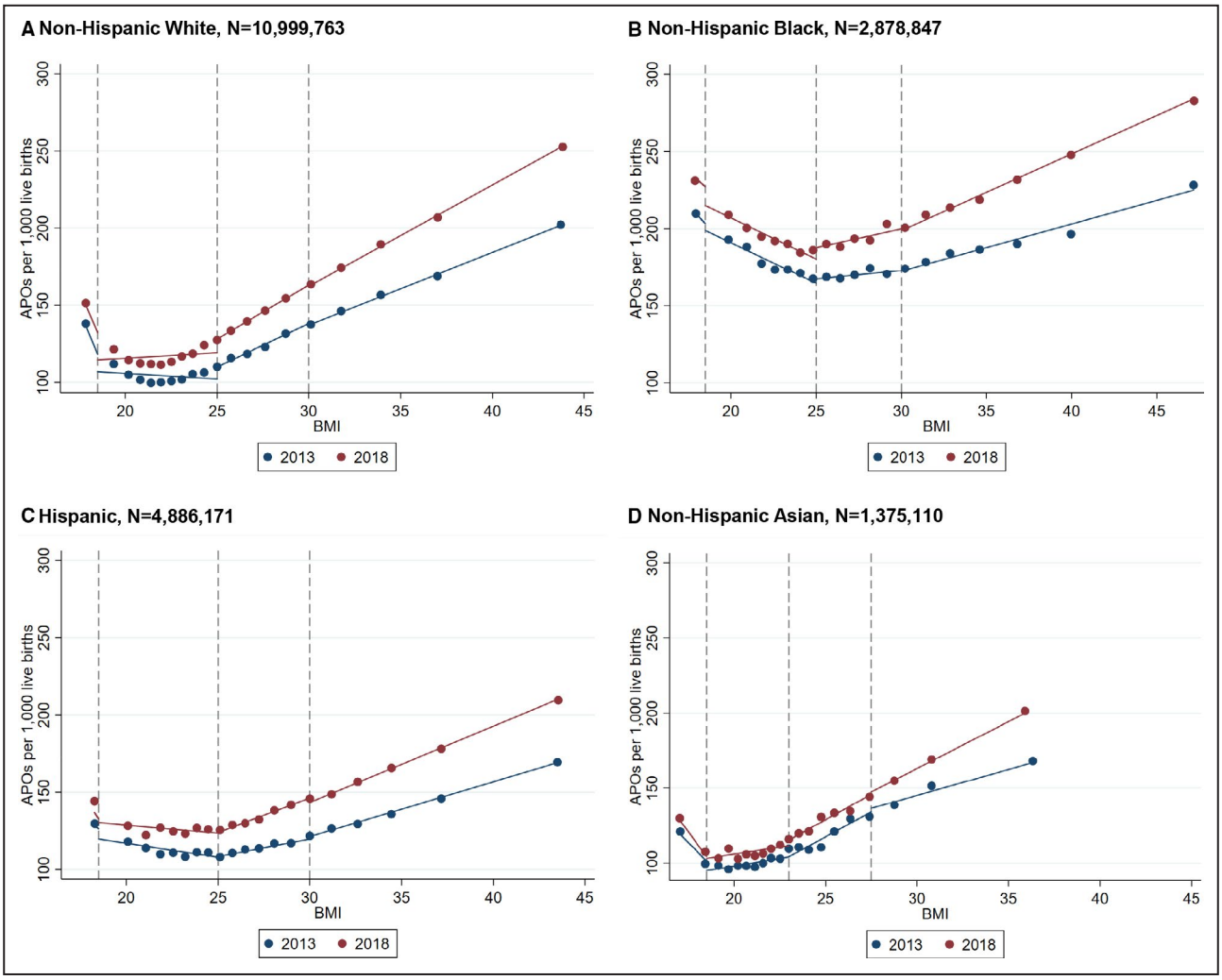

Figure 4. Association between prepregnancy BMI and APOs adjusted for age and stratified by race and ethnicity in the United States, 2013 and 2018.

We assessed associations of continuous prepregnancy BMI with APO in (**A**) non-Hispanic White, (**B**) non-Hispanic Black, (**C**) Hispanic, and (**D**) non-Hispanic Asian women. For each race and ethnicity group, we plotted the conditional expectation of APO rate on BMI, adjusted for age, in 2013 and 2018 using 20 equal-sized bins, and superimposed separate linear fit lines within each BMI category. Vertical dashed lines represent BMI category cut points (18.5 kg/m^2, 25 kg/m^2, and 30 kg/m^2; 18.5 kg/m^2, 23.0 kg/m^2, and 27.5 kg/m^2 in Asian women). There was a J-shaped relationship between continuous prepregnancy BMI and APOs for all race and ethnicity groups, with both underweight and obesity associated with higher risk of APOs compared with normal BMI. Within overweight and obesity strata, the slopes of the linear splines for overweight and obesity increased between 2013 and 2018, suggesting increasing APO risk associated with excess weight. APO indicates adverse pregnancy outcome; and BMI, body mass index.

fms-like tyrosine kinase 1.[2] Although the finding that obesity has differential associations with the APO subtypes, as well as with co-occurrence of APOs, is not necessarily inconsistent with this hypothesis, the grouping of APOs continues to be an area of controversy, and the best analytic approach remains to be determined. Observed heterogeneity across race and ethnicity subgroups may be related to underlying social determinants of health that may affect key factors, such as nutritional status and food insecurity, which have been associated with APOs.[30,31] Inverse associations between obesity and SGA found in this study were also described in the HAPO (Hyperglycemia and Adverse Pregnancy Outcomes) study[32]; however, this finding does not contradict the importance of achieving healthy weight before pregnancy, given the numerous other short- and long-term risks associated with prepregnancy obesity for mothers and their offspring.[33] We add to the existing literature by reporting annual PAFs to provide both estimates and changes over time, which comprehensively depicts the population burden of APOs attributable to prepregnancy obesity. Increases in PAFs have occurred in the context of younger age at onset of obesity[34] and older maternal age at delivery.[3] The combination of these 2 factors may result in a longer

Table 2. Prevalence, Adjusted OR, and PAF for Adverse Pregnancy Outcomes Associated with Prepregnancy Obesity Compared With Normal BMI in the United States, 2013 and 2018

	2013			2018			*P* for Linear Trend
	Prevalence*	OR (95% CI)	PAF (95% CI)	Prevalence*	OR (95% CI)	PAF (95% CI)	PAF
Non-Hispanic White							
Any APO	123.3	1.70 (1.68 to 1.72)	10.6% (10.4 to 10.9)	145.3	1.94 (1.92 to 1.96)	14.7% (14.5 to 15.0)	<0.001
Preterm birth	65.8	1.18 (1.16 to 1.19)	3.4% (3.0 to 3.7)	67.6	1.27 (1.26 to 1.29)	5.8% (5.5 to 6.2)	<0.001
Low birth weight	48.9	0.91 (0.89 to 0.93)	–1.9%† (–2.3 to –1.5)	49.6	0.93 (0.92 to 0.95)	–1.7%† (–2.1 to –1.2)	0.137
Pregnancy-associated hypertension	50.2	3.61 (3.55 to 3.67)	28.8% (28.4 to 29.2)	74.5	3.50 (3.45 to 3.55)	30.3% (30.0 to 30.7)	0.023
>1 APO	36.6	1.28 (1.25 to 1.30)	5.3% (4.8 to 5.8)	39.8	1.42 (1.39 to 1.45)	8.7% (8.2 to 9.2)	<0.001
Non-Hispanic Black							
Any APO	181.4	1.15 (1.12 to 1.17)	3.7% (3.1 to 4.2)	209.1	1.27 (1.25 to 1.29)	6.9% (6.4 to 7.4)	0.001
Preterm birth	103.4	0.94 (0.91 to 0.96)	–1.9%† (–2.7 to –1.2)	108.9	0.99 (0.97 to 1.02)	–0.3%† (–1.0 to 0.5)	0.107
Low birth weight	103.4	0.80 (0.78 to 0.82)	–6.4%† (–7.1 to –5.7)	110.7	0.80 (0.78 to 0.82)	–7.1%† (–7.8 to –6.3)	0.208
Pregnancy-associated hypertension	59.2	2.37 (2.29 to 2.45)	26.6% (25.6 to 27.5)	86.3	2.37 (2.31 to 2.43)	28.2% (27.4 to 28.9)	0.172
>1 APO	73.7	0.98 (0.95 to 1.01)	–0.5%† (–1.4 to 0.4)	81.5	1.01 (0.99 to 1.04)	0.5% (–0.5 to 1.4)	0.518
Hispanic							
Any APO	119.9	1.35 (1.32 to 1.37)	7.0% (6.5 to 7.4)	142.5	1.48 (1.45 to 1.50)	10.4% (9.9 to 10.8)	0.009
Preterm birth	74.2	1.16 (1.14 to 1.19)	3.7% (3.2 to 4.3)	79.2	1.21 (1.18 to 1.23)	5.5% (4.9 to 6.1)	0.023
Low birth weight	56.2	0.93 (0.90 to 0.95)	–1.8%† (–2.4 to –1.1)	59.3	0.91 (0.89 to 0.94)	–2.5%† (–3.2 to –1.8)	0.264
Pregnancy-associated hypertension	36.2	2.70 (2.61 to 2.78)	25.8% (25.0 to 26.6)	57.5	2.57 (2.51 to 2.63)	27.3% (26.6 to 27.9)	0.705
>1 APO	41.3	1.21 (1.17 to 1.24)	4.8% (4.0 to 5.5)	46.0	1.25 (1.21 to 1.28)	6.5% (5.7 to 7.3)	0.058
Non-Hispanic Asian							
Any APO	113.1	1.67 (1.61 to 1.74)	7.4% (6.8 to 8.0)	127.5	1.77 (1.71 to 1.83)	9.7% (9.1 to 10.3)	0.003
Preterm birth	66.6	1.46 (1.38 to 1.53)	5.7% (4.9 to 6.5)	67.9	1.48 (1.42 to 1.55)	7.1% (6.3 to 8.0)	0.127
Low birth weight	63.8	1.15 (1.09 to 1.22)	2.0% (1.2 to 2.8)	66.8	1.15 (1.10 to 1.21)	2.4% (1.6 to 3.2)	0.317
Pregnancy-associated hypertension	26.6	3.93 (3.65 to 4.23)	24.2% (22.6 to 25.6)	41.1	3.80 (3.60 to 4.01)	26.5% (25.3 to 27.6)	0.168
>1 APO	39.6	1.52 (1.42 to 1.62)	6.4% (5.3 to 7.5)	42.4	1.64 (1.55 to 1.74)	9.3% (8.2 to 10.5)	0.040

APO indicates adverse pregnancy outcome; BMI, body mass index; OR, odds ratio; and PAF, population attributable fraction.
*Per 1000 live births.
†Negative PAF reflects OR <1, ie, higher risk in women with normal weight compared with women with obesity.

potential duration of obesity before pregnancy and may contribute to risk of APOs through underlying mechanisms of inflammation, oxidative stress, and endothelial function. In addition, increasing rates of prehypertension and pre–diabetes mellitus among women of reproductive age may be another reason why we observed increases in the risk relationship between obesity and APOs over time.

Our findings highlight maternal obesity as a growing major public health concern. Between 2013 and 2018, the percentage of women with a normal BMI prepregnancy decreased while the percentage of women with prepregnancy obesity increased across all race and ethnicity groups. By 2018, only 1 in 3 non-Hispanic Black women began pregnancy at normal BMI. Both obesity and APOs have been linked to subsequent cardiovascular risk in women, including incident hypertension,[19,35,36] development of CVD,[7–9,37,38] and all-cause mortality.[10,39–43] In addition, obesity and APOs are recognized as risk factors for excess weight, elevated blood pressure, and CVD in offspring that may reflect possible adverse effects of programming in utero and intergenerational transmission of CVD risk.[44,45] Importantly, the prevalence of prepregnancy obesity in our study (26.8% in 2018) was lower than national estimates of obesity among all women of reproductive

age (39.7%),[46] which may lead to an underestimation of the population burden attributable to obesity. This may be related to the exclusion of maternal data on fetal deaths or women who were unable to become pregnant in our sample who are more likely to have severe obesity. Alternatively, prepregnancy obesity may have been underestimated in our study. However, we observed similar increases in prepregnancy BMI across all race and ethnicity groups over the study period compared with the general population.

Our analysis further expands upon previous studies that have identified significant racial disparities in obesity and APOs with higher absolute rates among non-Hispanic Black women compared with non-Hispanic White women. While non-Hispanic Black women with prepregnancy obesity had a higher absolute rate of APOs than non-Hispanic White women with prepregnancy obesity (231.4 versus 200.6 per 1000 live births in 2018), the disparity was more pronounced within women with normal prepregnancy BMI; nearly 1 in 5 non-Hispanic Black women with prepregnancy normal BMI experienced an APO in 2018, compared with just under 1 in 9 non-Hispanic White women at normal BMI. This may explain our finding that ORs for APOs associated with obesity were higher for non-Hispanic White and non-Hispanic Asian women than for non-Hispanic Black women, as there was a nearly 2-fold difference in risk in the reference groups in 2018. Although women with a known diagnosis of prepregnancy diabetes mellitus or hypertension were excluded from the primary analysis, subclinical elevations in preconception blood pressure have been associated with risk of APOs.[47] Differences in modifiable risk factors not meeting clinical thresholds warrant increased awareness, screening, and focused prevention to optimize prepregnancy cardiometabolic health and improve pregnancy-related and longer-term outcomes for women and offspring. Inequality in access to prenatal care likely contributes to the disparity,[48] as well as individual and neighborhood-level social determinants of health, as has been found for hypertension, diabetes mellitus,[49] and CVD.[50] Addressing these factors as well as root causes of health inequities, such as structural racism,[51] are necessary to equitably improve maternal health for all.

This study has several limitations. First, there is a potential for miscoding. However, prepregnancy height and weight and ascertainment of APOs were based on data recorded by the healthcare professional at delivery and use standardized protocols to integrate information from maternal report and medical record abstraction. Second, validation studies suggest limited sensitivity but high specificity for prepregnancy hypertension and diabetes mellitus,[52,53] implying that the exclusion of these conditions may have missed some cases. However, the sensitivity analysis reincluding these conditions yielded similar results. Third, our study likely underestimates true population rates of APOs given that birth certificates usually underestimate the prevalence of pregnancy-associated hypertension, and data collection ends at delivery and does not capture postpartum preeclampsia. However, a key strength is the use of all live births in the United States to allow for robust, generalizable estimates stratified by race and ethnicity. Fourth, the serial cross-sectional design of the study included multiparous women (60.9%), some of whom could have had repeat pregnancies during the study period, but our sensitivity analysis from nulliparous women reported similar patterns and temporal increases in PAF. Fifth, although the focus of this study was on vascular-related APOs, gestational diabetes mellitus is an important pregnancy outcome for future study of obesity-related risk. Additionally, we examined vascular-related APOs as a composite and individually to account for the possibility that prepregnancy obesity may have differential associations with each APO subtype. Finally, our analysis did not account for other important modifiable risk factors, such as physical inactivity and poor-quality diet.

In this nationwide study of all live births in the United States, the prevalence of prepregnancy obesity and the relative contribution of maternal obesity toward APOs significantly increased between 2013 and 2018 in all race and ethnicity groups. While risk for APOs was associated with prepregnancy obesity in 1 in 7 to 1 in 14 women in 2018, targeting excess weight before conception represents a key modifiable risk factor that is rapidly increasing and may be driving unfavorable trends in APOs, in contrast with risk associated with age and other nonmodifiable factors (eg, family history, nulliparity). Finally, these data also highlight the need to address persistent racial disparities in APOs that are accounted for, only in part, by prepregnancy obesity, and may be more broadly related to access to high-quality health care before conception and during pregnancy. Addressing underlying social determinants of health is also necessary to equitably improve cardiometabolic health and reverse recent unfavorable trends in rates of APOs.

ARTICLE INFORMATION

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Disclosures

None.

Supplementary Material

Data S1
Table S1–S5

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SUPPLEMENTAL MATERIAL

Data S1.

SUPPLEMENTAL METHODS

Statistical Analysis

The mathematical definition of population attributable fraction (PAF) has been described by Rockhill et al. as:[20]

$$\frac{P(D) - \sum_C P(D|\bar{C}, \bar{E})P(C)}{P(D)}$$

where $P(D)$ is the probability of disease in the population and $\sum_C P(D|\bar{C}, \bar{E})P(C)$ is the marginal conditional probability of disease averaged over a set of confounders (C) and counterfactual exposures (E). The division by $P(D)$ in the denominator makes the PAF a relative statistic, rather than an absolute statistic (which would be the population attributable risk).

We used the Stata module *punaf* to calculate PAF.[19] This module operationalizes the definition by Rockhill et al. by using a logistic regression model to estimate predicted margins of population APO prevalence under two scenarios specified by the user. For our study, we used normal BMI as the referent in our regression models and specified the scenarios as follows: first, the observed categorical BMI distribution in the population, representing $P(D)$, and second, a counterfactual scenario in which a non-ideal BMI category, such as obesity, is eliminated from the population, representing $\sum_C P(D|\bar{C}, \bar{E})P(C)$. The ratio of these two quantities (subtracted from 1) is the PAF. This approach produces PAF estimates that are valid when odds ratios (OR) of the exposure are adjusted for covariates.[20]

Table S1. Trends in the prevalence of pre-pregnancy body mass index categories stratified by race/ethnicity, 2013-2018.

	2013	2014	2015	2016	2017	2018
	Prevalence, %					
Non-Hispanic White						
Underweight	3.9%	3.9%	3.7%	3.5%	3.4%	3.2%
Normal weight	50.4%	50.1%	49.2%	48.6%	47.6%	46.6%
Overweight	24.1%	24.1%	24.4%	24.7%	24.9%	25.4%
Obese	21.6%	21.9%	22.7%	23.2%	24.0%	24.8%
Non-Hispanic Black						
Underweight	3.6%	3.5%	3.4%	3.3%	3.3%	3.2%
Normal weight	36.5%	36.1%	35.6%	34.9%	34.4%	33.3%
Overweight	27.4%	27.2%	27.1%	27.2%	27.1%	27.2%
Obese	32.5%	33.3%	33.9%	34.7%	35.1%	36.2%
Hispanic						
Underweight	2.9%	2.8%	2.8%	2.7%	2.6%	2.4%
Normal weight	41.4%	40.7%	39.9%	38.9%	37.8%	36.5%
Overweight	29.7%	29.8%	30.0%	30.2%	30.3%	30.5%
Obese	26.0%	26.7%	27.3%	28.2%	29.3%	30.5%
Non-Hispanic Asian						
Underweight	8.4%	8.5%	8.0%	8.0%	7.4%	6.9%
Normal weight	46.7%	46.6%	45.6%	44.8%	43.6%	42.0%
Overweight	29.6%	29.9%	30.5%	30.9%	31.7%	32.4%
Obese	15.3%	14.9%	15.8%	16.2%	17.3%	18.6%

*Underweight: <18.5 kg/m^2; Normal weight: 18.5-24.9 kg/m^2, 18.5-22.9 kg/m^2 for Asian women; Overweight: 25.0-29.9 kg/m^2, 23.0-27.4 kg/m^2 for Asian women; Obese: ≥30.0 kg/m^2, ≥27.5 kg/m^2 for Asian women

Table S2. Unadjusted rates of adverse pregnancy outcomes stratified by race/ethnicity, 2013-2018.

	2013	2014	2015	2016	2017	2018
	APOs per 1,000 live births					
Non-Hispanic White						
Underweight	149.7	152.8	152.5	155.7	160.9	162.2
Normal weight	104.6	106.3	107.4	110.3	112.5	116.5
Overweight	121.5	122.6	126.9	130.6	135.9	142.0
Obese	164.3	169.2	174.9	183.6	190.4	200.6
Non-Hispanic Black						
Underweight	233.0	228.6	240.3	241.9	246.4	251.4
Normal weight	176.7	178.4	183.7	187.3	191.6	196.5
Overweight	167.2	171.2	176.0	178.8	183.1	190.0
Obese	192.9	200.8	209.3	216.9	221.3	231.4
Hispanic						
Underweight	147.2	150.9	150.8	153.8	155.2	160.5
Normal weight	110.0	109.9	112.7	116.7	121.5	125.4
Overweight	113.7	115.9	119.7	124.6	127.3	133.3
Obese	139.6	145.0	153.2	157.5	163.1	170.7
Non-Hispanic Asian						
Underweight	111.9	107.6	111.6	116.8	110.9	120.5
Normal weight	99.4	97.6	102.6	103	106.5	107.9
Overweight	116.2	114.2	120.3	123.7	124.8	129.2
Obese	149.3	151.9	161.5	160.7	165.8	171.3

*Underweight: <18.5 kg/m^2; Normal weight: 18.5-24.9 kg/m^2, 18.5-22.9 kg/m^2 for Asian women; Overweight: 25.0-29.9 kg/m^2, 23.0-27.4 kg/m^2 for Asian women; Obese: ≥30.0 kg/m^2, ≥27.5 kg/m^2 for Asian women

†APO represents adverse pregnancy outcome

Table S3. Adjusted odds ratio and population attributable fraction for small for gestational age associated with pre-pregnancy obesity compared to normal body mass index in the United States, 2013 and 2018.

	2013			2018		
	Prevalence*	**OR (95% CI)**	**PAF (95% CI)**	**Prevalence***	**OR (95% CI)**	**PAF (95% CI)**
Non-Hispanic White	73.6	0.70 (0.69, 0.71)	-6.8%† (-7.1, -6.5)	72.1	0.69 (0.68, 0.70)	-8.1%† (-8.4, -7.8)
Non-Hispanic Black	147.5	0.72 (0.70, 0.73)	-8.7%† (-9.3, -8.1)	151.5	0.71 (0.69, 0.72)	-10.2%† (-10.8, -9.6)
Hispanic	85.5	0.67 (0.66, 0.69)	-8.7%† (-9.2, -8.2)	85.8	0.67 (0.66, 0.68)	-10.5%† (-11.1, -10.0)
Non-Hispanic Asian	122	0.76 (0.73, 0.80)	-3.3%† (-3.8, -2.8)	125.4	0.77 (0.74, 0.80)	-3.9%† (-4.4, -3.4)

*per 1,000 live births

†Negative PAF reflects OR<1, i.e. higher risk in women with normal weight compared to women with obesity

‡OR represents odds ratio; CI confidence interval; PAF population attributable fraction

Table S4. Adjusted odds ratio and population attributable fraction for adverse pregnancy outcomes associated with pre-pregnancy obesity compared to normal body mass index in nulliparous women in the United States, 2013 and 2018.

	2013		2018	
	OR (95% CI)	**PAF, % (95% CI)**	**OR (95% CI)**	**PAF, % (95% CI)**
Non-Hispanic White				
Any APO	1.92 (1.88, 1.95)	11.6% (11.2, 11.9)	2.12 (2.09, 2.15)	15.1% (14.8, 15.5)
Preterm birth	1.33 (1.29, 1.36)	5.3% (4.8, 5.8)	1.40 (1.37, 1.43)	7.5% (7.0, 8.0)
Low birthweight	1.09 (1.06, 1.12)	1.5% (1.0, 2.0)	1.09 (1.06, 1.12)	1.9% (1.3, 2.5)
Pregnancy-associated HTN	3.38 (3.31, 3.46)	25.0% (24.5, 25.5)	3.26 (3.19, 3.32)	26.5% (26.1, 27.0)
>1 APO	1.50 (1.45, 1.54)	8.0% (7.4, 8.6)	1.58 (1.54, 1.63)	10.8% (10.1, 11.5)
Non-Hispanic Black				
Any APO	1.32 (1.28, 1.36)	6.1% (5.4, 6.8)	1.43 (1.39, 1.47)	8.9% (8.2, 9.5)
Preterm birth	1.11 (1.07, 1.16)	2.7% (1.6, 3.7)	1.16 (1.12, 1.21)	4.4% (3.3, 5.5)
Low birthweight	0.94 (0.90, 0.97)	-1.6%* (-2.5, -0.7)	0.94 (0.90, 0.97)	-1.8%* (-2.8, -0.8)
Pregnancy-associated HTN	2.18 (2.09, 2.29)	21.1% (19.9, 22.3)	2.24 (2.15, 2.32)	23.1% (22.1, 24.2)
>1 APO	1.17 (1.12, 1.22)	4.0% (2.8, 5.1)	1.21 (1.16, 1.26)	5.6% (4.3, 6.8)
Hispanic				
Any APO	1.57 (1.53, 1.62)	8.3% (7.8, 8.9)	1.66 (1.62, 1.70)	11.0% (10.5, 11.6)
Preterm birth	1.38 (1.32, 1.43)	6.2% (5.4, 7.0)	1.36 (1.31, 1.41)	7.3% (6.5, 8.2)
Low birthweight	1.10 (1.05, 1.14)	1.8% (1.0, 2.6)	1.06 (1.02, 1.10)	1.3% (0.4, 2.2)
Pregnancy-associated HTN	2.68 (2.57, 2.81)	21.5% (20.5, 22.6)	2.52 (2.43, 2.60)	22.9% (22.0, 23.8)
>1 APO	1.48 (1.41, 1.55)	7.9% (6.9, 8.9)	1.46 (1.40, 1.52)	9.3% (8.2, 10.4)
Non-Hispanic Asian				
Any APO	1.85 (1.75, 1.97)	7.2% (6.5, 8.0)	1.84 (1.75, 1.93)	8.6% (7.9, 9.4)
Preterm birth	1.61 (1.49, 1.74)	5.9% (4.8, 6.9)	1.60 (1.49, 1.71)	7.2% (6.1, 8.3)
Low birthweight	1.30 (1.20, 1.41)	3.1% (2.1, 4.0)	1.24 (1.16, 1.33)	3.2% (2.2, 4.1)
Pregnancy-associated HTN	3.93 (3.56, 4.35)	21.2% (19.3, 23.1)	3.53 (3.28, 3.79)	22.0% (20.6, 23.5)
>1 APO	1.75 (1.59, 1.92)	7.3% (5.9, 8.7)	1.85 (1.71, 2.01)	10.0% (8.6, 11.4)

*Negative PAF reflects OR<1, i.e. higher risk in women with normal weight compared to women with obesity
†OR represents odds ratio; CI confidence interval; PAF population attributable fraction

Table S5. Adjusted odds ratio and population attributable fraction for adverse pregnancy outcomes associated with pre-pregnancy obesity compared to normal body mass index including pre-pregnancy hypertension and diabetes in the United States, 2013 and 2018.

	2013		2018	
	OR (95% CI)	**PAF, % (95% CI)**	**OR (95% CI)**	**PAF, % (95% CI)**
Non-Hispanic White				
Any APO	1.71 (1.69, 1.73)	11.0% (10.8, 11.2)	1.94 (1.92, 1.96)	15.1% (14.9, 15.3)
Preterm birth	1.24 (1.22, 1.26)	4.6% (4.2, 4.9)	1.35 (1.34, 1.37)	7.6% (7.2, 7.9)
Low birthweight	0.95 (0.93, 0.97)	-1.1%* (-1.5, -0.7)	0.98 (0.97, 1.00)	-0.4%* (-0.8, 0.0)
Pregnancy-associated HTN	3.49 (3.43, 3.55)	28.6% (28.2, 29.0)	3.35 (3.30, 3.39)	29.9% (29.6, 30.3)
>1 APO	1.32 (1.29, 1.35)	6.2% (5.7, 6.7)	1.47 (1.44, 1.50)	9.9% (9.4, 10.4)
Non-Hispanic Black				
Any APO	1.17 (1.15, 1.19)	4.3% (3.8, 4.8)	1.28 (1.26, 1.30)	7.4% (6.9, 7.9)
Preterm birth	1.00 (0.98, 1.02)	0.0% (-0.8, 0.7)	1.07 (1.05, 1.09)	2.3% (1.5, 3.0)
Low birthweight	0.84 (0.82, 0.86)	-5.2%* (-5.9, -4.5)	0.85 (0.83, 0.86)	-5.6%* (-6.4, -4.9)
Pregnancy-associated HTN	2.27 (2.19, 2.34)	26.0% (25.0, 26.9)	2.24 (2.19, 2.30)	27.3% (26.5, 28.1)
>1 APO	1.03 (1.00, 1.06)	0.9% (0.0, 1.8)	1.06 (1.03, 1.09)	2.1% (1.2, 3.0)
Hispanic				
Any APO	1.38 (1.35, 1.40)	7.6% (7.2, 8.1)	1.51 (1.48, 1.53)	11.1% (10.7, 11.5)
Preterm birth	1.21 (1.19, 1.24)	4.8% (4.3, 5.4)	1.27 (1.24, 1.29)	7.0% (6.4, 7.6)
Low birthweight	0.96 (0.93, 0.98)	-1.0%* (-1.7, -0.4)	0.95 (0.93, 0.97)	-1.5%* (-2.2, -0.8)
Pregnancy-associated HTN	2.68 (2.60, 2.77)	26.1% (25.3, 26.9)	2.54 (2.48, 2.60)	27.4% (26.7, 28.1)
>1 APO	1.25 (1.22, 1.29)	5.8% (5.0, 6.6)	1.30 (1.26, 1.33)	7.9% (7.1, 8.6)
Non-Hispanic Asian				
Any APO	1.73 (1.66, 1.80)	8.1% (7.5, 8.7)	1.81 (1.75, 1.87)	10.4% (9.8, 11.0)
Preterm birth	1.55 (1.47, 1.62)	6.8% (6.0, 7.7)	1.56 (1.50, 1.63)	8.4% (7.6, 9.3)
Low birthweight	1.22 (1.15, 1.28)	2.8% (2.0, 3.7)	1.20 (1.15, 1.26)	3.3% (2.5, 4.1)
Pregnancy-associated HTN	3.91 (3.63, 4.20)	24.6% (23.1, 26.1)	3.75 (3.55, 3.95)	26.8% (25.6, 27.9)
>1 APO	1.62 (1.52, 1.73)	7.8% (6.6, 8.9)	1.72 (1.63, 1.81)	10.5% (9.4, 11.6)

*Negative PAF reflects OR<1, i.e. higher risk in women with normal weight compared to women with obesity
†OR represents odds ratio; CI confidence interval; PAF population attributable fraction