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Maternal Obesity and the Risk of Infant Death in the United States

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Abstract

Background—Maternal obesity (defined as prepregnancy body mass index [BMI] ≥30 kg/m^2) is associated with increased risk of neonatal death. Its association with infant death, postneonatal death, and cause-specific infant death is less well-characterized.

Methods—We studied the association between maternal obesity and the risk of infant death by using 1988 US National Maternal and Infant Health Survey data. A case-control analysis of 4265 infant deaths and 7293 controls was conducted using SUDAAN software. Self-reported prepregnancy BMI and weight gain were used in the primary analysis, whereas weight variables in medical records were used in a subset of 4308 women.

Results—Compared with normal weight women (prepregnancy BMI = 18.5–24.9 kg/m^2) who gained 0.30 to 0.44 kg/wk during pregnancy, obese women had increased risk of neonatal death and overall infant death. For obese women who had weight gain during pregnancy of <0.15, 0.15 to 0.29, 0.30 to 0.44, and ≥0.45 kg/wk, the adjusted odds ratios of infant death were 1.75 (95% confidence interval = 1.28–2.39), 1.42 (1.07–1.89), 1.59 (1.00–2.51), and 2.87 (1.98–4.16), respectively. Nonobese women with very low weight gain during pregnancy also had a higher risk of infant death. The subset with weight information from medical records had similar results for recorded prepregnancy BMI and weight gain. Maternal obesity was associated with neonatal death from pregnancy complications or disorders relating to short gestation and unspecified low birth weight.

Conclusions—Maternal obesity is associated with increased overall risk of infant death, mainly neonatal death.

Maternal obesity (often defined as prepregnancy body mass index [BMI] ≥30 kg/m^2) increases the risk of fetal death.[1–7] Several studies have suggested that maternal obesity increases the risk of neonatal death, defined as death in the first 7 or 28 days of life.[1,2,5,8–10] Previous studies have also suggested adverse effects of maternal obesity on the overall risk of infant death.[11,12] Lucas et al[11] reported increased risk of mortality up to 18 months in preterm babies born to obese mothers, but the study was limited to babies with birth weights of <1850 g. Baeten et al[12] found the risk of infant death doubled in obese women compared with lean women (BMI <20 kg/m^2), but the study was limited to nulliparous women, and no distinction was made between neonatal and postneonatal death. No study has examined the effect of maternal

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obesity on neonatal and postneonatal death separately. There is also a lack of research into the causes of infant death associated with maternal obesity.[5,11] Moreover, most studies of maternal obesity and neonatal or infant death have not taken into account weight gain during pregnancy,[5,8–11] which may modify the risk associated with maternal obesity. To address these questions, we analyzed data from the 1988 National Maternal and Infant Health Survey (NMIHS) to investigate the effect of maternal obesity on infant death. Although the data were relatively old, NMIHS is the most recent national dataset for this analysis. Few states have added maternal prepregnancy weight and height to the birth certificate, as recommended in the 2003 model birth certificate.[13] We quantified the risk of infant death, neonatal and post neonatal death, and cause-specific death by using this nationally representative dataset.

METHODS

The 1988 MISH was conducted by the National Center for Health Statistics to study factors related to poor pregnancy outcome. The survey included a nationally representative, stratified, systematic sample of 9953 women who gave births to live infants, 3309 who had late fetal deaths, and 5532 who had infant deaths.[14] African American infants were oversampled in all these groups.[14] Infants with very low birth weight (<1500 g) and moderately low birth weight (1500–2499 g) were oversampled among live births. After childbirth, mothers were mailed questionnaires about reproductive history, life style, prenatal care, delivery, postpartum conditions, and neonatal and infant health. Mothers were also asked to provide names and addresses of prenatal care providers and the hospital of delivery; providers and hospitals were then asked to provide medical records. About half of women had prenatal medical records in the dataset. The 1988 MISH has been described in detail elsewhere.[14]

In this case-control analysis of maternal obesity and infant death, we included only infant deaths and live births. Cases were infant deaths (n = 5330, after excluding 2 because of inability to differentiate neonatal or post neonatal death). Controls were live births who were still alive and older than 1 year at the time of interview (n = 7938). Neonatal deaths were infants who died within 28 days after birth, and post neonatal deaths were infants who died after 28 days but before the first birthday. In this dataset, we were able to calculate BMI and weight gain based on both self-reported and recorded prepregnancy weight and height. We calculated BMI as weight in kilograms divided by the square of height in meters, and weight gain during pregnancy as weight just before delivery minus prepregnancy weight. The questionnaire, administered, on average, 18 months after childbirth, included questions on mother's self-reported prepregnancy weight, weight just before delivery, and current height. For women with prenatal medical records, prepregnancy weight (recalled by women at a prenatal visit) and weight before delivery were recorded by physicians. Thus, recorded prepregnancy BMI was calculated from the prepregnancy weight in the medical record and the self-reported height (height was not recorded in the medical records), and recorded weight gain was calculated using 2 weights in the medical records. We excluded 364 women (3%) with either self-reported or recorded extreme BMI (<15 kg/m^2 or >45 kg/m^2) or extreme weight gain during pregnancy (<−30 lb or >80 lb). We further excluded 1124 women (8%) for whom no gestational age was recorded on the birth certificate (and for whom we were thus unable to calculate weekly weight gain) and 222 women (2%) with gestational age that was less than 20 weeks or more than 45 weeks. Thus, the final sample included 4265 cases (2667 neonatal deaths and 1598 post neonatal deaths) and 7293 controls.

Statistical Analysis

We analyzed the association between maternal prepregnancy BMI, weight gain, and infant death, as well as neonatal or post neonatal death only, using the same controls. We classified maternal prepregnancy BMI, according to World Health Organization definition,[15] into 4 categories: underweight, normal weight, overweight, and obese (Table 1). Weekly weight gain was calculated as weight gain during pregnancy divided by gestational weeks (kg/wk); this was grouped into 4 categories (Table 1) based on the distribution of self-reported weekly weight gain (median = 0.32 kg/wk, [interquartile range = 0.22–0.45 kg/wk]) and Institute of Medicine weight gain guidelines in 1990.[16] We focus mainly on the association between maternal obesity and infant death but also report findings for underweight and overweight women.

For statistical analysis, we first compared the risk of infant death among women within different pregnancy BMI categories without consideration of weight gain during pregnancy. This analysis can be compared with most previous studies in which BMI analyses were not adjusted for weight gain during pregnancy. We then tested interaction of prepregnancy BMI and weight gain during pregnancy and found significant interaction terms (lowest weight gain for overweight and obese women and highest weight gain for obese women) ($P < 0.10$). Therefore, we grouped prepregnancy BMI and weekly weight gain into a single variable with 16 levels, using normal weight and weekly weight gain of 0.30 to 0.44 kg as the reference group (with the lowest risk for infant death in the full sample). We also examined net weight gain (weight gain minus birth weight). Results were similar and are not presented here.

Multiple logistic regression models were used to calculate the odds ratios (ORs) and associated 95% confidence internals (CIs) for maternal prepregnancy BMI and weekly weight gain categories. Adjustments for a priori covariates (including race, maternal age at pregnancy, maternal education, maternal smoking during pregnancy, child's sex, live birth order, and plurality) were made in the multiple logistic regression models. We carried out sensitivity analyses in more homogeneous samples of singleton births and infants without reported birth defects. In secondary analyses, we stratified by race (whites, African Americans), parity (nulliparous, parous), preterm birth (<37, ≥37 weeks), and low birth weight (<2500, ≥2500 g) to explore whether the effect of maternal obesity persisted.

The associations of maternal obesity and cause-specific neonatal and post neonatal death were analyzed using the full sample of 11,558 women to search for plausible mechanisms. We used the International Classification of Diseases, 9th revision (ICD-9) to group the causes of infant deaths (based on death certificate) into broad, etiologically related categories, although there may be some overlap for underlying causes of death. For neonatal deaths, we studied pregnancy complications or disorders relating to short gestation and unspecified low birth weight (ICD codes 760–765, 767; n = 631), respiratory distress syndrome or other respiratory conditions (ICD 768–770; n = 702), and birth defects (ICD 740–759; n = 650). The ORs for different causes of neonatal death were calculated in separate logistic regression models with the same control group. For post neonatal death, we evaluated only sudden infant death syndrome (SIDS; ICD code 798.0; n = 570) separately because the number of deaths from other underlying causes was much smaller.

We gave preference to maternal self-reported prepregnancy BMI and weight gain because these were available for the full sample, whereas recorded prepregnancy BMI and weight gain were available for only 4308 women. For these 4308 women (815 neonatal deaths, 601 post neonatal deaths, and 2892 controls), we did secondary analysis to estimate the ORs of recorded prepregnancy BMI and weight gain. For women with medical records, these records contained information on diabetes, gestational diabetes, chronic hypertension, and blood pressure measurements made during prenatal visits. To test whether the association between maternal obesity and infant death could be explained by diabetes or hypertension, we did subanalyses after excluding 174 women with diabetes (30 with preexisting diabetes and 144 with gestational diabetes) or 270 women with hypertension (154 with chronic hypertension and 116 with gestational hypertension [the latter defined as prenatal systolic blood pressure >140 mm Hg or diastolic blood pressure >90 mm Hg at least twice after 20 weeks of gestation but without chronic hypertension[17]]). Among these 4308 women, there were 3357 with weight measured and recorded at 2 or more prenatal visits during the 14th through 28th weeks of gestation, when the weekly weight gain was linear and at its maximum.[18] These serial weight measures were abstracted from prenatal visit records. The median number of weight measures during 14 to 28 weeks gestation was 4 (interquartile range = 3–5), with the first measure at a median of 16 weeks (interquartile range = 15–17 weeks) and the last measure at a median of 27 weeks (interquartile range = 25–28 weeks). The weekly weight gain during this period was a median of 0.50 kg/wk (interquartile range = 0.34–0.66 kg/wk). Therefore, we can estimate the effects of recorded prepregnancy BMI and weekly weight gain during 14–28 weeks of gestation (categorized as <0.30 kg/wk, 0.30–0.49 kg/wk, 0.50–0.69 kg/wk, and ≥0.70 kg/wk) on infant death and compare them with the estimates from the full sample of 11,558 women.

Because the MISH used complex sampling techniques, we used SAS 9.1 (SAS Inc., Cary, NC) and SUDAAN 9.0 (Research Triangle Institute, Research Triangle Park, NC) for statistical analysis. SUDAAN gave risk estimates based on different sampling weights for each individual in the sample. For example, 7293 controls represented 3,036,202 live births in 1988, whereas 4265 cases represented 31,531 infant deaths in that year. Because the MISH is a nationally representative sample, the results can be readily extrapolated to the US general population in 1988.[14]

RESULTS

Self-reported prepregnancy BMI and weekly weight gain distributions by case or control status are shown in Table 1. Compared with controls, mothers of infants who died had a higher percentage of prepregnancy obesity (8.8% vs. 5.9%). As shown in Table 1, mothers of cases were more often African American and younger than 20 years old; a higher percentage smoked during pregnancy. Infants who died in the first year of life were more often male, of higher order live birth (≥3), part of a multiple birth, with reported birth defects, born at low birth weight, and preterm births.

The relation between self-reported prepregnancy BMI and weekly weight gain among both cases and controls is shown in Table 2. Obese women had the highest percentage of weight gain <0.15 kg/wk and the lowest percentage of weight gain ≥0.45 kg/wk. Their median weight gain was 0.23 kg/wk, compared with 0.35 kg/wk gained by normal weight women.

Without consideration of weight gain during pregnancy, obese women had higher risk of infant death compared with normal weight women (Table 3). Underweight women also had increased risk and overweight women had marginally increased risk.

When weight gain during pregnancy was taken into account, obese women had higher risk of infant death at all weight gain categories, compared with normal weight women with weight gain of 0.30 to 0.44 kg/wk (the reference group) (Table 4). Weight gain modified the risk of infant death depending on the women's prepregnancy weight. For underweight women, the lowest weight gain was associated with increased risk of infant death. This was less pronounced in normal weight women. In overweight women, the lowest weight gain was associated with the highest risk, but the highest weight gain also increased the risk, indicating a reversed "J" shape. In obese women, a J-shaped association was seen, with the highest weight gain associated with the highest risk. The effect of maternal prepregnancy BMI and weight gain on neonatal death was also evident, whereas that effect on post neonatal death was weaker and less precise. In a multinomial logistic regression model, the overall pattern of prepregnancy BMI and weight gain during pregnancy effect differed for neonatal and post neonatal death by Wald χ^2 test ($P < 0.01$), which suggested the effects for the 2 endpoints were not homogeneous.

The ORs of prepregnancy BMI and weight gain categories without any covariate adjustment (data not shown) were only slightly higher than reported in Table 4. Additional adjustment for multivitamin use during pregnancy, marital status during pregnancy, and participation in the federally funded Women, Infants, and Children nutrition program during pregnancy, in addition to current covariates, did not change the results substantially. For post neonatal death, adding breast-feeding status to the covariates did not affect the results. Subsample analysis using only singleton births or only infants without reported birth defects gave estimates similar to Table 4. The adverse effects of maternal obesity on infant death were evident in subanalyses by race, parity, preterm birth, or low birth weight.

Among causes of neonatal death, maternal obesity was associated with the risk of death from maternal pregnancy, labor, and delivery complications or disorders relating to short gestation and unspecified low birth weight, at all weight gain categories (Fig. 1). The association between maternal obesity and neonatal deaths from respiratory conditions, birth defects, and post neonatal SIDS was not consistent across weight-gain groups, but obese women with the highest weight gain had increased risk (Fig. 1).

For 4308 women with prenatal medical records, maternal obesity was also associated with higher risk of infant death (Table 5). The effects were largely similar to estimates for obese women in Table 4, but the precision of estimation was lower. Excluding women with diabetes and women with hypertension did not markedly change the risk estimate of maternal obesity and weight gain categories (data not shown). In these women with prenatal medical records, the correlation coefficient of self-reported and recorded prepregnancy BMI was 0.89 and that of self-reported weight gain and recorded weight gain was 0.55. Women with or without medical records did not differ in their prepregnancy BMI and weight gain categories (data not shown). The results in obese women from recorded prepregnancy BMI and weight gain during 14 to 28 gestational weeks (data not shown) were similar to those in Table 5.

DISCUSSION

Maternal prepregnancy obesity was associated with increased risk of neonatal death and overall infant death. The effect on post neonatal death was weaker and less precise. Weight gain during pregnancy modified the effect of maternal prepregnancy BMI. Women with data from prenatal medical records had similar findings. Obese women had higher risk for neonatal death from pregnancy complications or disorders relating to short gestation and unspecified low birth weight.

The results of overall infant death were as expected and in accordance with a previous study analyzing birth and death certificates in Washington State from 1992 to 1996.[12] Although Baeten et al[12] did not study post neonatal death separately, we found the effect of maternal obesity on post neonatal death was modest, whereas the effect on neonatal death was predominant. The earlier authors limited their study to nulliparous women; we also found adverse effects of maternal obesity also in parous women. Although Lucas et al[11] studied only the association among preterm infants, we found the effect of maternal obesity in babies who were not preterm or low birth weight. Studies on maternal obesity and neonatal death generally have suggested the association, although the magnitude of effect has varied among studies. Our results, if not taking weight gain into account, were similar to a recent paper using Danish National birth cohort (OR = 1.6 for obese women compared with normal weight women),[10] whereas other studies have reported ORs ranging from 1.2 to 2.6 (partly due to inconsistent definition of obesity and reference group).[1,5,8,9]

Authors of only a few studies have examined the effect of maternal obesity and weight gain during pregnancy in relation to neonatal death or infant death.[1,12] Cnattingius et al[1] did not find that weight gain modified the effect of maternal BMI on neonatal death, but they cautioned that a large proportion of women had missing information on weight gain. We found an interaction between maternal BMI and weight gain on the risk of infant death, and the results need to be confirmed in other studies. With renewed discussions of optimal weight gain for obese women,[19,20] the risk of infant mortality needs to be considered in addition to the risks of preeclampsia, cesarean section, and large- and small-for-gestational-age infants. Obese women may need to avoid excessive weight gain, but among nonobese women, very low weight gain may pose an increased risk of infant death.

It is biologically plausible that maternal obesity increases the risk of infant death. Increased risk of infant death may, indeed, be part of a continuum from reduced fertility,[21] miscarriage,[22] and stillbirth.[1–6] Maternal obesity increases the risk of gestational hypertension, preeclampsia, gestational diabetes, macrosomia, dystocia, labor induction, cesarean section, and postpartum hemorrhage.[23–28] It may also increase the risk of indicated preterm birth[29,30] and probably preterm premature rupture of membranes.[29] Maternal obesity has also been associated with increased risk of birth defects[31,32] and a decreased proportion of women who breast-feed.[33,34] Excluding some pregnancy complications such as gestational hypertension and diabetes changed only slightly the risk estimates of obesity.[10,12] This may be partly due to underreporting of these pregnancy complications; alternatively, these complications may represent only a portion of obesity-related problems.[10] Furthermore, obese women may experience subclinically perturbed metabolic profiles, such as dyslipidemia, hyperinsulinemia, elevated leptin concentrations, and a low-grade inflammatory response during pregnancy.[35]

Our study has several limitations. First the data we used were old. Since 1988, obesity prevalence has increased in women of all races,[36,37] and weight gain during pregnancy has increased as women follow more recent Institute of Medicine guidelines. Also, during this time, infant mortality has declined about 20%. This infant mortality decline may have been driven by surfactant therapy to reduce respiratory distress syndrome, “back to sleep” to reduce SIDS, and increased use of folic acid to reduce neural tube defects.[38] In contrast, infant mortality due to maternal complications or shorter gestation/low birth weight has not decreased and may have increased, which may be related to increasing obesity and infertility treatment.[38,39] Our findings are largely similar to previous studies with more recent data, which suggests that the association may not change dramatically. Still, confirmation from large prospective studies such as the National Children’s Study or birth cohorts from other developed countries is needed.

Second, recall bias and residual confounding cannot be ruled out. Women might recall their prepregnancy weight differently based on whether their newborns survived. Using prepregnancy weight recalled during pregnancy (when recall bias was less likely to be differential) yielded similar results for obese women. This attenuated the concern for self-reported BMI and weight gain. Third, this study was not a longitudinal cohort design, and we did not have much detailed information about pregnancy complications, labor, delivery, and neonatal conditions. Better elucidation of intermediate variables in the pathways was not possible. Fourth, the causes of infant deaths were derived from death certificates and contain some errors. Classification by causes of death also decreased the precision of estimation. The relation of maternal obesity and cause-specific infant death needs to be studied further.

Even so, this analysis has strong points. The data were nationally representative, and the sample size was big enough to ensure sufficient power for relatively rare outcomes such as post neonatal death. We were able to separate neonatal and post neonatal death and consider weight gain during pregnancy.

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In 1999 –2002, about 29% of nonpregnant US women aged 20 to 39 years had BMIs of ≥30 kg/m^2.[40] With the increasing trend in childhood obesity, the prevalence of maternal obesity during pregnancy is probably going to be even higher in the near future.[41] We have found an increase in the risk of neonatal and overall infant death associated with maternal obesity. Infant mortality in the United States is higher than at least 20 other developed countries.[39] If maternal obesity indeed increases the risk of infant death in the general population, obesity prevention should be explored as a measure to reduce infant mortality.

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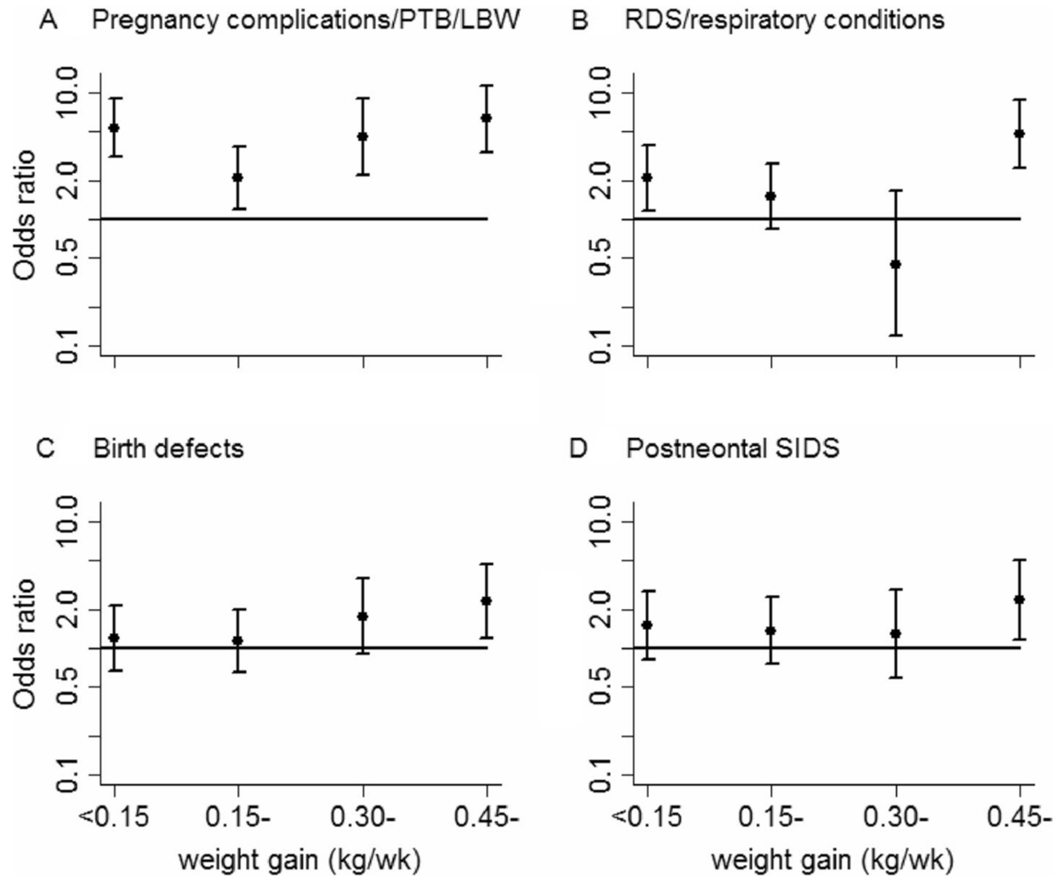

FIGURE 1.

Adjusted ORs and 95% CIs for neonatal and post neonatal causes in obese women, compared with normal weight women with weight gain of 0.30 to 0.44 kg/wk. Neonatal causes were: A, pregnancy complications or disorders relating to short gestation (preterm birth [PTB]) and unspecified low birth weight (LBW); B, respiratory distress syndrome (RDS) and other respiratory conditions; and C, birth defects. D, Post neonatal cause was sudden infant death syndrome (SIDS).

TABLE 1

Maternal and Infant Characteristics of Cases and Controls Based on the 1988 National Maternal and Infant Health Survey

	Infant Deaths			
	Neonatal	**Post neonatal**	**Total**	**Controls**
No.	2667	1598	4265	7293
N SUDAAN estimate	19,365	12,166	31,531	3,036,202
	%	%	%	%
Maternal self-reported prepregnancy BMI (kg/m^2)				
<18.5 (underweight)	11	12	11	10
18.5–24.9 (normal weight)	62	64	63	68
25–29.9 (overweight)	18	17	17	16
≥30 (obese)	9	8	9	6
Self-reported weight gain during pregnancy (kg/wk)				
<0.15	17	14	16	8
0.15–0.29	29	31	30	30
0.30–0.44	25	30	27	34
≥0.45	29	25	27	27
Maternal race				
White	69	70	69	79
African American	28	27	27	16
Others	3	4	3	5
Maternal age at pregnancy (y)				
<20	17	18	17	12
20–24	26	32	28	28
25–29	29	27	28	32
30–34	20	16	18	21
≥35	9	7	8	8
Maternal education (y)				
<9	28	28	28	32
9–12	47	51	49	41
>12	25	21	23	27
Maternal smoking during pregnancy				
Yes	33	41	36	30
No	67	60	64	71
Sex				
Male	56	57	57	52
Female	44	43	43	48
Live birth order				
1	42	34	39	42
2	30	32	31	33

	Infant Deaths			
	Neonatal	Post neonatal	Total	Controls
≥3	27	34	30	25
Plurality				
Singleton	87	95	90	98
Multiple birth	13	5	10	2
Reported birth defects				
No	86	93	89	99
Yes	14	7	11	1
Birth weight (g)				
<2500	73	30	56	6
≥2500	27	70	44	94
Preterm birth				
Yes	71	31	55	9
No	29	69	45	91

TABLE 2

Self-Reported Weekly Weight Gain During Pregnancy Stratified by Self-Reported Prepregnancy BMI Category, Both Cases and Controls Included

Maternal Self-Reported Prepregnancy BMI (kg/m^2)	Weight Gain During Pregnancy (kg/wk)			
	<0.15 %	0.15–0.29 %	0.30–0.44 %	≥0.45 %
<18.5	3.8	29.1	36.5	30.6
18.5–24.9	5.9	29.1	36.3	28.8
25–29.9	13.6	32.1	29.6	24.7
≥30	31.5	37.8	16.2	14.5

TABLE 3

Association of Maternal Self-Reported Prepregnancy BMI With Neonatal, Post neonatal, and Infant Death, No Weight Gain Adjustment

Maternal Prepregnancy BMI (kg/m^2)	**Neonatal Death OR (95% CI)**	**Postneonatal Death OR (95% CI)**	**Infant Death OR (95% CI)**
<18.5	1.20 (1.01–1.43)	1.24 (1.02–1.51)	1.22 (1.05–1.41)
18.5–24.9[a]	1.00	1.00	1.00
25–29.9	1.15 (1.00–1.32)	1.07 (0.91–1.27)	1.12 (0.99–1.26)
≥30	1.57 (1.30–1.90)	1.28 (1.02–1.61)	1.46 (1.23–1.73)

Adjusted for race, maternal age at pregnancy, maternal education, maternal smoking during pregnancy, child’s sex, live birth order, and plurality.

[a]Reference category.

TABLE 4

Association of Maternal Self-Reported Prepregnancy BMI and Weekly Weight Gain Categories With Neonatal, Post neonatal, and Infant Deaths

Maternal Prepregnancy BMI (kg/m^2)	Weight Gain During Pregnancy (kg/wk)	Neonatal Death OR (95% CI)	Post neonatal Death OR (95% CI)	Infant Death OR (95% CI)
<18.5	<0.15	4.51 (2.74–7.40)	3.47 (1.88–6.40)	4.07 (2.57–6.46)
	0.15–0.29	1.75 (1.28–2.38)	1.72 (1.22–2.43)	1.74 (1.34–2.27)
	0.30–0.44	1.34 (0.98–1.84)	1.30 (0.92–1.84)	1.33 (1.02–1.73)
	≥0.45	1.32 (0.94–1.86)	0.76 (0.49–1.18)	1.07 (0.79–1.45)
18.5–24.9	<0.15	3.10 (2.49–3.87)	1.97 (1.51–2.55)	2.59 (2.13–3.15)
	0.15–0.29	1.42 (1.20–1.69)	1.12 (0.92–1.36)	1.29 (1.12–1.49)
	0.30–0.44[a]	1.00	1.00	1.00
	≥0.45	1.18 (0.99–1.41)	0.95 (0.78–1.16)	1.08 (0.94–1.26)
25–29.9	<0.15	2.23 (1.64–3.04)	1.19 (0.81–1.75)	1.77 (1.35–2.33)
	0.15–0.29	1.36 (1.05–1.76)	0.95 (0.70–1.29)	1.18 (0.95–1.48)
	0.30–0.44	1.17 (0.88–1.55)	1.40 (1.04–1.90)	1.26 (0.99–1.59)
	≥0.45	1.63 (1.25–2.14)	1.17 (0.85–1.62)	1.44 (1.14–1.82)
≥30	<0.15	2.17 (1.53–3.07)	1.22 (0.79–1.88)	1.75 (1.28–2.39)
	0.15–0.29	1.44 (1.03–2.02)	1.36 (0.92–2.01)	1.42 (1.07–1.89)
	0.30–0.44	1.82 (1.10–3.00)	1.31 (0.75–2.29)	1.59 (1.00–2.51)
	≥0.45	3.50 (2.34–5.25)	1.99 (1.21–3.29)	2.87 (1.98–4.16)

Adjusted for race, maternal age at pregnancy, maternal education, maternal smoking during pregnancy, child's sex, live birth order, and plurality.

[a]Reference category.

TABLE 5

Association of Maternal Recorded Prepregnancy BMI and Weekly Weight Gain Categories With Neonatal, Post neonatal, and Infant Deaths

Maternal Prepregnancy BMI (kg/m^2)	Weight Gain During Pregnancy (kg/wk)	Neonatal Death OR (95% CI)	Post neonatal Death OR (95% CI)	Infant Death OR (95% CI)
<18.5	<0.15	7.30 (2.27–23.47)	3.92 (1.12–13.68)	5.67 (1.94–16.64)
	0.15–0.29	1.73 (0.99–3.01)	1.61 (0.90–2.89)	1.68 (1.06–2.66)
	0.30–0.44	0.94 (0.53–1.65)	1.73 (1.06–2.84)	1.32 (0.87–1.99)
	≥0.45	0.63 (0.28–1.42)	0.89 (0.41–1.96)	0.74 (0.40–1.37)
18.5–24.9	<0.15	4.61 (2.95–7.22)	3.10 (1.91–5.03)	3.90 (2.65–5.74)
	0.15–0.29	1.47 (1.09–1.98)	1.36 (1.00–1.86)	1.43 (1.12–1.81)
	0.30–0.44[a]	1.00	1.00	1.00
	≥0.45	0.82 (0.60–1.12)	0.96 (0.69–1.34)	0.89 (0.69–1.14)
25–29.9	<0.15	2.36 (1.41–3.92)	1.23 (0.64–2.38)	1.81 (1.15–2.85)
	0.15–0.29	1.92 (1.27–2.90)	1.10 (0.67–1.79)	1.52 (1.07–2.16)
	0.30–0.44	0.74 (0.45–1.22)	1.64 (1.09–2.47)	1.13 (0.78–1.62)
	≥0.45	1.14 (0.69–1.87)	1.38 (0.83–2.29)	1.24 (0.83–1.86)
≥30	<0.15	2.24 (1.37–3.66)	1.06 (0.58–1.93)	1.71 (1.12–2.61)
	0.15–0.29	2.37 (1.50–3.74)	0.74 (0.39–1.41)	1.58 (1.05–2.37)
	0.30–0.44	1.81 (1.05–3.13)	1.20 (0.61–2.34)	1.53 (0.95–2.45)
	≥0.45	2.29 (1.28–4.10)	1.46 (0.71–3.02)	1.94 (1.16–3.24)

Adjusted for race, maternal age at pregnancy, maternal education, maternal smoking during pregnancy, child’s sex, live birth order, and plurality.

[a]Reference category.