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Obstetric and Neonatal Risks Among Obese Women Without Chronic Disease

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Abstract

Objectives—To investigate whether prepregnancy obesity is associated with adverse pregnancy outcomes among women without chronic disease.

Methods—Singleton deliveries (n=112,309) among mothers without chronic diseases in the Consortium on Safe Labor, a retrospective U.S. cohort, were analyzed using Poisson regression with robust variance estimation. Relative risks (RR) and 95% confidence intervals (CI) estimated perinatal risks in relation to pre-pregnancy obesity status adjusted for age, race–ethnicity, parity, insurance, smoking and alcohol use during pregnancy, and study site.

Results—Obstetric risks were variably (and mostly marginally) increased as BMI category and obesity class increased. In particular, the risk of gestational hypertensive disorders, gestational diabetes, cesarean delivery and induction increased in a dose-response fashion. For example, the percent of gestational diabetes among obese class III women was 14.6% in contrast to 2.8% among normal BMI women, corresponding RR (95% CI) 1.99(1.86–2.13), 2.94(2.73–3.18), 3.97(3.61–4.36) and 5.47(4.96–6.04) for overweight, obese class I, obese class II, and obese class II women, respectively, compared with normal BMI women. Similarly, neonatal risks increased in a dose-response fashion with maternal BMI status including preterm birth <32 weeks, large for gestational age (LGA), transient tachypnea, sepsis and intensive care unit admission. The percent of LGA infants increased from 7.9% among normal BMI women to 17.3% among obese class III women and RR increased to 1.52(1.45–1.58), 1.74(1.65–1.83), 1.93(1.79–2.07) and 2.32(2.14–2.52) as BMI category increased.

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Conclusions—Prepregnancy obesity is associated with increased risks of a wide range of adverse pregnancy and neonatal outcomes among women without chronic diseases.

Introduction

Nearly half of U.S. women of childbearing-age (48%) are overweight or obese.[1] Obesity has been associated with an increased risk of adverse pregnancy outcomes including stillbirth, preeclampsia, gestational diabetes mellitus (GDM), cesarean delivery, macrosomia, and congenital anomalies.[2–6] However, it remains unclear whether these obstetric and neonatal complications are due to obesity itself or pre-existing co-morbidity. Many less prevalent, but serious complications have not been studied.

Several studies have reported that a subset of individuals with obesity exhibit favorable metabolic and inflammation profiles[7, 8] and meta-analyses found that overweight or moderately obese individuals have significantly lower or no elevation in all-cause mortality rates as compared with their normal weight counterparts.[9, 10] These reports have fueled interest in whether an obese but metabolically healthy subgroup exists.[11]

Only two studies, conducted in the United Kingdom[12] and Sweden[13], have explored potential independent associations between obesity and pregnancy complications among low-risk women by comprehensively excluding women with pre-existing diseases. Given the differences in medical care systems, racial composition, and higher obesity rate, a U.S. study investigating the independent impact of obesity on pregnancy outcomes is warranted. Furthermore, these studies had relatively small sample sizes and explored a limited number of outcomes. Therefore we aimed to investigate the association of pre-pregnancy obesity among women without chronic diseases with perinatal outcomes in a large, contemporary U.S. cohort with further restrictions based on two common weight-related pregnancy complications, gestational hypertension and GDM, as well as gestational weight gain.

Materials and Methods

We used data from the Consortium on Safe Labor (CSL), a retrospective cohort of deliveries at ≥23 weeks from 12 U.S. clinical centers (2002–2008). Details of the cohort have been described elsewhere.[14] Briefly, electronic medical records of hospital delivery admission and discharge summaries with International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes (Appendix 1, available online at http://links.lww.com/xxx) were abstracted for both mothers and infants. Maternal records included maternal demographic characteristics, medical, reproductive, and prenatal history, intrapartum interventions and postpartum complications. Neonatal characteristics included gestational age, delivery room summary and medical conditions. Large-for-gestational age (LGA; highest 10 percent of age and sex-specific birth weight) was calculated based on distributions in the CSL data.[15] The CSL was approved by the institutional review boards of all participating institutions (listed in the acknowledgements).

Singleton deliveries among women of normal body mass index (BMI) or higher who entered pregnancy without pre-existing chronic diseases were used for this secondary analysis (Appendix 2, available online at http://links.lww.com/xxx). Among 223,394 singleton

deliveries in the CSL, 148,469 (66%) had information on both maternal pre-pregnancy weight and height to calculate BMI (kg/m^2). Women with chronic diseases including hypertension, diabetes, asthma, depression, human immunodeficiency virus infection, and gastrointestinal, renal, heart, or thyroid disease recorded in their medical record or by ICD-9-CM code in the discharge summary (Appendix 3, available online at http://links.lww.com/xxx) were excluded (n=29,273), as were the 6,822 deliveries to underweight women (BMI <18.5) and 65 deliveries missing maternal age. The final sample for the main analyses was 112,309 deliveries among 106,552 women. A majority of women (95%) contributed only one pregnancy and the number of pregnancies from the same woman for each outcome is presented in Appendix 4 (available online at http://links.lww.com/xxx).

Maternal pre-pregnancy BMI was classified into four groups: normal BMI (18.5–24.9), overweight (25–29.9), obese class I (30–34.9), obese class II (35–39.9) and obese class III (≥ 40). Gestational weight gain was calculated using pre-pregnancy weight and weight reported in the delivery admission medical record. To estimate gestational weight gain, we accounted for differences in the weeks of gestation at delivery by estimating the projected weight gain using the weekly rate of gestational weight gain in second and third trimester assuming the pregnancy lasted 40 weeks[16] and categorized women according to the BMI-specific Institute of Medicine (IOM) guidelines.[17] Covariates were selected *a priori*: maternal age (continuous), race/ethnicity (White, Black, Hispanic, Asian/Pacific Islander, multi-race/other/unknown), insurance type (private, public/self pay, other/unknown), marital status (married, unmarried, unknown), parity (nulliparous, multiparous), smoking (yes, no/unknown) and alcohol use (yes, no/unknown) during pregnancy, and study site.

Obstetric outcomes included gestational hypertensive disorders (i.e., gestational hypertension, preeclampsia and eclampsia); GDM; placenta previa; cesarean delivery; induction; augmentation; placental abruption; third- or fourth-degree laceration; postpartum hemorrhage; blood transfusion; fever; infection; wound complication; hysterectomy; maternal intensive care unit (ICU) admission; and acute cardiovascular events (i.e., stroke, heart failure, cardiac arrest or failure, and unspecified acute cardiovascular diseases).

Outcomes among neonates included both spontaneous and indicated preterm birth (<37 weeks of gestation), early (<32 weeks) and late preterm birth (32–<37 weeks), stillbirth, LGA, birth injury, congenital anomaly, transient tachypnea, apnea, aspiration, asphyxia, respiratory distress syndrome, sepsis, necrotizing enterocolitis, seizure, intracranial hemorrhage, peri- and intraventricular hemorrhage (PVH-IVH), retinopathy of prematurity and neonatal intensive care unit (NICU) admission.

To assess overall risk of obesity, we explored two composite outcome measures (yes and no) to assess the global risk of any event: one that excluded common obstetric interventions (cesarean delivery, induction and oxytocin augmentation) and the second which included all outcomes studied.

The delivery was the unit of analysis for all statistical testing. Descriptive statistics included the mean for maternal age and percentages for categorical variables. Significance testing for descriptive statistics used linear or multinomial logistic regression with generalized

estimating equations to account for multiple deliveries from the same woman. Modified multivariable Poisson regressions with a log-link function[18] were fitted to calculate relative risks (RRs) and 95% confidence intervals (CIs) with a first-order autoregressive covariance structure accounting for repeated pregnancies, after adjustment for above-listed covariates. Normal BMI was the reference category. Test of linear trend was conducted by fitting the median BMI value for each obesity group as a continuous variable in the models.

Deliveries not at risk for a specific outcome or where the risks were very low were excluded in corresponding analyses. Specifically, prelabor cesarean deliveries were excluded for induction and intrapartum cesarean delivery. Cesarean deliveries after induction or spontaneous labor were analyzed separately. Labor augmentation with oxytocin was analyzed among women with spontaneous labor only. Third- or fourth-degree laceration was analyzed among vaginal deliveries. Early preterm births before 32 weeks were excluded in the analysis of late preterm birth. Neonatal respiratory distress syndrome, necrotizing enterocolitis, PVH-IVH and retinopathy of prematurity were analyzed among preterm deliveries less than 37 weeks of gestation. Sites which did not report specific outcomes were excluded from that analysis.

To test the robustness of our findings, we conducted several sensitivity analyses. First, we restricted analyses to women who did not develop gestational hypertensive disorders or GDM (Appendix 5, available online at http://links.lww.com/xxx). Second, for the combined risk of obstetric and neonatal outcomes, we further restricted analyses to women who had gestational weight gain within the recommended range according to the IOM guidelines.[17] All analyses were performed using SAS software version 9.4 (SAS Institute Inc, Cary, NC).

Results

Among singleton deliveries in the CSL, compared to women with missing BMI data, women with BMI data were more likely to be White (52% vs 45%), to be married (62% vs 52%) and less likely to have private insurance (52 % vs 63%), but were similar with respect to the prevalence of pre-existing chronic diseases (20% for both) and for a composite of all outcome measures (87% vs 86%). Of the 148,469 singleton deliveries with pre-pregnancy BMI data, the proportion of women with pre-existing diseases increased with increasing BMI: 16%, 21%, 26%, 33% and 39% of women with normal BMI, overweight, obese class I, obese class II and obese class III, respectively (data not presented). In the final analytic sample of 112,309 singleton deliveries with maternal BMI ≥ 18.5 kg/m^2 and without pre-existing chronic diseases, 41% of mothers were overweight or obese before pregnancy. Mothers who were obese were more likely to be Black, unmarried, have public insurance and be multiparous than normal BMI women (p <0.01 for all comparisons) (Table 1).

As presented in Table 2, risk for gestational hypertensive disorders increased with increasing BMI and reached a nearly four-fold increase among obese class III women compared with women of normal BMI. The risk for GDM followed a similar pattern, but was even higher with more than five-fold increase among obese class III women. In contrast, risk for placental previa was decreased by 35% among obese class II women as compared with their normal BMI counterparts. With regard to route of delivery, overweight or obese women

were at significantly higher risk of cesarean delivery as well as prelabor cesarean delivery. Even after labor started spontaneously or by induction, overweight or obese women were more likely to have a cesarean delivery compared with normal BMI women. In contrast, among vaginal deliveries, the risk of operative vaginal delivery decreased among women with class II obesity. Among women with spontaneous labor, the risk of augmentation using oxytocin was slightly increased among overweight or obese women. Among women without a prelabor cesarean delivery, the risk of labor induction was significantly increased by severity of pre-pregnancy obesity. Among vaginal deliveries, risk of third- or fourth-degree laceration was significantly decreased among obese class I and class II women by 25%. Obese women were more likely to experience major puerperal infections and the risk of infection of genitourinary tract and complication of surgical wounds was increased two-fold among women with class III obesity. The risk of acute cardiovascular events significantly increased among obese class II and class III women. Obesity was not associated with an increased risk of hemorrhage, blood transfusion, hysterectomy or maternal ICU admission.

Pre-pregnancy obesity was associated with an increased risk of early preterm birth before 32 weeks by 15–31% (Table 3). Maternal obesity increased the risk for infants to be LGA, have transient tachypnea, sepsis and NICU admission in a dose-response fashion. Risks of stillbirth, birth injury, congenital anomaly, apnea, aspiration and seizure were also elevated, but reached statistical significance only among women in some obesity subgroups. Similarly, the risks of neonatal respiratory distress syndrome, necrotizing enterocolitis, PVH-IVH and retinopathy of prematurity among preterm births were increased in specific obesity subgroups. There was no significant association between maternal obesity and late preterm birth, neonatal asphyxia or intracranial hemorrhage.

We examined a composite variable comprised of all obstetric and neonatal complications, but excluding interventions (cesarean delivery, induction, oxytocin augmentation) (Table 4). The risk of any pregnancy complication was increased by 18–47% among overweight or obese women. These combined risks were attenuated to 5–12%, but remained significant when we included all outcomes studied.

In a sensitivity analysis restricted to women who did not develop gestational hypertensive disorders or GDM, results were similar for most outcomes (Appendix 6–7) and for the composite variables (Table 4). Further restriction to women who also had gestational weight gain within IOM guidelines showed a similar pattern of risk by severity of obesity (Table 4).

Discussion

Women who were obese but without any pre-pregnancy chronic diseases were at significantly increased risk of a wide range of obstetric interventions and obstetric and neonatal complications compared with normal BMI women. Moreover, obese women who entered pregnancy without comorbidity, did not develop pregnancy complications such as gestational hypertensive disorders or GDM, and gained weight within recommended guidelines, still experienced elevated risk for obstetric and neonatal complications. We found increased risks of relatively rare outcomes that other studies could not observe including maternal acute cardiovascular events and neonatal transient tachypnea, necrotizing

enterocolitis, PVH-IVH and retinopathy of prematurity among deliveries to overweight or obese women.

Many prior studies did not account for pre-existing morbidity[3, 19, 20] or only considered hypertensive disorders or diabetes.[2, 5, 21–25] In contrast, we focused on obstetric and neonatal risks experienced by women without chronic diseases, and additionally among those who did not develop pregnancy complications and who had gestational weight gain within the guidelines.

Obstetric risks were higher among overweight or obese women without other pre-pregnancy chronic diseases in our study including gestational hypertensive disorders, GDM, prelabor and intrapartum cesarean deliveries, induction, maternal fever, and complication of surgical wounds, which is consistent with previous reports without stringent exclusions.[2–4, 25, 26]

Our findings support findings from the Swedish Medical Birth Registry, where excess maternal weight was associated with significantly decreased risk of third- or fourth-degree laceration among singleton vaginal deliveries in primiparous women.[21] This inverse association could be partially attributable to thicker soft connective tissues in obese women which might protect against deeper laceration[27], to decreased attempts of operational vaginal delivery for obese women, or due to the large portion of obesity-related high-risk pregnancies, including those with LGA infants, that were delivered by cesarean.

In our study, women with severe obesity were twice as likely to have an acute cardiovascular event during labor and delivery compared with normal BMI women. Cardiovascular events are the first leading U.S. cause of pregnancy-related mortality (15%).[28] Our findings suggest this understudied outcome is an important area of concern for severely obese women and further studies on the specific acute cardiovascular diseases are needed.

Mcintyre et al.[3] reported an increased risk of neonatal respiratory distress syndrome with maternal obesity in Australia. We also observed increased risk of neonatal respiratory distress syndrome among obese women and other neonatal respiratory complications including apnea among overweight women, aspiration among class II and class III obesity and transient tachypnea in a dose-response manner by maternal obesity.

Use of a large contemporary U.S. obstetric cohort is a strength of our study, allowing us to investigate rare endpoints by obesity severity. We were also able to use rich clinical data to restrict our cohort to women without chronic diseases or common gestational disorders who also had appropriate gestational weight gain. Some limitations of our study should also be noted. Pre-pregnancy BMI was not available for 33.5% of deliveries, but reassuringly, those who were missing data had similar rates of chronic diseases and the composite outcomes studied. In addition, pre-pregnancy BMI was calculated using weight and height abstracted from electronic medical records and some of these data were likely self-reported. However, self-reported BMI has been reported to have high specificity (96–98%) and sensitivity (86–92%) in women of childbearing age (20–49 years).[29] Since we used data abstracted from electronic medical records and discharge summary ICD-9-CM codes, we were limited in our ability to discriminate an active “no” from the absence of a positive response. Therefore, some outcomes and lifestyle risk factors (e.g. smoking) might have been missed if they were

not recorded, or not recorded properly. However, validation studies demonstrated high concordance between manual chart abstraction and information downloaded from electronic medical records in CSL data.[14] Lastly, even though our data included a large U.S. sample, states with the highest obesity rates were not included hindering further detailed analysis on an extremely obese group (BMI >50).

In our study, 39% of women with normal BMI experienced one or more complications even before we considered common obstetric interventions and overweight or obese women were more likely to experience obstetric and neonatal complications than normal BMI women. Optimizing maternal weight prior to pregnancy is important and may help to prevent these adverse outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic characteristics of singleton pregnancies among women without pre-pregnancy diseases by pre-pregnancy obesity, Consortium on Safe Labor 2002–2008

Characteristics	Normal BMI (18.5–24.9) (n=66,463, 59.2%)	Overweight (25–29.9) (n=26,364, 23.5%)	Obese I (30–34.9) (n= 11,598, 10.3%)	Obese II (35–39.9) (n=4,779, 4.3%)	Obese III (≥ 40) (n=3,105, 2.8%)	P value*
Age (years)	27.4 (±6.1)	27.7 (±6.0)	27.8 (±5.9)	27.8 (±5.7)	27.8 (±5.6)	< 0.001
Race/ethnicity, n (%)						
White	37,372 (56.2)	12,031 (45.6)	5,045 (43.5)	2,098 (43.9)	1,209 (38.9)	< 0.001
Black	9,901 (14.9)	5,780 (21.9)	3,082 (26.6)	1,479 (31.0)	1,238 (39.9)	
Hispanic	12,195 (18.4)	6,340 (24.1)	2,596 (22.4)	895 (18.7)	475 (15.3)	
Asian/Pacific Islanders	3,200 (4.8)	664 (2.5)	242 (2.1)	90 (1.9)	45 (1.5)	
Multi-race/Others/Unknown	3,795 (5.7)	1,549 (5.9)	633 (5.5)	217 (4.5)	138 (4.4)	
Marital status, n (%)						< 0.001
Married	44,778 (67.4)	16,050 (60.9)	6,667 (57.5)	2,632 (55.1)	1,493 (48.1)	
Unmarried	20,709 (31.2)	9,819 (37.2)	4,689 (40.4)	2,033 (42.5)	1,532 (49.3)	
Unknown	976 (1.5)	495 (1.9)	242 (2.1)	114 (2.4)	80 (2.6)	
Insurance type, n (%)						< 0.001
Private	36,693 (55.2)	13,268 (50.3)	5,752 (49.6)	2,403 (50.3)	1,447 (46.6)	
Public/Self pay	18,037 (27.1)	9,400 (35.7)	4,594 (39.6)	1,970 (41.2)	1,443(46.5)	
Others/Unknown	11,733 (17.7)	3,696 (14.0)	1,252 (10.8)	406 (8.5)	215 (6.9)	
Parity, n (%)						< 0.001
Nulliparous	29,992 (45.1)	9,477 (36.0)	3,600 (31.0)	1,454 (30.4)	955 (30.8)	
Smoking, n (%)	3,420 (5.2)	1,588 (6.0)	806 (7.0)	366 (7.7)	248 (8.0)	0.002
Alcohol, n (%)	1,111 (1.7)	396 (1.5)	176 (1.5)	73 (1.5)	44 (1.4)	0.01

More than one delivery was contributed by 2, 878 normal BMI women (4.3%), 863 overweight women (3.3%), 351 obese class I women (3.0%), 114 obese class II (2.4%), and 95 obese class III women (3.1%). To adjust for clustering, models included robust standard errors from generalized estimating equations.

*P values are based on generalized estimating equations and adjusted for study site.

Table 2

Obstetric complications of singleton pregnancies among women without pre-pregnancy diseases by pre-pregnancy obesity, Consortium on Safe Labor 2002–2008

Outcomes	Normal BMI		Overweight		Obese I		Obese II		Obese III		P for trend *
	N (%)	RR	N (%)	RR (95% CI)	N (%)	RR (95% CI)	N (%)	RR (95% CI)	N (%)	RR (95% CI)	
Gestational hypertensive disorders	3,351(5.0)	Reference	2,096 (8.0)	1.65 (1.57–1.74)	1,274 (11.0)	2.34 (2.20–2.49)	631 (13.2)	2.78 (2.56–3.01)	536 (17.3)	3.55 (3.26–3.86)	< 0.001
Gestational Diabetes	1,834 (2.8)	Reference	1,495 (5.7)	1.99 (1.86–2.13)	959 (8.3)	2.94 (2.73–3.18)	517 (10.8)	3.97 (3.61–4.36)	452 (14.6)	5.47 (4.96–6.04)	< 0.001
Placental previa	447 (0.7)	Reference	177 (0.7)	0.92 (0.77–1.09)	87 (0.8)	0.99 (0.78–1.25)	23 (0.5)	0.65 (0.43–0.98)	16 (0.5)	0.62 (0.37–1.05)	0.02
Cesarean delivery	14,872(22.4)	Reference	7,562 (28.7)	1.26 (1.23–1.29)	3,936 (33.9)	1.49 (1.45–1.53)	1,830 (38.3)	1.70 (1.64–1.77)	1,457 (46.9)	2.01 (1.93–2.10)	< 0.001
Prelabor cesarean delivery	5,323 (8.0)	Reference	2,690 (10.2)	1.15 (1.10–1.20)	1,459 (12.6)	1.36 (1.29–1.44)	710 (14.9)	1.64 (1.53–1.76)	600 (19.3)	2.02 (1.88–2.18)	< 0.001
Intrapartum cesarean deliver	9,549 (15.6)	Reference	4,872 (20.6)	1.33 (1.29–1.37)	2,477 (24.4)	1.62 (1.56–1.68)	1,120 (27.5)	1.84 (1.75–1.9)	857 (34.2)	2.09 (2.07–2.32)	< 0.001
Cesarean delivery after induction	4,020 (16.9)	Reference	2,100 (21.2)	1.28 (1.23–1.34)	1,041 (24.1)	1.53 (1.44–1.61)	482 (26.5)	1.70 (1.58–1.84)	412 (33.8)	1.94 (1.80–2.11)	< 0.001
Cesarean delivery after spontaneous labor	5,529 (14.8)	Reference	2,772 (20.2)	1.36 (1.31–1.42)	1,436 (24.7)	1.66 (1.58–1.74)	638 (28.4)	1.92 (1.79–2.05)	445 (34.6)	2.27 (2.10–2.45)	< 0.001
Operative vaginal delivery	4,247 (8.7)	Reference	1,273 (7.4)	1.00 (0.94–1.06)	450 (6.6)	0.97 (0.89–1.07)	142 (5.5)	0.82 (0.70–0.96)	88 (6.3)	0.95 (0.78–1.16)	0.08
Induction	23,775 (38.9)	Reference	9,916 (41.9)	1.14 (1.12–1.16)	4,320 (42.6)	1.20 (1.17–1.23)	1,820 (44.7)	1.28 (1.24–1.33)	1,218 (48.6)	1.39 (1.34–1.45)	< 0.001
Oxytocin augmentation	19,009 (50.9)	Reference	7,193 (52.3)	1.06 (1.04–1.07)	3,002 (51.6)	1.06 (1.04–1.09)	1,145 (50.9)	1.05 (1.01–1.09)	672 (52.2)	1.08 (1.03–1.13)	< 0.001
Abruption	937 (1.4)	Reference	378 (1.4)	0.93 (0.82–1.05)	190 (1.6)	0.95 (0.81–1.11)	67 (1.4)	0.80 (0.62–1.02)	51 (1.6)	0.84 (0.63–1.11)	0.04
Third- or fourth-degree laceration	1,571 (3.4)	Reference	439 (2.6)	0.93 (0.84–1.03)	130 (1.9)	0.75 (0.63–0.90)	49 (1.8)	0.75 (0.56–0.99)	24 (1.6)	0.68 (0.46–1.02)	< 0.001
Hemorrhage	4,643 (7.0)	Reference	1,943 (7.4)	1.04 (0.99–1.10)	865 (7.5)	1.03 (0.96–1.10)	369 (7.7)	1.03 (0.93–1.15)	234 (7.5)	1.02 (0.89–1.15)	0.32
Blood transfusion	2,212 (5.0)	Reference	782 (4.8)	0.99 (0.92–1.07)	335 (4.8)	1.00 (0.90–1.12)	136 (4.7)	0.98 (0.83–1.17)	71 (4.0)	0.95 (0.76–1.19)	0.74
Maternal fever	1,132 (1.7)	Reference	540 (2.1)	1.17 (1.06–1.30)	236 (2.0)	1.14 (0.99–1.31)	110 (2.3)	1.27 (1.04–1.54)	83 (2.7)	1.37 (1.10–1.71)	< 0.001
Major puerperal infection	260 (0.4)	Reference	130 (0.5)	1.24 (1.00–1.53)	63 (0.5)	1.39 (1.05–1.84)	37 (0.8)	1.93 (1.36–2.74)	23 (0.7)	1.75 (1.15–2.68)	< 0.001
Infection of genitourinary tract	77 (0.1)	Reference	44 (0.2)	1.31 (0.89–1.92)	21 (0.2)	1.33 (0.81–2.20)	8 (0.2)	1.18 (0.56–2.48)	11 (0.4)	2.24 (1.16–4.34)	0.03
Complication of surgical wounds	209 (0.3)	Reference	86 (0.3)	1.10 (0.85–1.41)	43 (0.4)	1.27 (0.91–1.77)	22 (0.5)	1.55 (0.99–2.41)	19 (0.6)	2.17 (1.34–3.51)	< 0.001
Hysterectomy	39 (0.07)	Reference	11 (0.05)	0.64 (0.32–1.29)	12 (0.1)	1.53 (0.78–3.00)	2 (0.05)	0.61 (0.15–2.50)	3 (0.12)	1.36 (0.40–4.65)	0.75
Acute cardiovascular events	125 (0.2)	Reference	62 (0.2)	1.19 (0.87–1.63)	33 (0.3)	1.43 (0.97–2.12)	18 (0.4)	1.88 (1.15–3.07)	14 (0.5)	2.17 (1.24–3.81)	< 0.001
Maternal ICU admission	314 (0.6)	Reference	133 (0.6)	1.10 (0.90–1.35)	53 (0.5)	1.15 (0.86–1.54)	15 (0.4)	1.05 (0.63–1.77)	14 (0.5)	1.55 (0.91–2.63)	0.11

BMI, body mass index; ICU, intensive care unit

Relative risks (RR) were adjusted for maternal age, maternal race, insurance type, marital status, parity, smoking and alcohol use during pregnancy and study site.

* Test of linear trend was conducted by using the median BMI value for each obesity group and fitting this as a continuous variable in the logistic regression models.

Gestational hypertensive disorders included gestational hypertension, preeclampsia, and eclampsia and acute cardiovascular events included ischemic heart disease, heart failure, cardiac arrest/failure, and unspecified cardiovascular postpartum complications.

Specific outcomes were analyzed among respective deliveries at risk and sites which did not report specific outcomes were excluded from respective analysis: Intrapartum cesarean delivery and induction among spontaneous or induced labor (n=101,527), cesarean delivery among induction (n=41,049), cesarean delivery among spontaneous labors (n=60,478), operative vaginal delivery among vaginal deliveries (n=77,271), oxytocin augmentation among spontaneous labors (n=60,478), third- or fourth-degree laceration was analyzed among vaginal deliveries (n=75,189), blood transfusion among 72,362 deliveries, hysterectomy among 94,914 deliveries, maternal ICU admission among 95,111 deliveries.

Table 3

Neonatal complications of singleton pregnancies among women without pre-pregnancy diseases by pre-pregnancy obesity, Consortium on Safe Labor 2002–2008

Outcomes	Normal BMI		Overweight		Obese I		Obese II		Obese III		P for trend *
	N (%)	RR	N (%)	RR (95% CI)	N (%)	RR (95% CI)	N (%)	RR (95% CI)	N (%)	RR (95% CI)	
Preterm birth < 37 weeks	5,930 (8.9)	Reference	2,507 (9.5)	1.00 (0.96–1.05)	1,206 (10.4)	1.06 (1.00–1.13)	503 (10.5)	1.06 (0.97–1.16)	342 (11.0)	1.04 (0.94–1.16)	0.06
Early preterm birth < 32 weeks	953 (1.4)	Reference	482 (1.8)	1.15 (1.03–1.28)	248 (2.1)	1.28 (1.11–1.48)	107 (2.2)	1.31 (1.07–1.61)	75 (2.4)	1.28 (1.01–1.63)	< 0.001
Late preterm birth 32–<37 weeks	4,977 (7.6)	Reference	2,025 (7.8)	0.98 (0.93–1.03)	958 (8.4)	1.02 (0.95–1.09)	396 (8.5)	1.01 (0.92–1.12)	267 (8.8)	1.00 (0.89–1.13)	0.82
Stillbirth	206 (0.3)	Reference	91 (0.4)	1.07 (0.83–1.37)	53 (0.5)	1.43 (1.05–1.96)	15 (0.3)	1.01 (0.59–1.74)	14 (0.5)	1.41 (0.82–2.45)	0.09
Large for Gestational Age	5,272(7.9)	Reference	3,171 (12.0)	1.52 (1.45–1.58)	1,584 (13.7)	1.74 (1.65–1.83)	712 (14.9)	1.93 (1.79–2.07)	538 (17.3)	2.32 (2.14–2.52)	< 0.001
Birth Injury	1,161 (1.8)	Reference	486 (1.8)	1.17 (1.05–1.30)	203 (1.8)	1.17 (1.01–1.35)	98 (2.1)	1.37 (1.11–1.67)	58 (1.9)	1.25 (0.96–1.62)	< 0.001
Congenital anomaly	3,923 (5.9)	Reference	1,673 (6.4)	1.08 (1.02–1.14)	728 (6.3)	1.07 (0.99–1.16)	317 (6.6)	1.12 (1.00–1.25)	225 (7.3)	1.20 (1.05–1.36)	< 0.001
Transient tachypnea	1,780 (2.7)	Reference	887 (3.4)	1.20 (1.11–1.30)	427 (3.7)	1.27 (1.14–1.41)	194 (4.1)	1.36 (1.17–1.58)	146 (4.7)	1.46 (1.24–1.73)	< 0.001
Apnea	862(1.4)	Reference	436 (1.8)	1.16 (1.03–1.30)	191 (1.7)	1.09 (0.93–1.28)	76 (1.7)	1.03 (0.81–1.30)	52 (1.7)	0.98 (0.74–1.30)	0.45
Aspiration	297 (0.5)	Reference	144 (0.6)	1.21 (0.99–1.48)	83 (0.7)	1.58 (1.04–2.03)	30 (0.6)	1.33 (0.91–1.95)	28 (0.9)	1.81 (1.22–2.67)	< 0.001
Asphyxia	165 (0.3)	Reference	73 (0.3)	1.09 (0.83–1.45)	25 (0.2)	0.85 (0.55–1.31)	16 (0.3)	1.33 (0.79–2.25)	9 (0.3)	1.11 (0.57–2.15)	0.59
Sepsis	1,367 (2.1)	Reference	697 (2.6)	1.21 (1.10–1.33)	332 (2.9)	1.28 (1.13–1.44)	158 (3.3)	1.46 (1.24–1.73)	119 (3.8)	1.55 (1.28–1.87)	< 0.001
Seizure	107 (0.2)	Reference	44 (0.2)	1.01 (0.70–1.45)	31 (0.3)	1.59 (1.04–2.41)	14 (0.3)	1.70 (0.96–3.01)	7 (0.2)	1.19 (0.54–2.64)	0.04
Intracranial hemorrhage	130 (0.2)	Reference	65 (0.3)	1.12 (0.82–1.51)	34 (0.3)	1.27 (0.86–1.87)	15 (0.3)	1.37 (0.80–2.34)	6 (0.2)	0.73 (0.32–1.65)	0.48
NICU admission	5,880 (8.9)	Reference	2,848 (10.8)	1.16 (1.11–1.21)	1,335 (11.5)	1.20 (1.13–1.27)	610 (12.8)	1.30 (1.20–1.41)	449 (14.5)	1.38 (1.26–1.51)	< 0.001
Among preterm births											
Respiratory distress syndrome	1,182 (19.9)	Reference	532 (21.2)	1.06 (0.97–1.16)	287 (23.8)	1.16 (1.04–1.30)	139 (27.6)	1.35 (1.16–1.57)	89 (26.0)	1.26 (1.05–1.52)	< 0.001
Necrotizing enterocolitis	86 (1.5)	Reference	39 (1.6)	1.13 (0.77–1.65)	16 (1.3)	0.98 (0.57–1.67)	14 (2.8)	2.10 (1.20–3.67)	8 (2.3)	1.75 (0.85–3.60)	0.03
PVH–IVH	208 (3.5)	Reference	109 (4.4)	1.23 (0.98–1.54)	60 (5.0)	1.46 (1.10–1.93)	24 (4.8)	1.40 (0.93–2.13)	15 (4.4)	1.21 (0.72–2.03)	0.01
Retinopathy of prematurity	151 (2.6)	Reference	85 (3.4)	1.31 (1.01–1.71)	32 (2.7)	1.09 (0.74–1.59)	18 (3.6)	1.47 (0.91–2.37)	12 (3.5)	1.25 (0.70–2.23)	0.11

BMI, body mass index; NICU, neonatal intensive care unit; PVH-IVH, peri- and intraventricular hemorrhage

Relative risks (RR) were adjusted for maternal age, maternal race, insurance type, marital status, parity, smoking and alcohol use during pregnancy, and study site.

* Test of linear trend was conducted by using the median BMI value for each obesity group and fitting this as a continuous variable in the logistic regression models.

Respiratory distress syndrome, necrotizing enterocolitis, PVH-IVH and retinopathy prematurity were analyzed among preterm births before 37 weeks of gestation (n=10,488). Preterm birth <32 weeks were excluded in the analysis of late preterm birth (n=110, 444) and apnea was analyzed among 105,742 deliveries.

Table 4

Combined risk of obstetric and neonatal complications by pre-pregnancy obesity, Consortium on Safe Labor 2002–2008

Outcomes	Main analysis among mothers without pre-pregnancy diseases (n=112,309)			No gestational hypertensive disorder or GDM (n=99,785)			No gestational hypertensive disorder or GDM and appropriate gestational weight gain (n=23,434)		
	Events		RR (95% CI)	Events		RR (95% CI)	Events		RR (95% CI)
	N	(%)		N	(%)		N	(%)	
All combined outcomes									
Normal BMI	56,349	84.8	Reference	51,288	83.5	Reference	15,137	82.1	Reference
Overweight	23,332	88.5	1.05 (1.05–1.06)	19,895	86.8	1.05 (1.04–1.06)	2,609	84.3	1.04 (1.03–1.06)
Obese I	10,410	89.8	1.07 (1.07–1.08)	8,324	87.5	1.06 (1.06–1.07)	939	87.6	1.09 (1.07–1.12)
Obese II	4,349	91.0	1.09 (1.08–1.10)	3,290	88.4	1.08 (1.07–1.10)	461	87.5	1.09 (1.05–1.12)
Obese III	2,910	93.7	1.12 (1.11–1.13)	2,029	91.2	1.11 (1.10–1.13)	269	91.2	1.15 (1.10–1.19)
Combined obstetric and neonatal complications excluding obstetric interventions (cesarean delivery, induction and oxytocin augmentation)									
Normal BMI	25,637	38.6	Reference	20,576	33.5	Reference	5,620	30.5	Reference
Overweight	11,939	45.3	1.18 (1.16–1.20)	8,502	37.1	1.11 (1.09–1.13)	997	32.2	1.07 (1.02–1.14)
Obese I	5,692	49.1	1.27 (1.25–1.30)	3,606	37.9	1.13 (1.10–1.16)	376	35.1	1.17 (1.07–1.27)
Obese II	2,491	52.1	1.35 (1.31–1.39)	1,432	38.5	1.14 (1.09–1.19)	185	35.1	1.15 (1.02–1.29)
Obese III	1,774	57.1	1.47 (1.42–1.63)	893	40.2	1.18 (1.11–1.24)	127	43.1	1.39 (1.22–1.59)

BMI, body mass index

Relative risks (RR) were adjusted for maternal age, maternal race, insurance type, marital status, parity, smoking and alcohol use during pregnancy and study site.

All combined outcomes included all studied outcomes in Table 2 and 3.