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Defining maternal obesity in studies of birth outcomes: Comparing ICD-9 codes at delivery and measures on the birth certificate

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Abstract

Background: Using ICD-9 codes underestimates the prevalence of obesity in adults; however, the validity of these codes in studies of pregnancy-related outcomes is not known.

Objectives: To compare classification of maternal obesity based on ICD-9 codes in hospital discharge records versus data from birth certificates in the same women, examine predictors of agreement, and assess how associations between obesity and two birth outcomes differ by source of weight data.

Methods: This population-based study included 2,329,145 California births between 2007 and 2012. We compared data on obesity from childbirth hospital discharge records (ICD-9 codes for obesity) and birth certificates (pre-pregnancy body mass index (BMI) calculated from weight and height) and identified predictors of agreement between the two sources. Logistic regression models assessed whether the two definitions of obesity resulted in different estimates of the associations of obesity with caesarean birth and large for gestational age.

Results: Overall, 464,754 women (20.0%) had obesity based on their pre-pregnancy BMI while only 100,002 (4.3%) had an obesity-related ICD-9 code. The sensitivity of ICD-9-based obesity was low at 16.2%; however, obesity codes were highly specific at 98.7%, with a negative predictive value of 82.5% and a positive predictive value of 75.2%. Among women with obesity identified by the birth certificate, those with pre-pregnancy and pregnancy-related complications (eg, diabetes, hypertension) were more likely to have an obesity-related diagnosis in their delivery

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hospital discharge record. Using ICD-9 codes overestimated the association of obesity with caesarean birth and newborn large for gestational age.

Conclusions: ICD-9 codes in childbirth discharge records captured only one in five women with pre-pregnancy obesity. Sensitivity varied by maternal characteristics and conditions. This misclassification resulted in bias when examining the association of obesity and pregnancy-related outcomes.

Keywords

obesity; pregnancy; misclassification

Background

Maternal pre-pregnancy obesity is linked to a range of adverse pregnancy outcomes such as gestational diabetes, caesarean birth, preterm birth, large-for-gestational age newborns, and increased risk of perinatal death.[1–8] Body mass index (BMI) calculated from height and weight is the recommended metric for identifying maternal obesity in studies for which obtaining measured values is not feasible, such as retrospective studies, as well as prospective studies that enroll women after pregnancy has already begun.[9] While height and weight measures on birth certificates tend to underestimate pre-pregnancy weight, a recent meta-analysis suggested that this underreporting did not substantially bias estimations in association between obesity and birth outcomes.[10]

Some studies use International Classification of Diseases, Ninth Revision (ICD-9) codes from birth hospitalization discharge records to identify obesity. The most relevant ICD-9 code for research on pregnancy-related outcomes is 649.1x (obesity complicating pregnancy, childbirth, or the puerperium), but other codes exist, and there is variability in which ICD9 codes are used.[11–15] Previous research examining the validity of ICD-9 codes to define obesity in non-pregnant adults indicates that these codes substantially underestimate the prevalence of obesity,[16,17] and a small study of 276 pregnant women found the validity of ICD-9 codes to be poor.[18] However, the validity of these codes in pregnancy-related research at a population level is not known.

To understand the usefulness of ICD-9 codes in childbirth hospitalization discharge records to define pre-pregnancy obesity, we compared them with an “alloyed gold standard”: obesity defined by BMI estimated from pre-pregnancy height and weight that is systematically recorded in the California birth certificate. Specifically, we examined a) which specific ICD-9 codes were most commonly used to report obesity at delivery in this population, b) the relative validity of these ICD-9 codes to define obesity, overall and by maternal characteristics and conditions, and c) which maternal characteristics and conditions were most strongly associated with the sensitivity of ICD-9 codes to define obesity relative to BMI from birth records. Two outcomes that have been consistently linked to pre-pregnancy obesity are caesarean birth (maternal outcome) and large for gestational age (infant outcome).[6,19] To assess whether the different data sources for defining obesity affected associations with pregnancy-related outcomes, we compared the risk of these two outcomes using ICD-9 codes at delivery and pre-pregnancy BMI from the birth certificate.

Methods

This population-based study used linked data from live birth and fetal death certificates and maternal hospital discharge records for births in California between 2007 and 2012 (n = 3,137,749).

Cohort Selection

We excluded 87,975 births without successful linkages between birth certificates and maternal hospital discharge records. We also excluded 19,562 deliveries with gestational age < 20 weeks and 153 with gestational ages >45 due to concern of inaccurate data entry. Among women with more than one birth in the study period, we only included the first birth (495,161 births excluded). Lastly, we excluded 205,753 women who were missing the pre-pregnancy height and/or weight. Differences in characteristics for women excluded due to missing pre-pregnancy height and/or weight can be found in eTable 1 in the Supplemental Materials. The final analytical sample included 2,329,145 women (Figure 1).

Measures of Obesity

We first identified and classified the BMI category for women with data on pre-pregnancy height and weight on the birth certificate. If available, pre-pregnancy weight is obtained from physician measures at the first prenatal visit, otherwise, pre-pregnancy weight is recalled by the mother before her birth hospitalization discharge. BMI classes were determined using standard World Health Organization definitions: underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), obese class 1 (BMI 30.0–34.9), obese class 2 (BMI 35.0–39.9), and obese class 3 (≥40).[20]

We also classified obesity based on ICD-9 codes in delivery hospital discharge records. Obesity was defined as presence of least one diagnosis code of 278.00 (obesity, unspecified), 278.01 (morbid obesity), 278.03 (obesity hypoventilation syndrome), V85.3x (BMI 30–39, adult), V85.4x (BMI 40 or greater, adult), or 649.1x (obesity complicating pregnancy, childbirth, or the puerperium).

Statistical analysis

For each BMI class defined by using the birth certificate (referred to as ‘pre-pregnancy obesity’), we examined how many women had each of the ICD-9 diagnosis codes for obesity in their delivery hospitalization discharge record. We then calculated a range of indices – sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) – to examine the relative validity of the diagnosis of obesity in the maternal hospital discharge record versus birth certificates. Sensitivity is the probability of having an ICD-9 diagnosis code for obesity in the delivery discharge record when an individual was identified as having pre-pregnancy obesity, and specificity is the probability of not having an ICD-9 diagnosis code for obesity when an individual was identified as not having pre-pregnancy obesity. PPV is the probability of having pre-pregnancy obesity when an ICD-9 code was present in the delivery discharge record, and NPV is the probability of not having pre-pregnancy obesity when an ICD-9 code was not present in the delivery discharge record.

We also examined these indices by maternal demographic characteristics and pre-pregnancy and pregnancy-related clinical conditions, which were selected *a priori*. Maternal demographic characteristics included race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Asian, other/missing), nativity (US-born, foreign-born), year of delivery (2007, 2008, 2009, 2010, 2011, 2012), age at delivery (<20, 20–24, 25–29, 30–34, 35–39, ≥40 years), highest education level (high school or less, some college, completed college, and missing), insurance type at delivery (government-assisted, private, other, and missing), and parity (primiparous and multiparous). Clinical conditions were defined using both information from the birth certificate and from the maternal delivery discharge record and include pre-pregnancy diabetes, pre-pregnancy hypertension, gestational diabetes, gestational hypertension, and pre-eclampsia.

To understand factors associated with sensitivity, we conducted log-binomial regression models among women who had pre-pregnancy obesity (pre-pregnancy BMI ≥ 30 km/m^2). Specifically, we examined whether any of the maternal characteristics or conditions were associated with risk of having an ICD-9 diagnosis of obesity among these women.

Lastly, we compared the risk of two pregnancy-related outcomes from the birth certificate (caesarean birth, large for gestational age) among women with and without obesity, first using ICD-9 diagnosis codes to define obesity, then using pre-pregnancy BMI to define obesity. Large for gestational age was defined as infants at or above the 90th percentile in birth weight among infants of the same sex and same gestational age.[21] The adjusted models included maternal demographic characteristics (race/ethnicity, education level, nativity, payer at birth hospitalization, year of delivery, age at delivery, parity), and pre-pregnancy conditions (diabetes hypertension) – the causal diagram can be found in eFigure 1 in the Supplemental Materials. All data management and analyses were performed using SAS (version 9.4; SAS Institute, Cary, NC).

Ethics Approval

Linked data were obtained from the California Office of Statewide Health Planning and Development (OSHPD). Stanford University Institutional Review Board and the California State Committee for the Protection of Human Subjects reviewed and approved this study.

Results

Overall, 464,754 women (20.0%) had obesity based on pre-pregnancy BMI and 100,002 (4.3%) based only on ICD-9 codes. Table 1 shows that less than 1% of women in the underweight and normal BMI groups were classified as having obesity by ICD-9 code, and while the concordance between the two methods increased with BMI category, even among women with Class 3 obesity, only about 40% had an ICD-9 code. The most commonly used ICD-9 code was 649.1x (obesity complicating pregnancy, childbirth, or the puerperium).

Table 2 shows that, among women with obesity based on pre-pregnancy BMI, the sensitivity of any diagnosis of obesity in the maternal hospital discharge record was only 16.2%. However, obesity codes were highly specific at 98.7%, with a PPV of 75.2% and an NPV of 82.5%. The relative validity of an obesity diagnosis varied substantially across maternal

characteristics and clinical conditions. PPV ranged from 62.3% (women < 20 years old) to 88.6% (women with pre-existing hypertension), NPV ranged from 57.6% (women with pre-existing diabetes) to 93.9% (Asian/Pacific Islander women), sensitivity ranged from 11.2% (foreign-born women) to 34.7% (women with pre-existing diabetes), and specificity ranged from 95.0% (women with pre-existing diabetes) to 99.2% (women giving birth in 2007).

Table 3 shows the association of maternal characteristics with ICD9 reporting of obesity among women with pre-pregnancy BMI (i.e., sensitivity). Among women with pre-pregnancy obesity, those who had pre-pregnancy conditions (hypertension, diabetes), gestational diabetes, were US-born, non-Hispanic Black, had private health insurance, and gave birth in more recent years had the greatest risk of having an ICD-9 code for obesity reported at delivery, relative to their respective reference groups (Table 3).

Having confirmed that using ICD-9 codes at delivery substantially underestimated the prevalence of obesity, we assessed whether this resulted in bias in the association between obesity and pregnancy outcomes. When defining obesity using pre-pregnancy BMI, the adjusted risk of caesarean birth among women with obesity were much lower than when defining obesity using ICD-9 diagnosis codes (aRR 1.63, 95% CI 1.62, 1.64 and aRR 2.17, 95% CI 2.14, 2.20, respectively) (Table 4). Similarly, the adjusted risk of having a large for gestational age newborn among women with obesity was lower when using pre-pregnancy BMI to define obesity than when using ICD-9 diagnosis codes to define obesity (aRR 1.82, 95% CI 1.80, 1.84, and aRR 2.05, 95% CI 2.01, 2.08, respectively).

Comment

Principle findings

The linked California birth certificates and maternal hospitalization discharge records provided an opportunity to conduct a state-wide analysis of the relative validity of ICD-9 coding for obesity among pregnant women, compared to the more consistently collected BMI data from birth certificates. We found that less than one in five women with high BMI also had an ICD-9 code indicating obesity. The risk of receiving an obesity-related ICD-9 code varied substantially across maternal characteristics and conditions. For example, women with pre-pregnancy and pregnancy complications like diabetes and hypertension were more likely to have a code for obesity than women without these complications.

Strengths of the study

A major strength of this study is the large dataset, and the linkages between administrative claims and birth records for the California population.

Limitations of the data

Our reference method for categorizing mothers into BMI categories was based on height and weight collected from the birth certificate on nearly all women in the study sample. However, this is an “alloyed gold” standard because most of these data were reported, rather than directly measured, and are subject to error.[22] While such errors do not appear to bias associations with maternal and child outcomes[10], a true gold standard would be based on

measured pre-pregnancy weight and height, which is not feasible at the population level. Second, while the focus of this study was pre-pregnancy obesity, the available ICD-9 codes do not discriminate between obesity at delivery or pre-pregnancy obesity. Further, we only examined examples of bias in associations of obesity with two birth outcomes; including ICD9-based obesity as a confounder is likely an insufficient adjustment, but the impact on actual results will depend on the particular outcome being studied and what other related confounders are available. Third, 205,753 women were excluded from the analytic sample due to missing information needed to calculate BMI. Women missing either height or weight on the birth certificate had different characteristics than women not missing height or weight on the birth certificate (see eTable 1 in the Supplemental Materials). However, women who were more likely to be missing BMI information on their birth certificates – non-Hispanic Black women, Hispanic women, women whose birth hospitalization was paid for by Medicaid, foreign-born women – tended to have worse ICD-9 validity estimates, and missing data on maternal height and weight decreased over time - from 11.5 percent missing in 2007 to 5.6 percent missing in 2012. Thus, if there had been no missing data, we would have expected the validity estimates to be similar or worse than what we found in our study. Fourth, the source of pre-pregnancy weight (either physician measure at first prenatal visit or self-report at birth hospitalization) is heterogeneous, but there is no indicator in the birth certificate as to the source of the data.

For women who do not have physician measures of pre-pregnancy weight, there may be issues of recall bias given the time lapse between weight measurement pre-pregnancy and the collection of the data. A study examining discrepancies in self-reported pre-pregnancy weight and medical-record ascertained height and weight at the first prenatal visit found that among women who were identified as having obesity on the birth certificate, there was good agreement with medically-ascertained obesity, but some disagreement in the class of obesity.[22] Finally, our dataset ended in 2012, and we saw that with time the validity of the ICD codes to define obesity improved. Additionally, ICD-10 codes, which were implemented in late 2015, have more specific codes for obesity, which could improve sensitivity. However, a recent study using ICD-10 codes to measure obesity found that the sensitivity of these codes remained at less than 35%.[17] ICD-9 codes also exist for underweight and overweight; it is important to address their validity as well.

Interpretation

The poor performance of ICD-9 codes to identify women with obesity is likely due to US hospital coding practices, in which coders are encouraged to only abstract codes that contribute to some payment-relevant element of the hospitalization (e.g., length of stay, justifying a test or a procedure).[23] Since codes related to the birth will be the most relevant in the files we examined, we would only expect to see obesity-related codes if obesity was identified as complicating the birth or related to reasons for length of stay. Additionally, using ICD-9 codes to define obesity resulted in stronger associations with adverse pregnancy-related outcomes than using pre-pregnancy BMI to define obesity. This may be due to women who had an obesity-related ICD-9 code in their birth hospitalization discharge having more complications in pregnancy. Taken together, our results highlight the extent to

which ICD-9 codes underestimate the prevalence of obesity in pregnant women and bias that may result from this misclassification.

Our findings that ICD-9 codes for obesity have low sensitivity, high specificityy, and reasonable PPV and NPV is consistent with previous research in non-perinatal samples.[17,24] These results are also consistent with one previous study of 276 pregnant women, which used information from electronic medical records (including an obesity checkbox and a review of the Problem List structured field) to determine the validity of obesity codes, finding a sensitivity of 15.0 and specificity of 99.4.[18]

Previous studies of pregnancy outcomes have used different combinations of ICD 9 codes to define obesity. Several studies did not include ICD-9 code 649.1x to define obesity, which indicates complications of pregnancy attributed to obesity and was the most commonly used code in our data;[14,15] this likely resulted in even greater bias as the specificity of their codes would have been even lower than what we found. Other studies have indicated that ICD-9 codes were used to define obesity but did not list the specific codes used, making it impossible to know how biased their definition was.[25–29] Regardless, the low sensitivity of ICD-9 codes for identifying pregnant individuals with obesity suggests substantial misclassification. Thus, we recommend caution when using these codes as a proxy for obesity and encourage reporting of which codes were used. For researchers using ICD-9 codes to defined obesity in pregnancy, we recommend adjusting for measurement error through bias analysis.[30] Further, we recommend that researchers using claims data discuss specific codes used in a given study with professionals who have experience with how the codes are used in practice (e.g., medical coders, health care providers). While not on its own sufficient to guarantee that codes are used in logical and research-appropriate ways, this practice reveals information that may guide research and interpretation of findings. This practical information will be increasingly important US research switches between claims recorded using ICD-9 and ICD-10 codes.

Conclusions

The use of ICD-9 codes from delivery discharge records in this study substantially underestimated the true prevalence of obesity. Under-coding of obesity in discharge records was not random – the sensitivity of these codes varied significantly by maternal demographics and clinical conditions. While we confirmed associations between obesity and two birth outcomes using both measures of obesity, the use of ICD-9 codes yielded higher relative risks than when using obesity defined by data from the birth certificate. Our results suggest caution in interpreting results that use ICD-9 codes to examine pre-pregnancy obesity and emphasize the need for accurate information on pre-pregnancy body size for future studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Social media quote

ICD-9 codes in childbirth discharge records captured only one in five women with pre-pregnancy obesity. This misclassification resulted in bias when examining the association of obesity and pregnancy-related outcomes.

Synopsis

Study question:

How well do obesity-related ICD-9 diagnosis codes at birth hospitalization discharge capture pre-pregnancy obesity?

What's already known:

Obesity-related ICD-9 diagnosis codes poorly capture obesity in non-perinatal samples.

What this study adds:

ICD-9 codes in childbirth discharge records captured only one in five women with pre-pregnancy obesity. Measures of reliability varied by maternal characteristics and conditions. This misclassification resulted in an overestimation of the effect of obesity when examining the association between obesity and pregnancy-related outcomes.

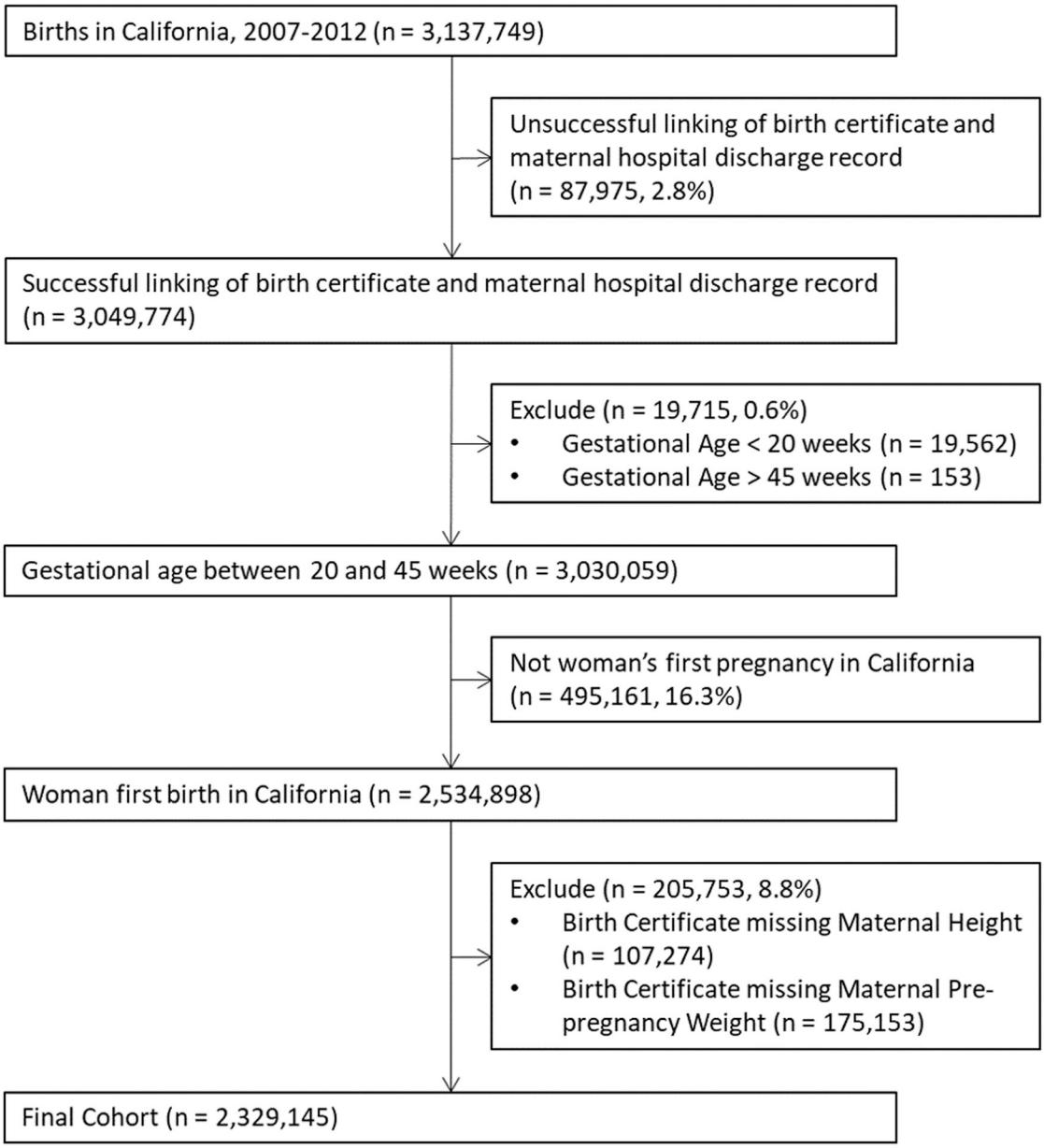

Figure 1.
Cohort Selection Process

Table 1.

Comparison of ICD-9 obesity codes from childbirth hospitalization discharge records with pre-pregnancy body mass index category from birth certificates (n = 2,329,145)

	Pre-Pregnancy Body Mass Index (based on birth certificate data)					
	Underweight (n = 98,272)	**Normal Weight (n = 1,177,845)**	**Overweight (n = 608,659)**	**Obesity Class 1 (n = 290,550)**	**Obesity Class 2 (n = 116,251)**	**Obesity Class 3 (n = 66,697)**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
At least one ICD-9 Code for Obesity *	137 (0.1)	6,890 (0.6)	18,092 (3.0)	26,727 (9.2)	23,527 (20.24)	26,629 (39.9)
Specific ICD-9 Code						
278.00 - obesity, unspecified	103 (0.1)	5,381 (0.5)	14,188 (2.3)	20,623 (7.1)	15,286 (13.2)	11,029 (16.5)
278.01 - morbid obesity	17 (0.0)	567 (0.1)	1,639 (0.3)	4,108 (1.4)	6,819 (5.9)	14,177 (21.3)
278.03 - obesity hypoventilation syndrome	0	0	0	<15	<15	<15
V85.3x - BMI between 30–39, adult	27 (0.0)	2,041 (0.2)	6,386 (1.1)	7,471 (2.6)	3,034 (2.6)	465 (0.7)
V85.4x - BMI 40 or greater, adult	<15	255 (0.0)	662 (0.1)	2,556 (0.9)	5,695 (4.9)	9,429 (14.1)
649.1x - obesity complicating pregnancy, childbirth, or the puerperium	134 (0.1)	6,059 (0.5)	16,157 (2.7)	25,220 (8.7)	22,522 (19.4)	25,562 (38.3)

Note: Underweight = BMI < 18.5, Normal Weight = BMI 18.5–24.9, Overweight = BMI 25.0–29.9, Obesity Class 1 = BMI 30.0–34.9, Obesity Class 2 = BMI 35.0–39.9, Obesity Class 3 = BMI ≥ 40.0

*Women can have more than one obesity code in their delivery hospitalization discharge abstract

NOTE: Cells with fewer than 15 observations have been suppressed to maintain confidentiality

Table 2.

Obesity Prevalence and Relative Validity of ICD-9 Diagnoses Compared to Pre-Pregnancy Obesity from Birth Certificate; Overall and by Maternal Characteristics and Pre-Pregnancy Clinical Conditions (n = 2,329,145)

	Obesity Prevalence		Relative Validity of ICD-9 Codes (95% CI)			
	Pre-pregnancy BMI from Birth Certificate (n, %)	Based on ICD-9 Codes at Delivery Discharge (n, %)	Positive Predictive Value	Negative Predictive Value	Sensitivity	Specificity
All	464,754 (20.0)	100,002 (4.3)	75.2 (75.0, 75.5)	82.5 (82.5, 82.6)	16.2 (16.1, 16.3)	98.7 (98.7, 98.7)
Maternal Race/ Ethnicity						
Non-Hispanic White	101,289 (16.5)	25,291 (4.1)	75.9 (75.3, 76.3)	86.1 (86.0, 86.2)	18.9 (18.7, 19.2)	98.8 (98.8, 98.8)
Non-Hispanic Black	34,828 (27.5)	10,727 (8.5)	78.6 (78.0, 79.3)	77.2 (77.0, 77.5)	24.2 (23.8, 24.7)	97.5 (97.4, 97.6)
Hispanic	287,885 (24.2)	56,059 (4.6)	75.7 (75.3, 76.0)	78.3 (78.2, 78.4)	14.2 (14.1, 14.4)	98.5 (98.5, 98.6)
Asian/Pacific Islander	21,455 (7.1)	5,495 (1.8)	60.7 (59.4, 62.0)	93.9 (93.9, 94.0)	15.6 (15.1, 16.0)	99.2 (99.2, 99.3)
Other/Missing	9,297 (18.6)	2,430 (4.9)	77.2 (75.4, 78.8)	84.4 (84.1, 84.7)	20.2 (19.4, 21.0)	98.6 (98.5, 98.8)
Nativity						
US-Born	282,501 (22.3)	70,385 (5.6)	77.8 (77.5, 78.1)	81.0 (80.9, 81.0)	19.4 (19.3, 19.5)	98.4 (98.4, 98.4)
Foreign-Born	182,253 (17.1)	29,617 (2.8)	69.1 (68.6, 69.6)	84.3(84.3, 84.4)	11.2 (11.1, 11.4)	99.0 (98.9, 99.0)
Birth Year						
2007	91,263 (19.2)	13,693 (2.9)	78.0 (77.3, 78.7)	82.6 (82,5, 82.7)	11.7 (11.5, 11.9)	99.2 (99.2, 99.2)
2008	89,001 (19.6)	15,495 (3.4)	76.3 (75.6, 76.9)	82.4 (82.3, 82.5)	13.3 (13.1, 13.5)	99.0 (99.0, 99.0)
2009	80,730 (20.2)	16,049 (4.0)	76.3 (75.7, 77,0)	81.2 (82.1, 82,3)	15.2 (14.9, 15.4)	98.8 (98.8, 98.9)
2010	72,810 (20.4)	17,149 (4.8)	75.6 (74.9, 76.2)	82.4 (82.3, 82.5)	17.8 (17.5, 18.1)	98.5 (98.5, 98.6)
2011	67,401 (20.5)	18,967 (5.8)	72.2 (71.5, 72.8)	82.7 (82.6, 82.8)	20.3 (20.0, 20.6)	98.0 (97.9, 98.0)
2012	63,549 (20.3)	18,649 (6.0)	74.3 (73.7, 74.9)	83.1 (83.0, 83.2)	21.8 (21.5, 22.1)	98.1 (98.0, 98.1)
Mother's Age						
<20	28,685 (12.6)	6,409 (2.8)	62.3 (61.1, 63.5)	88.8 (88.7, 89.0)	13.9 (13.5, 14.3)	98.8 (98.7, 98.8)
20–24	99,295 (20.2)	20,432 (4.2)	74.0 (73.4, 74.6)	82.1 (82.0, 82.3)	15.2 (15.0, 15.4)	98.6 (98.6, 98.7)
25–29	133,413 (21.6)	28,038 (4.5)	76.2 (75.7, 76.7)	81.0 (80.9, 81.1)	16.0 (15.8, 16.2)	98.6 (98.6, 98.7)
30–34	116,894 (20.3)	25,962 (4.5)	77.0 (76.5, 77.5)	82.4 (82.3, 82.5)	17.1 (16.9, 17.3)	98.7 (98.7, 98.7)
35–49	67,727 (20.7)	14,915 (4.6)	77.3 (76.6, 78.0)	82.0 (81.9, 82.1)	17.0 (16.7, 17.3)	98.7 (98.7, 98.7)
≥40	18,740 (21.1)	4,246 (4.8)	76.7 (75.4, 78.0)	81.7 (81.5, 82.0)	17.4 (16.9, 17.9)	98.6 (98.5, 98.7)
Mother's Education Level						
High School or Less	273,985 (23.3)	52,330 (4.5)	75.5 (75.1, 75.9)	79.1 (79.0,79.2)	14.4 (14.3, 14.6)	98.6 (98.6, 98.6)
Some College	121,555 (23.3)	30,166 (5.8)	78.1 (77.6, 78.6)	80.1 (80.0, 80.2)	19.4 (19.2, 19.6)	98.4 (98.3, 98.4)
Completed College	56,226 (10.2)	14,565 (2.6)	68.9 (68.1, 69.6)	91.4 (91.4, 91.5)	17.9 (17.5, 18.2)	99.1 (99.1, 99.1)

	Obesity Prevalence		Relative Validity of ICD-9 Codes (95% CI)			
	Pre-pregnancy BMI from Birth Certificate (n, %)	**Based on ICD-9 Codes at Delivery Discharge (n, %)**	**Positive Predictive Value**	**Negative Predictive Value**	**Sensitivity**	**Specificity**
Unknown/ Missing	12,988 (16.7)	2,941 (3.8)	73.1 (71.4, 74.7)	85.6 (85.3, 85.8)	16.6 (15.9, 17.2)	98.8 (98.7, 98.9)
Payment Type at birth						
Medi-Cal	260,898 (23.1)	45,837 (4.1)	76.4 (76.0, 76.8)	79.1 (79.1, 79.2)	13.4 (13.3, 13.6)	98.8 (98.7, 98.8)
Private	183,789 (17.0)	50,184 (4.6)	74.6 (74.3, 75.0)	85.8 (85.8, 85.9)	20.4 (20.2, 20.6)	98.6 (98.6, 98.6)
Other/Unknown	20,067 (17.2)	3,981 (3.4)	69.8 (68.4, 71.3)	84.7 (84.5, 84.9)	13.9 (13.4, 14.3)	98.8 (98.7, 98.8)
Parity						
Nulliparous	170,040 (15.3)	47,036 (4.2)	72.1 (71.6, 72.5)	87.2 (87.1, 87.2)	19.9 (19.7, 20.1)	98.6 (98.6, 98.6)
Multiparous	294,714 (24.1)	52,966 (4.3)	78.1 (77.7, 78.4)	78.3 (78.2, 78.4)	14.0 (13.9, 14.2)	98.8 (98.7, 98.8)
Pre-Pregnancy Diabetes						
No	451,178 (19.6)	94,954 (4.1)	74.6 (74.3, 74.9)	82.8 (82.7, 82.8)	15.7 (15.6, 15.8)	98.7 (98.7, 98.7)
Yes	13,576 (50.9)	5,048 (18.9)	87.1 (86.1, 88.0)	57.6 (56.9, 58.2)	32.4 (31.6, 33.2)	95.0 (94.6, 95.4)
Pre-Pregnancy Hypertension						
No	440,287 (19.3)	90,412 (4.0)	73.8 (73.5, 74.1)	83.0 (82.9, 83.0)	15.2 (15.1, 15.3)	98.7 (98.7, 98.7)
Yes	24,467 (50.5)	9,590 (19.8)	88.6 (87.9, 89.2)	58.9 (58.4, 59.4)	34.7 (34.1, 35.3)	95.4 (95.2, 95.7)
Gestational Diabetes						
No	393,501 (15.0)	80,781 (3.8)	73.2 (72.9, 73.5)	83.7 (83.7, 83.8)	15.0 (14.9, 15.1)	98.8 (98.7, 98.8)
Yes	71,253 (36.6)	19.221 (9.9)	83.7 (83.2, 84.2)	68.6 (68.4, 68.8)	22.6 (22.3, 22.9)	97.5 (97.4, 97.6)
Gestational Hypertension						
No	431,235 (19.3)	89,526 (4.0)	74.5 (74.2, 74.8)	83.0 (82.9, 83.0)	15.5 (15.4, 15.6)	98.7 (98.7, 98.8)
Yes	33,519 (34.3)	10,476 (10.7)	81.5 (80.8, 82.3)	71.4 (71.1, 71.7)	25.5 (25.0, 26.0)	97.0 (96.8, 97.1)
Pre-Eclampsia						
No	427,328 (19.3)	87,503 (4.0)	74.5 (74.2, 74.8)	83.0 (83.0, 83.1)	15.3 (15.1, 15.4)	98.8 (98.7, 98.8)
Yes	37,426 (33.5)	12,499 (11.2)	80.7 (80.0, 81.4)	72.5 (72.2, 72.7)	27.0 (26.5, 27.4)	96.8 (96.6, 96.9)

Table 3.

Risk of having an ICD-9 code for obesity at delivery among women who were identified with obesity on the Birth Certificate (n = 464,754)

	Pre-Pregnancy Obesity from Birth Certificate	ICD-9 Obesity Diagnosis at Delivery	Relative Risk (95% CI)	
	N	n (% of Obesity)	Unadjusted	Adjusted
Maternal Race/Ethnicity				
Non-Hispanic White	101,289	19,187 (18.9)	1.00 (Reference)	1.00 (Reference)
Non-Hispanic Black	34,828	8,428 (24.2)	1.37 (1.33, 1.41)	1.46 (1.42, 1.51)
Hispanic	297,885	42,420 (14.2)	0.71 (0.70, 0.72)	0.99 (0.97, 1.01)
Asian/Pacific Islander	21,455	3,336 (15.6)	0.79 (0.76, 0.82)	0.90 (0.87, 0.94)
Other/Missing	9,297	1,875 (20.2)	1.08 (1.03, 1.14)	1.20 (1.13, 1.27)
Nativity				
US-Born	282,501	54,786 (19.4)	1.90 (1.87, 1.94)	1.65 (1.61, 1.68)
Foreign-Born	182,253	20,460 (11.2)	1.00 (Reference)	1.00 (Reference)
Birth Year				
2007	91,263	10,678 (11.7)	1.00 (Reference)	1.00 (Reference)
2008	89,001	11,817 (13.3)	1.16 (1.12, 1.19)	1.16 (1.13, 1.19)
2009	80,730	12,252 (16.3)	1.35 (1.31, 1.39)	1.35 (1.32, 1.39)
2010	72,810	12,958 (17.8)	1.63 (1.59, 1.68)	1.63 (1.58, 1.67)
2011	67,401	13,685 (20.3)	1.92 (1.87, 1.98)	1.88 (1.83, 1.94)
2012	63,549	13,856 (21.8)	2.10 (2.05, 2.16)	2.04 (1.99, 2.10)
Mother's Age				
<20	28,685	3,992 (13.9)	0.85 (0.82, 0.88)	0.76 (0.73, 0.79)
20–24	99,295	15,111 (15.2)	0.94 (0.92, 0.96)	0.92 (0.89, 0.94)
25–29	133,413	21,371 (16.0)	1.00 (Reference)	1.00 (Reference)
30–34	116,894	19,982 (17.1)	1.08 (1.06, 1.10)	1.06 (1.04, 1.08)
35–49	67,727	11,532 (17.0)	1.08 (1.05, 1.10)	1.02 (1.00, 1.05)
≥40	18,740	3,258 (17.4)	1.10 (1.06, 1.15)	0.96 (0.92, 1.00)
Mother's Education Level				
High School or Less	273,985	39,508 (14.4)	1.00 (Reference)	1.00 (Reference)
Some College	121,555	23,555 (19.4)	1.43 (1.40, 1.45)	0.99 (0.97, 1.01)
Completed College	56,226	10,034 (17.9)	1.29 (1.26, 1.32)	0.79 (0.77, 0.81)
Unknown/Missing	12,988	2,149 (16.6)	1.18 (1.12, 1.23)	0.90 (0.85, 0.95)
Payment Type at birth				
Medi-Cal	260,898	35,011 (13.4)	1.00 (Reference)	1.00 (Reference)
Private	183,789	37,455 (20.4)	1.65 (1.63, 1.68)	1.43 (1.41, 1.46)
Other/Unknown	20,067	2,780 (13.9)	1.04 (1.00, 1.08)	0.97 (0.93, 1.01)
Parity				
Nulliparous	170,040	33,890 (19.9)	1.52 (1.50, 1.55)	1.31 (1.28, 1.33)

	Pre-Pregnancy Obesity from Birth Certificate	ICD-9 Obesity Diagnosis at Delivery	Relative Risk (95% CI)	
	N	n (% of Obesity)	Unadjusted	Adjusted
Multiparous	284,714	41,356 (14.0)	1.00 (Reference)	1.00 (Reference)
Pre-existing Diabetes				
No	451,178	70,850 (15.7)	1.00 (Reference)	1.00 (Reference)
Yes	13,576	4,396 (32.4)	2.57 (2.48, 2.67)	2.07 (1.99, 2.16)
Pre-existing Hypertension				
No	440,287	66,753 (15.2)	1.00 (Reference)	1.00 (Reference)
Yes	24,467	8,493 (34.7)	2.98 (2.89, 3.06)	2.11 (2.05, 2.18)
Gestational Diabetes				
No	393,501	59,154 (15.0)	1.00 (Reference)	1.00 (Reference)
Yes	71,253	16,092 (22.6)	1.65 (1.62, 1.68)	1.56 (1.52, 1.59)
Gestational Hypertension				
No	431,235	66,705 (15.5)	1.00 (Reference)	1.00 (Reference)
Yes	33,519	8,541 (25.5)	1.87 (1.82, 1.92)	1.25 (1.21, 1.29)
Pre-Eclampsia				
No	427,328	65,156 (15.3)	1.00 (Reference)	1.00 (Reference)
Yes	37,426	10,090 (27.0)	2.05 (2.00, 2.10)	1.33 (1.29, 1.37)

Table 4.

Frequency of and Relative Risk for Caesarean Birth and Large for Gestational Age by Measure of Obesity

Outcome	Measure of Obesity	Obese		Not Obese		Relative Risk (95% CI)	
		N	Cases (%)	N	Cases (%)	Unadjusted	Adjusted[a]
Caesarean Birth	Pre-Pregnancy BMI from Birth Certificate	473,498	203,093 (43.9)	1,885,231	562,372 (29.8)	1.77 (1.75, 1.78)	1.69 (1.68, 1.70)
	ICD-9 codes at Delivery	102,002	54,668 (53.6)	2,256,727	710,797 (31.5)	2.51 (2.48, 2.54)	2.30 (2.27, 2.33)
Large for Gestational Age	Pre-Pregnancy BMI from Birth Certificate	473,498	67,814 (14.3)	1,885,231	137,191 (7.3)	2.13 (2.11, 2.15)	1.89 (1.87, 1.91)
	ICD-9 codes at Delivery	102,002	17,737 (17.4)	2,256,727	187,267 (8.3)	2.32 (2.28, 2.36)	2.15 (2.12, 2.19)

[a]Adjusted for maternal race/ethnicity, nativity, year of delivery, age, education level, payer at delivery, parity, pre-existing diabetes, pre-existing hypertension