Obstetrics and Gynecology

Original Article

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The impact of prepregnancy body mass index on pregnancy and neonatal outcomes

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Abstract

Context: The obesity epidemic in the United States is continuing to worsen. Obesity is a known risk factor for pregnancy morbidity. However, many studies use the patient's body mass index (BMI) at the time of delivery, do not stratify by class of obesity, or utilize billing codes as the basis of their study, which are noted to be inaccurate.

Objectives: This study aims to investigate the prepregnancy BMI class specific risks for pregnancy and neonatal complications based on a prepregnancy BMI class.

Methods: We conducted a retrospective cohort study of 40,256 pregnant women with 55,202 singleton births between October 16, 2007 and December 3, 2023. We assessed the risk of pregnancy and neonatal morbidity based on the maternal prepregnancy BMI category. The primary outcome was composite maternal morbidity, including hypertensive disorders of pregnancy (i.e., gestational hypertension [GHTN] and preeclampsia), and gestational diabetes mellitus (GDM), adjusted for pregestational diabetes mellitus and chronic hypertension (cHTN). Secondary maternal outcomes included preterm premature rupture of membranes (PPROM), preterm delivery (PTD<37 and <32 weeks), induction of labor (IOL), cesarean delivery (CD), and postpartum hemorrhage (PPH). Neonatal outcomes included a composite adverse outcome (including stillbirth, intraventricular hemorrhage (IVH), hypoglycemia, respiratory distress syndrome [RDS], APGAR [Appearance, Pulse, Grimace, Activity, and Respiration] <7 at 5 min, and neonatal intensive care unit [NICU] admission), birthweight, fetal growth restriction (FGR), and macrosomia.

Results: Composite maternal morbidity (odds ratio [OR] 4.40, confidence interval [CI] 3.70–5.22 for class III obesity [BMI≥40.0 kg/m^2] compared with normal BMI), hypertensive disorders of pregnancy (HDP), GDM, PTD, IOL, CD, PPH, neonatal composite morbidity, hypoglycemia, RDS, APGAR<7 at 5 min, NICU admission, and macrosomia showed a significant increasing test of trend among BMI classes. Increased BMI was protective for FGR.

Conclusions: Our data provides BMI-class specific odds ratios (ORs) for adverse pregnancy outcomes. Increased BMI class significantly increases the risk of HDP, GDM, IOL, CD, composite adverse neonatal outcomes, and macrosomia, and decreases the risk of FGR. Attaining a healthier BMI category prior to conception may lower pregnancy morbidity.

Keywords: maternal morbidity; neonatal morbidity; obesity; pregnancy complications

The obesity epidemic in the United States (US) is well established as are its long-term health consequences. Recently, efforts have focused on understanding the impact of obesity on reproductive-aged and pregnant women, as more than one in three women in the United States are overweight and greater than 50 % of pregnant women are overweight or obese [1, 2].

Many studies have shown that women who are overweight or obese are at risk for pregnancy complications including gestational diabetes mellitus (GDM), hypertensive disorders of pregnancy (HDP), cesarean delivery (CD), and longer operative time, thus increasing their risk of infection, the length of time under anesthesia, and blood loss [3–8]. There are also increased risks of complications for the neonate such as prematurity, stillbirth, macrosomia, lower APGAR (Appearance, Pulse, Grimace, Activity, and Respiration) scores at 5 min, and respiratory distress syndrome (RDS) [4–6, 9–13].

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Although several studies have demonstrated the increased pregnancy morbidity associated with obesity, the applicability of the findings are limited by study design. Some studies did not assess the risks associated with the specific class of obesity; therefore, we cannot be certain if women in higher obesity classes are at more or less risk of adverse pregnancy outcomes as compared to those in lower obesity classes [8, 13–15]. Some studies assessed outcomes based on body mass index (BMI) at time of delivery, at which point it is too late to intervene to reduce risks [7, 16]. Several studies measured outcomes based on billing codes alone [4, 17–19], which have been shown to be insufficient and inaccurate with significant potential for error [20, 21]. Some studies were based outside of the US and so the results may not be generalizable to the US population [3, 5, 6] and one study within the US only assessed the impact on the outcomes of birthweight [11]. It is necessary to clearly understand the extent to which BMI affects pregnancy morbidity so that mitigation strategies can be appropriately employed preconception [22].

Methods

This is a Geisinger IRB-approved (#2017-0520) retrospective cohort study of pregnant women who delivered singleton births within all five delivery hospitals in the Geisinger Health System in Pennsylvania between October 16, 2007 and December 3, 2023. We queried the electronic health records (EHRs) and included all pregnancies in which the maternal prepregnancy BMI was greater than or equal to 18.5 kg/m^2. BMI was assigned based on measurements taken between three months prior to conception and one month after their last menstrual period. We excluded pregnancies complicated by multifetal gestations and where a pre-gravid BMI was not recorded or classified as underweight. Neonates were only included if they were linked in the EHR to the mother. The cohort was stratified by the primary predictor of interest, i.e., the prepregnancy BMI category: normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and class I (30.0–34.9 kg/m^2), class II (35.0–39.9 kg/m^2), and class III (40.0 kg/m^2) obese [23].

Demographic variables were assessed within each category of BMI, including age at delivery, self-reported race/ethnicity, marital status, insurance, parity, education, tobacco use, pregestational diabetes mellitus, and chronic hypertension (cHTN). The primary outcome was composite maternal morbidity (i.e., gestational hypertension [GHTN], preeclampsia, and GDM), adjusted for diabetes mellitus and cHTN. Secondary pregnancy outcomes included preterm prelabor rupture of membranes (PPROM), preterm delivery (PTD<37 and <32 weeks), induction of labor (IOL), CD, and postpartum hemorrhage (PPH). Neonatal outcomes included a composite adverse outcome (that included stillbirth, intraventricular hemorrhage [IVH], hypoglycemia, RDS, APGAR<7 at 5 min [in cases of live births], shoulder dystocia, and neonatal intensive care unit [NICU] admission), birthweight, fetal growth restriction (FGR), and macrosomia (birthweight>4,000 g). IVH and RDS were assessed within the first six months of life. Missing data were excluded.

For several of the outcomes, algorithms were created to improve demarcation of these outcomes, some of which are delineated in a separate publication [20]. Since that publication, we have updated the definition of PPH to reflect ≥1,000 cc of blood loss at delivery, regardless of mode. For some of the outcomes assessed, billing codes (i.e., International Classification of Diseases [ICD-9 and ICD-10] codes) were utilized as a basis, i.e., PPROM, IVH, and RDS. Some outcomes were discrete fields that were able to be abstracted from the EHR, i.e., birthweight and APGAR scores.

Data are reported as frequency and percentage for categorical variables and mean and standard deviation (SD) for continuous variables. To model the binary outcomes of interest, a generalized mixed linear regression (log-binomial) model for the binary outcomes with a random effect to account for repeated pregnancies was performed. For the continuous outcome of birthweight, a mixed linear model including a random effect to account for the repeated pregnancies was performed. We controlled for maternal age at delivery, race/ethnicity, marital status, medical assistance, parity, prenatal smoking status, diabetes mellitus, and cHTN. The following outcomes were controlled for history of the same: GHTN, preeclampsia, GDM, PPROM, PTD, CD, PPH, stillbirth, macrosomia, and shoulder dystocia. The odds ratios (ORs) or applicable estimate and 95 % CIs are reported for each BMI class. Those with normal prepregnancy BMI were used as the reference group. A test of trend was performed for each outcome utilizing the described modeling techniques for binary or continuous outcomes as appropriate, where the variable BMI class is included in the model as continuous. We did a stratified analysis by parity: nulliparity vs. multiparity. A p value less than 0.05 was considered significant. All analyses were performed using SAS 9.4v (SAS Institute, Inc., Cary, NC).

Results

A total of 40,256 patients with 55,202 singleton pregnancies and available information on 53,664 neonates were included. Among the pregnancies, 21,102 (38.2 %) of the patients were normal weight, 14,388 (26.1 %) were overweight, 9,268 (16.8 %) were class I obese, 5,675 (10.3 %) were class II obese, and 4,769 (8.6 %) were class III obese. The average maternal age at delivery was 28.5 years (SD 5.6). The majority of women were non-Hispanic White (79.7 %), married (58.7 %), privately insured (51.8 %), and parous (61.0 %); 16.8 % smoked prenatally, 2.7 % had pregestational diabetes, and 5.0 % had pre-existing hypertension. Demographic characteristics varied among BMI categories (Table 1). Table 2 shows the association between each BMI classification and maternal and neonatal adverse outcomes of interest. After controlling, we observed statistically significant increasing ORs across BMI classes for several adverse outcomes such that as BMI increased from one class to the next, so did the odds of certain adverse outcomes including IOL and CD (Table 2). Higher BMI classes had a protective effect on the incidence of FGR, most significantly in overweight and class I patients as compared to those who were of normal weight (OR 0.73, 95 % CI 0.66–0.81; OR 0.70, 95 % CI 0.62–0.80,

Table 1: Demographic characteristics by maternal body mass index (BMI) class for all pregnancies.

	BMI Classes, n (%)					Total (n=55,202)
	Normal (n=21,102)	Overweight (n=14,388)	Class I (n=9,268)	Class II (n=5,675)	Class III (n=4,769)	
Mean age at delivery, years (SD)	28.0 (5.70)	28.6 (5.59)	28.7 (5.57)	28.8 (5.46)	29.2 (5.28)	28.5 (5.60)
Race/ethnicity (of 40,256 patients)						
White/Non-Hispanic	12,986 (80.6 %)	8,140 (77.8 %)	5,108 (78.5 %)	3,168 (80.9 %)	2,678 (82.4 %)	32,080 (79.7 %)
White/Hispanic	1,067 (6.6 %)	911 (8.7 %)	563 (8.7 %)	300 (7.7 %)	183 (5.6 %)	3,024 (7.5 %)
Black/Non-Hispanic	814 (5.1 %)	620 (5.9 %)	405 (6.2 %)	250 (6.4 %)	240 (7.4 %)	2,329 (5.8 %)
Black/Hispanic	151 (0.9 %)	144 (1.4 %)	115 (1.8 %)	53 (1.4 %)	47 (1.4 %)	510 (1.3 %)
Other/Non-Hispanic	547 (3.4 %)	265 (2.5 %)	98 (1.5 %)	31 (0.8 %)	15 (0.5 %)	956 (2.4 %)
Other/Hispanic	131 (0.8 %)	104 (1.0 %)	54 (0.8 %)	26 (0.7 %)	30 (0.9 %)	345 (0.9 %)
Unknown	420 (2.6 %)	285 (2.7 %)	162 (2.5 %)	89 (2.3 %)	56 (1.7 %)	1,012 (2.5 %)
Marital status						
Married/significant other	12,413 (58.8 %)	8,577 (59.6 %)	5,406 (58.3 %)	3,327 (58.6 %)	2,703 (56.7 %)	32,426 (58.7 %)
Single/divorced/separated/ widowed	8,603 (40.8 %)	5,736 (39.9 %)	3,820 (41.2 %)	2,316 (40.8 %)	2,045 (42.9 %)	22,520 (40.8 %)
Unknown	86 (0.4 %)	75 (0.5 %)	42 (0.5 %)	32 (0.6 %)	21 (0.4 %)	256 (0.5 %)
Insurance						
Private	11,362 (53.8 %)	7,666 (53.3 %)	4,647 (50.1 %)	2,721 (47.9 %)	2,194 (46.0 %)	28,590 (51.8 %)
Public	9,500 (45.0 %)	6,550 (45.5 %)	4,527 (48.8 %)	2,902 (51.1 %)	2,540 (53.3 %)	26,019 (47.1 %)
Unknown	240 (1.1 %)	172 (1.2 %)	94 (1.0 %)	52 (0.9 %)	35 (0.7 %)	593 (1.1 %)
Parity						
Nulliparous (0)	9,103 (43.1 %)	5,501 (38.2 %)	3,184 (34.4 %)	1,926 (33.9 %)	1,579 (33.1 %)	21,293 (38.6 %)
Multiparous (≥1)	11,893 (56.4 %)	8,829 (61.4 %)	6,053 (65.3 %)	3,729 (65.7 %)	3,182 (66.7 %)	33,686 (61.0 %)
Unknown	106 (0.5 %)	58 (0.4 %)	31 (0.3 %)	20 (0.4 %)	8 (0.2 %)	223 (0.4 %)
Education, years						
≤12	4,804 (22.8 %)	3,334 (23.2 %)	2,417 (26.1 %)	1,690 (29.8 %)	1,604 (33.6 %)	13,849 (25.1 %)
13–16	4,571 (21.7 %)	3,227 (22.4 %)	2,194 (23.7 %)	1,485 (26.2 %)	1,318 (27.6 %)	12,795 (23.2 %)
17+	1,726 (8.2 %)	892 (6.2 %)	451 (4.9 %)	242 (4.3 %)	159 (3.3 %)	3,470 (6.3 %)
Unknown	10,001 (47.4 %)	6,935 (48.2 %)	4,206 (45.4 %)	2,258 (39.8 %)	1,688 (35.4 %)	25,088 (45.4 %)
Tobacco use						
No	16,671 (79.0 %)	11,609 (80.7 %)	7,491 (80.8 %)	4,562 (80.4 %)	3,847 (80.7 %)	44,180 (80.0 %)
Yes	3,776 (17.9 %)	2,320 (16.1 %)	1,474 (15.9 %)	934 (16.5 %)	753 (15.8 %)	9,257 (16.8 %)
Unknown	655 (3.1 %)	459 (3.2 %)	303 (3.3 %)	179 (3.2 %)	169 (3.5 %)	1,765 (3.2 %)
Pregestational diabetes	195 (0.9 %)	286 (2.0 %)	320 (3.5 %)	314 (5.5 %)	361 (7.6 %)	1,476 (2.7 %)
Chronic hypertension	291 (1.4 %)	443 (3.1 %)	597 (6.4 %)	545 (9.6 %)	872 (18.3 %)	2,748 (5.0 %)

BMI, body mass index; SD, standard deviation.

respectively). There was a significantly increased risk of a PTD<32 weeks and a significant test of trend for increased odds of macrosomia as compared to normal-weight patients as BMI class increased. Stillbirth (n=24) and IVH (n=200) cases were small in numbers, and therefore, comparison across groups may not have clinical relevance. There is an increase in composite maternal morbidity with increasing BMI class: those who are overweight, class I, class II, and class III obese were 1.72, 2.66, 3.35, and 4.40 times as likely to have maternal morbidity as compared to those with normal-pregnancy BMI (Figure 1), respectively. These findings are maintained in the subanalysis of nulliparous patients vs. multiparous patients (data not shown). An increased risk was also seen for composite neonatal morbidity, although the increase was not as strong as maternal morbidity.

Discussion

As BMI class increased, the odds of composite pregnancy morbidity increased to as much as 4.4 for a patient with class III obesity as compared to one with normal prepregnancy BMI. Composite neonatal morbidity also increased. While it seems intuitive that patients with class III obesity would be at the highest risk for adverse outcomes, this is one of the larger studies in the United States assessing these outcomes

Table 2: Association between body mass index (BMI) classification and maternal and fetal complication.

	BMI Classes									Test of trend Adjusted p value
	Normal reference group (n=21,102)	Overweight (n=14,388)		Class I (n=9,268)		Class II (n=5,675)		Class III (n=4,769)		
Maternal risks	n (%)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	
Composite maternal morbidity[c]	2,874 (13.6 %)	3,198 (22.2 %)	1.72 (1.63–1.82)	2,833 (30.6 %)	2.66 (2.50–2.84)	2,067 (36.4 %)	3.35 (3.08–3.65)	2,060 (43.2 %)	4.40 (3.70–5.22)	<0.01[a]
Gestational hypertension	1,174 (5.6 %)	1,418 (9.9 %)	1.82 (1.67–1.97)	1,187 (12.8 %)	2.54 (2.32–2.77)	888 (15.6 %)	3.14 (2.81–3.52)	929 (19.5 %)	4.55 (3.67–5.63)	<0.01[a]
Preeclampsia	671 (3.2 %)	689 (4.8 %)	1.39 (1.25–1.55)	634 (6.8 %)	1.85 (1.64–2.08)	484 (8.5 %)	2.13 (1.83–2.48)	520 (10.9 %)	2.35 (1.74–3.19)	<0.01[a]
Gestational diabetes mellitus	1,159 (5.5 %)	1,316 (9.1 %)	1.66 (1.52–1.81)	1,308 (14.1 %)	2.75 (2.51–3.00)	998 (17.6 %)	3.62 (3.23–4.05)	969 (20.3 %)	1.71 (1.56–1.88)	<0.01[a]
Preterm premature rupture of membranes	2,491 (11.8 %)	1,620 (11.3 %)	0.98 (0.91–1.04)	989 (10.7 %)	1.00 (0.91–1.10)	524 (9.2 %)	0.81 (0.72–0.92)	411 (8.6 %)	0.77 (0.60–1.00)	0.13[a]
Preterm delivery<37 weeks[f]	1734 (8.2 %)	1,122 (7.8 %)	0.91 (0.84–0.98)	843 (9.1 %)	0.95 (0.88–1.03)	576 (10.2 %)	1.08 (0.96–1.23)	510 (10.7 %)	1.03 (0.80–1.34)	0.12[a]
Preterm delivery<32 weeks[f]	231 (1.1 %)	187 (1.3 %)	1.15 (0.94–1.39)	160 (1.7 %)	1.42 (1.14–1.76)	117 (2.1 %)	1.71 (1.29–2.26)	92 (1.9 %)	1.44 (0.78–2.64)	<0.01[a]
Induction of labor	7,778 (36.9 %)	5,910 (41.1 %)	1.25 (1.19–1.3)	4,089 (44.1 %)	1.45 (1.37–1.53)	2,735 (48.2 %)	1.70 (1.58–1.83)	2,592 (54.4 %)	2.29 (2.04–2.57)	<0.01[a]
Mode of delivery, cesarean[f]	4,826 (22.9 %)	4,190 (29.1 %)	1.28 (1.22–1.35)	3,195 (34.5 %)	1.59 (1.49–1.69)	2,280 (40.2 %)	1.92 (1.74–2.11)	2,342 (49.2 %)	2.47 (2.17–2.81)	<0.01[a]
Postpartum hemorrhage	377 (2.4 %)	372 (3.4 %)	1.41 (1.22–1.64)	289 (4.1 %)	1.72 (1.46–2.03)	217 (5.2 %)	2.03 (1.52–2.73)	273 (7.8 %)	3.07 (2.08–4.54)	<0.01[a]
Missing	5,244	3,520		2,284		1,537		1,255		
Neonatal risks	**Normal (n=20,420)**	**Overweight (n=14,013)**		**Class I (n=9,033)**		**Class II (n=5,523)**		**Class III (n=4,675)**		
Composite neonatal morbidity[d]	3,093 (15.1 %)	2,287 (16.3 %)	1.06 (1.00–1.12)	1,619 (17.9 %)	1.12 (1.04–1.20)	1,174 (21.3 %)	1.32 (1.20–1.44)	1,155 (24.7 %)	1.47 (1.28–1.69)	<0.01[a]
Hypoglycemia	1,067 (5.2 %)	849 (6.1 %)	1.10 (1.00–1.20)	674 (7.5 %)	1.27 (1.14–1.41)	522 (9.5 %)	1.56 (1.36–1.78)	528 (11.3 %)	1.73 (1.42–2.12)	<0.01[a]
Respiratory distress syndrome	457 (2.2 %)	362 (2.6 %)	1.10 (0.96–1.27)	265 (2.9 %)	1.16 (0.99–1.37)	188 (3.4 %)	1.31 (1.06–1.62)	194 (4.1 %)	1.44 (1.05–1.97)	<0.01[a]
APGAR<7 at 5 min	422 (2.1 %)	356 (2.6 %)	1.21 (1.04–1.39)	230 (2.6 %)	1.17 (0.99–1.39)	189 (3.4 %)	1.52 (1.23–1.88)	206 (4.4 %)	1.86 (1.37–2.52)	<0.01[a]
Missing	124	92		55		38		24		
NICU admission	2,194 (10.7 %)	1,560 (11.1 %)	1.01 (0.94–1.09)	1,085 (12.0 %)	1.04 (0.96–1.13)	772 (14.0 %)	1.18 (1.05–1.31)	740 (15.8 %)	1.25 (1.06–1.47)	<0.01[a]
Shoulder dystocia	561 (2.7 %)	447 (3.2 %)	1.15 (1.02–1.31)	303 (3.4 %)	1.18 (1.02–1.37)	180 (3.3 %)	1.12 (0.91–1.37)	140 (3.0 %)	1.04 (0.74–1.44)	0.06[a]
Birthweight in grams, mean (SD) [e,f]	3,322.6 (7,458.22)	3,324.9 (636.80)	7.35 (−117.30–131.99)	3,334.0 (618.29)	20.25 (−137.55–178.04)	3,342.5 (638.58)	27.02 (−181.72–235.77)	3,345.3 (654.95)	117.18 (−230.18–310.27)	0.51[b]

Table 2: (continued)

	BMI Classes									Test of trend
	Normal reference group (n=21,102)	Overweight (n=14,388)		Class I (n=9,268)		Class II (n=5,675)		Class III (n=4,769)		Adjusted p value
Maternal risks	n (%)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	n (%)	OR (95 % CI)	
Fetal growth restriction	1,129 (5.5 %)	561 (4.0 %)	0.73 (0.66–0.81)	373 (4.1 %)	0.70 (0.62–0.8)	264 (4.8 %)	0.81 (0.68–0.97)	221 (4.7 %)	0.75 (0.52–1.08)	<0.01[a]
Macrosomia[f]	1,344 (6.6 %)	1,299 (9.3 %)	1.39 (1.28–1.50)	958 (10.6 %)	1.56 (1.42–1.71)	642 (11.6 %)	1.63 (1.44–1.84)	557 (11.9 %)	1.59 (1.32–1.93)	<0.01[a]

APGAR, Appearance, Pulse, Grimace, Activity, and Respiration; NICU, neonatal intensive care unit; OR, odds ratio; CI, confidence interval. [a]Test of Trend p value from logistic regression model, adjusted for age at delivery, race/ethnicity, marital status, medical assistance, parity, tobacco use, pregestational diabetes, chronic hypertension, history of outcome of interest (composite maternal, gestational hypertension, preeclampsia, gestational diabetes, preterm premature rupture of membranes, preterm delivery, cesarean, postpartum hemorrhage, composite neonatal, stillbirth, macrosomia, and shoulder dystocia). [b]Test of trend using general linear models adjusting for age at delivery, race/ethnicity, marital status, medical assistance, parity, tobacco use, pregestational diabetes, and chronic hypertension. [c]Composite maternal morbidity includes gestational hypertension, preeclampsia, and gestational diabetes. [d]Composite neonatal morbidity includes stillbirth, intraventricular hemorrhage, hypoglycemia, respiratory distress syndrome, APGAR score<7 at 5 min, and neonatal intensive care unit admission. [e]Estimate and 95 % CI is reported from linear regression model. [f]Data may be missing for the indicated variables in up to 38 pregnancies for maternal outcomes and 49 pregnancies for neonatal outcomes.

for the individual classes based on prepregnancy BMI. Patients with any class of obesity were at a significantly higher risk of developing hypertensive disorders of pregnancy or gestational diabetes as compared to those of normal weight. In fact, those with class III obesity were at significantly increased odds of developing GHTN (4.55), preeclampsia (2.35), and GDM (1.71), compared to their counterparts with normal prepregnancy BMI. As the obesity class increased, so did the odds of IOL, CD, PTD<32 weeks, and PPH. Obesity had a significant protective effect for FGR. The increase in macrosomia is clinically relevant, as those with class II obesity had 1.63 increased odds of having a macrosomic neonate as a patient with normal weight. Parity did not significantly affect these results.

Previous studies have demonstrated that pregnant women with obesity are at a higher risk of morbidity compared to women who are not obese [23–28]. Studies have shown similar results of increasing risk of GHTN, preeclampsia, gestational diabetes, and CD for patients with obesity and morbid obesity [17, 26]. A similar study in the United Kingdom showed that individuals with BMI>30 kg/m^2 have a 3.6 increased odds of developing gestational diabetes compared to patients with a normal BMI [16]. We were able to confirm these findings and additionally were able to include women with BMI>40 kg/m^2 and demonstrate that those patients are at highest risk of complications compared to patients with a normal BMI. Increased risk of GDM supports routine early screening for gestational diabetes (with a 1 h glucose challenge test) [14–16, 26, 29] for women with obesity. Multiple studies have also shown that obesity is an independent risk factor for CD, with an OR of 3.0 for patients with BMI≥35 kg/m^2 [26]. Our study showed increased odds for CD with each successive BMI class when compared to the normal BMI class, with patients with class III obesity having an OR of 2.47 (95 % CI 2.17–2.81). Although our institution recommends IOL for patients with class III obesity at 39 weeks, the increased CD rate does not appear to be related to this practice based on a prior study conducted at our institution [30].

Our study further demonstrates that as BMI increases from obesity class I to II to III, there is a significantly increased risk of developing GDM. Although some studies have stratified classes of obesity, they utilized ICD codes to identify outcomes, but ICD codes are considered unreliable overall [17, 18, 21]. Our data support the findings in Kim et al. [17], yet one-third of their cohort did not have recorded BMIs and the data were abstracted from ICD-9 codes alone.

One strength of our study is the large number of patients analyzed utilizing an electronic medical record system.

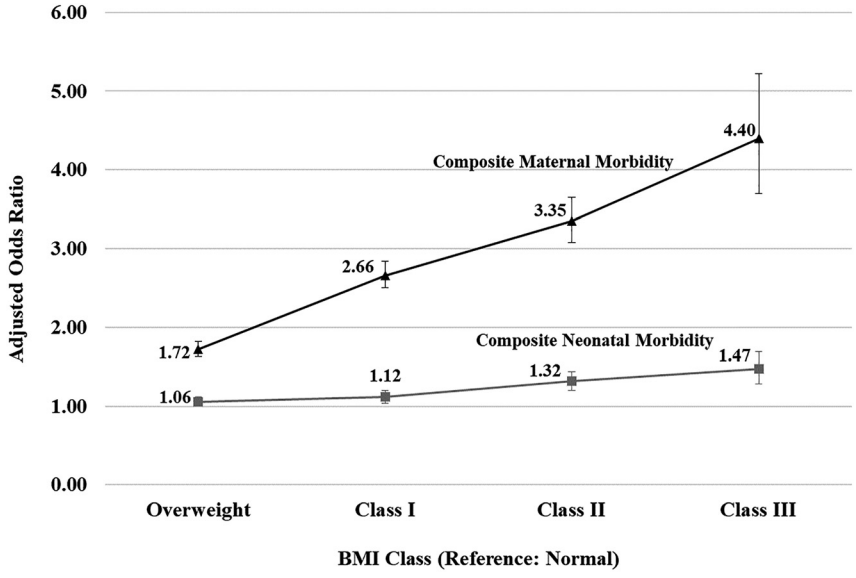

Figure 1: Odds of composite maternal and neonatal morbidity for various BMI classes. Composite maternal morbidity includes gestational hypertension, preeclampsia, and gestational diabetes mellitus. Composite neonatal morbidity includes stillbirth, intraventricular hemorrhage, hypoglycemia, respiratory distress syndrome, and APGAR score<7 at 5 min and neonatal intensive care unit admission.

Analyses were adjusted not only for potential confounders, such as demographic characteristics, but also for history of the outcome in prior pregnancy because this is generally the biggest risk factor for adverse outcomes in subsequent pregnancies. Additionally, previous studies utilized BMI at the time of delivery or combined all classes of obesity into one group, whereas our study assessed the individual BMI classes prepregnancy to assess how the risks for each specific obesity class.

Limitations include that our population is mostly non-Hispanic White, which may limit generalizability to other populations. Additionally, some adverse outcomes such as preterm birth, hemorrhage, and CD occur more frequently in racial/ethnic minority groups and therefore may not have occurred frequently in our population [31–33]. Despite our large numbers, certain outcomes (e.g., stillbirth and neonatal IVH) occurred at too small a frequency to be able to assess for significant differences between the classes. Neonatal charts were excluded if they were not linked to their mother, but because this represents only 1,538 neonates, we feel that it is unlikely that this would have significantly impacted the results. Finally, definitions of some of the variables changed throughout the study period, but we were consistent with our definitions as outlined in the Methods section.

Conclusions

In conclusion, this study showed an increasing trend in the risk of composite maternal and composite neonatal adverse outcomes as prepregnancy BMI increased. This information can be applied to facilitate antenatal counseling of pregnant women by providing prepregnancy BMI class-specific pregnancy outcomes.

Research ethics: The study was reviewed by Geisinger's IRB and approved.
Informed consent: Not applicable.
Author contributions: The authors have accepted responsibility for the entire content of this manuscript and approved its submission. AD Mackeen, M Schuster and K Angras were involved in conception of the study. Study design was formed by all authors. Data collection was performed by C Gray and V Boyd. Data analysis was performed by AJ Young. Date interpretation was performed by all authors. All authors contributed in manuscript drafting, editing, and completion.
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