THE OVERALL RISK OF MATERNAL OBSTETRIC COMPLICATIONS ASSOCIATED WITH OBESITY AND EXTREME OBESITY

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ABBREVIATIONS

Adj - Adjusted

ANOVA – Analysis of variance

BMI – Body mass index

CI – Confidence interval

G – gravdity

HP 2010 – Healthy People 2010

ICD-9-CM – International Classification of Diseases – 9 – Clinical Modification

IRB – Institutional Review Board

KFRI – Kaiser Foundation Research Institute

KPNW – Kaiser Permanente Northwest

L&D – Labor and delivery

N/A – not applicable

OR – Odds ratio

P – parity

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SUMMARY

During the last two decades, little progress has occurred toward reducing maternal mortality in the United States. In *Healthy People 2010*, a new index of maternal health was presented that describes the prevalence of maternal complications during hospitalized labor and delivery. The index includes obstetric complications, which are conditions caused by the pregnancy or management of the pregnancy, and pre-existing medical conditions, which are chronic medical conditions that may be aggravated by pregnancy. In **Chapter I**, we assess the prevalence of maternal morbidities during hospitalized labor and delivery among pregnant women enrolled in a large group practice health maintenance organization during 1998 - 2001. Nearly 30% of women had at least one type of morbidity, similar to previously published results in a nationally representative sample. In **Chapter II**, we assess the relationship between obesity, a potentially modifiable risk factor, and the overall risk of having any obstetric complication at the time of hospitalized labor and delivery. After adjusting for important confounding exposures, obese women had approximately 60% higher risk relative to those who were normal weight and extremely obese women had approximately 100% higher risk. The effect of obesity was greatest among women who used tobacco or were 30 years or older.

CHAPTER I -TRACKING MATERNAL MORBIDITY DURING LABOR AND DELIVERY USING AUTOMATED MEDICAL RECORD DATA

Abstract

Objective: To describe maternal morbidity during hospitalized labor and delivery using automated medical record data from women enrolled in a large group practice health maintenance organization. **Methods:** Pregnant women who were enrolled in Kaiser Permanente Northwest during 1998 – 2001 were identified using a previously validated complex computer software algorithm that uses multiple sources of electronic medical record data. Women were included if they gave birth to a live or stillborn infant and were ages 18-55 years. Maternal morbidities were assessed in labor and delivery hospitalization records using *International Classification of Diseases – 9 – Clinical Modification (ICD-9-CM)* codes developed for a new index of maternal health in *Healthy People 2010*. The prevalence of having at least one obstetric complication, at least one pre-existing medical condition, or both during the labor and delivery hospitalization was calculated. Cesarean delivery was also assessed using *ICD-9-CM* codes and is presented separately. **Results:** Among 15,088 women who had eligible pregnancies, 4120 (27.3%) had at least one type of obstetric complication, 521 (3.5%) had at least one type of pre-existing medical condition, and 4458 (29.5%) had either of these two types of morbidities. 3207 women (21.3%) gave birth by cesarean delivery and 6496 (43.1%) had any type of morbidity, including obstetric complications, pre-existing medical conditions, or cesarean delivery. The most common types of obstetric complications were hypertensive disorders of pregnancy (8.1%), 3rd or 4th degree perineal lacerations (4.5%), other types of obstetric trauma (3.8%), gestational diabetes mellitus (3.5%), and postpartum hemorrhage (3.4%). Chronic hypertension was the most common

type of pre-existing medical condition (1.4%). **Conclusions:** Maternal morbidities during labor and delivery were common among pregnant women enrolled in a large health maintenance organization during 1998 – 2001. Automated medical records from large managed care health plans could be used to track trends in maternal morbidities over time and to identify potentially modifiable risk factors.

Background

Until recently, the only national indicator of women's health during pregnancy, childbirth, and the puerperium has been maternal mortality (USDHHS, 1991). Maternal mortality is defined as deaths that occurred during pregnancy or 42 days after the end of pregnancy and are attributed to complications of pregnancy, childbirth, or the puerperium. It is reported as a ratio of the number of maternal deaths per 100,000 live births. In the 1930's, the maternal death ratio was 670 per 100,000 live births and it declined over time through the 1970's (CDC, 1998). Since 1982 the reported ratio has remained between seven and eight deaths per 100,000 live births.

In *Healthy People 2000*, the goal was to reduce the maternal mortality ratio to 3.3 deaths per 100,000 live births (USDHHS, 1991) and because no progress occurred during the last decade, the goal in *Healthy People 2010* remains the same (USDHHS, 2000). Statistics from the World Health Organization reveal that 20 other countries have maternal mortality rates lower than the United States, indicating that further progress is possible (WHO, 1996). Leading causes of pregnancy-related death include hemorrhage, embolism, and hypertensive disorders of pregnancy and causes vary by pregnancy outcome type (Berg, 1996). Maternal deaths are highly significant for society because of their premature nature and the large impact they have on families.

A new index of maternal health is presented in *Healthy People 2010* that assesses maternal morbidities during labor and delivery (USDHHS, 2000). Labor and delivery is a time period during which most maternal deaths and serious maternal morbidities occur (Berg, 1996). Measuring maternal morbidity through this method allows morbidities less

severe than death to be monitored. In 1998, 31% of women giving birth had at least one type of maternal morbidity during hospitalized labor and delivery, excluding cesarean delivery or mental health conditions alone, and the goal in *Healthy People 2010* is to reduce this figure to 24% of women giving birth (USDHHS, 2000).

Danel and colleagues recently described the prevalence of the specific complications that make up the *Healthy People 2010* index using data from the National Hospital Discharge Survey (NHDS) from 1993 to1997 (Danel, 2003). The most common obstetric complications were third and fourth degree lacerations (5.0%), other obstetric traumas including cervical lacerations and pelvic trauma (3.8%), preeclampsia and eclampsia (3.0%), gestational diabetes mellitus (2.8%), genitourinary infections (2.7%), postpartum hemorrhages (2.0%), and amnionitis (1.9%). Chronic hypertension was the most common preexisting medical condition (1.5%). No other data describing the prevalence of maternal morbidity using the *Healthy People 2010* methodology have been published, nor have high-risk groups been well characterized.

In the present study, we describe the prevalence of maternal morbidities during labor and delivery among 15,088 women who were enrolled in a managed care health care organization during 1998-2001. Previously published results from NHDS in 1993-1997 are also presented for comparison. Automated medical records from large health maintenance organizations could potentially be used to assess longitudinal trends over time, evaluate for modifiable risk factors, and evaluate the impact of health systems or population-based interventions targeting such risk factors.

Methods

Electronic medical record data from 1998 to 2001 were analyzed for women who were members of Kaiser Permanente Northwest (KPNW), a large prepaid non-profit group practice health maintenance organization. Pregnant women were identified through a computer software algorithm designed for a study that describes maternal morbidities before, during, and after pregnancy among women with all types of pregnancy outcomes (Hornbrook, 2005). The computer algorithm uses multiple sources of automated data (e.g., KPNW enrollment records, hospital discharge abstracts, and electronic ambulatory medical records) in a hierarchical manner to identify pregnancy outcomes (e.g., live or stillborn infant), the date the pregnancy ended, and the gestational age at the time of delivery, then calculates the date the pregnancy started to define the periods before, during, and after pregnancy. When compared to medical record review, the algorithm assigned the correct outcome, end date, and gestational age for 98-100% of pregnancies that it identified as resulting in a live birth (Hornbrook, 2005).

The computer algorithm censors data from women who had less than 42 days of KPNW eligibility, were not eligible for medical care at the time of the labor and delivery hospitalization, or did not have at least one complete pregnancy, including 8 weeks postpartum, during 1998 – 2001. If a woman had evidence of a pregnancy (e.g., a positive pregnancy test) but no definitive information on what the outcome was, then the algorithm would not include the pregnancy. Detailed descriptions of the computer algorithm and the study validating the accuracy of the algorithm are submitted for publication separately.

The data set for the parent study on maternal morbidity includes all *International Classification of Diseases - 9 -Clinical Modification (ICD-9-CM)* diagnoses and procedures codes that were recorded during outpatient or inpatient encounters for pregnant women during 1998 - 2001. Information is also available describing age, race, parity, number of live born infants (resulting from the pregnancy included in the study), gestational age at time of labor and delivery, length of labor and delivery hospitalization, dates of eligibility for KPNW coverage, and dates of Medicaid or Washington Basic Health Plan enrollment.

For the present study, women were included if they were identified through the computer algorithm as a) having had a pregnancy that resulted in giving birth to a one or more live or stillborn infants during 1998-2001 and b) aged 18 to 55 years at the time of giving birth. For women who had one more than one identified pregnancy during 1998-2001 meeting these criteria, the first eligible pregnancy per woman was selected for inclusion in this study.

Maternal morbidities were assessed using *ICD-9-CM* diagnoses codes describing complications of pregnancy, childbirth, and the puerperium that were developed for the new *Healthy People 2010* index "Maternal complications during hospitalized labor and delivery" (Objective 16-5a; USDHHS, 2000). Additional codes that were developed by Danel and colleagues and are outside of the chapter on pregnancy, childbirth, and the peurperium were also included. Cesarean delivery, an event that is not measured in the *Healthy People 2010* Objective 16-5a, was evaluated by Danel and colleagues and was evaluated in the present study. *ICD-9-CM* codes indicating specific morbidities (e.g., post-partum hemorrhage) are based on those used by Danel and colleagues. All *ICD-9-*

CM codes were provided by Isabella Danel (personal communication; Danel, 2004) and are presented in **Table 1**.

Three broad categories of morbidities were assessed: obstetric complications, pre-existing medical conditions, and cesarean delivery. Obstetric complications are conditions caused by the pregnancy or management of the pregnancy and include antepartum hemorrhage, postpartum hemorrhage, all forms of pregnancy-induced hypertension, multiple types of obstetric traumas, multiple types of infections, gestational diabetes mellitus, and multiple rare complications such as anesthesia complications, wound complications, deep venous thrombosis, pulmonary embolism, and cerebrovascular events (Danel, 2003). Conditions that were not considered to be morbidities were those thought to be normal occurrences during delivery (e.g., first and second degree perineal lacerations) or conditions that were managed successfully without any substantial effect on the woman's health. Preterm labor and operative vaginal deliveries were not included as morbidities unless associated with other morbidities such as hemorrhage, infection, or disseminated intravascular coagulation. Mental health conditions or morbidities affecting only the health of the fetus with no impact on the woman's health were also not included here.

Pre-existing medical conditions were defined as conditions that could be aggravated by pregnancy thus contributing to overall maternal morbidity. The following pre-existing medical conditions were assessed: pre-existing hypertension, diabetes mellitus, asthma, cardiac disease, and renal disease.

All morbidities were assessed using records from the labor and delivery hospitalization in order to parallel the methods used in *Healthy People 2010*. If a woman

had an *ICD-9-CM* code for a maternal morbidity in discharge records from an antepartum hospitalization or from electronic outpatient medical records but not in records from her labor and delivery hospitalization, she would not be classified as having had morbidity by these methods.

The prevalence of each type of specific obstetric complication, each type of specific pre-existing medical condition, any obstetric complication, and any pre-existing medical condition was calculated as follows: 100% x (number of women with an *ICD-9-CM* code indicating the condition ÷ total number of eligible pregnant women). The percentage of all eligible pregnant women who gave birth by cesarean delivery was also calculated. Summary prevalence estimates were calculated describing the percentage of women with any morbidity, *excluding* cesarean delivery alone (i.e., percentage of women who had either an obstetric complication or a pre-existing medical condition) and the percentage of women with any morbidity, *including* cesarean delivery. For all prevalence estimates, each woman is counted only once, regardless of how many complications she had. Presentation of all results was designed to be comparable to previous work by Danel and colleagues (Danel, 2003). All data analyses were conducted using SPSS software.

Previously reported results from National Hospital Discharge Survey data from 1993 –1997 are presented for comparison, but no statistical tests were conducted to determine whether the prevalence estimates were different from those in the KPNW women.

Institutional Review Board

The study protocol was approved by the institutional review board (IRB) at Kaiser Foundation Research Institute (KFRI; FWA 00002344 –IRB 00000405). The protocol was also reviewed by the IRB at Oregon Health and Science University and authority was waived to KFRI.

Results

The computer algorithm identified 15,088 women who met all inclusion criteria. Their demographic and clinical characteristics are described in **Table 2**. The average gestational age at the time of giving birth was 38.9 weeks and the average length of hospitalization for labor and delivery was 2.6 days.

Results describing the prevalence of maternal morbidities at the time of labor and delivery hospitalization are presented in **Table 3**. 4458 women (29.5%) had any type of morbidity, excluding cesarean delivery alone. 2038 (13.5%) had a cesarean delivery with no other type of morbidity and 1169 (7.7%) had a cesarean delivery *and* either an obstetric complication or pre-existing medical condition. Previously published results from NHDS data from 1993-1997 are also presented for comparison (Danel, 2003).

Discussion

Among pregnant women enrolled in a large health maintenance organization who gave birth to a live or stillborn infant during 1998 - 2001, nearly 30% had either an obstetric complication or a pre-existing medical condition during hospitalized labor and

delivery. Hypertensive disorders of pregnancy, 3rd and 4th degree perineal lacerations, other types of obstetric trauma, gestational diabetes mellitus, and postpartum hemorrhage were the most common types of obstetric complications. 4% of women had a pre-existing medical condition at the time of labor and delivery and the most common condition was chronic hypertension, which was diagnosed in less than 2% of women.

Danel and colleagues have previously reported that 30.7% of women giving birth had a maternal morbidity, excluding cesarean alone, using population-based data from the NHDS from 1993 – 1997 (Danel, 2003). *Healthy People 2010* reports that 31.2% of women giving birth had a maternal morbidity using NHDS data from 1998 (USDHHS, 2000). Because our results are from a different population and a later time period, it is unknown whether the prevalence has remained constant over time or if change has occurred but is not apparent due to the population differences. Furthermore, we did not assess whether the small difference between our estimate and the previous result from NHDS was statistically significant. It will be useful to assess trends in maternal morbidities using KPNW from additional years than were included for the present study.

The prevalence of having any type of pregnancy-induced hypertension was higher in the KPNW women (8.1%) compared to 3% reported previously from the NHDS data. However, others have reported that the incidence of pregnancy-induced hypertension is 6 to 8% (National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy, 2000).

The use of *ICD-9-CM* codes to assess maternal morbidities has limitations. The codes for some complications, such as types of hemorrhage, do not distinguish between the degrees of severity of the complication. As a result, while it is possible to measure

the percentage of women who had any morbidity during labor and delivery, it is not possible to determine the severity of their morbidities. Misclassification of the morbidities may have also occurred. The validation study that was conducted to test the pregnancy-identifying computer algorithm evaluated the accuracy of identifying the pregnancy outcome type, date, and length of gestation but not the sensitivity or specificity of using *ICD-9-CM* codes to identify specific maternal morbidities. Studies are needed. Future algorithms could be developed that consider other types of available automated data for assessing individual maternal morbidity outcomes, such as laboratory data to help with classify preeclampsia and eclampsia, that could improve the sensitivity and specificity for detecting maternal morbidity outcomes when using automated medical record data.

Despite these limitations, *ICD-9-CM* codes are a valuable method for assessing maternal morbidities because their definitions are consistent across geographical areas and the information is widely available from administrative hospital discharge records. In addition, using *ICD-9-CM* codes is a cost-effective method for assessing morbidities among large populations of pregnant women, as we did in the present study.

Morbidities assessed during the antepartum or later postpartum are not included here nor are maternal mental health conditions or infant health outcomes, all of which are important to consider for the overall picture of maternal and child health resulting from pregnancy.

This study demonstrates the feasibility of tracking a new *Healthy People 2010* index of maternal morbidity using automated medical records from a large managed care health plan. During 1998 – 2001, the prevalence of maternal morbidities in the KPNW

was similar to national estimates and exceeded the *Healthy People 2010* goal of reducing the prevalence of maternal morbidities to 24% of women giving birth in the United States. Studies evaluating modifiable risk factors will be needed in order to develop national prevention strategies.

CHAPTER II – THE OVERALL RISK OF MATERNAL OBSTETRIC COMPLICATIONS ASSOCIATED WITH OBESITY AND EXTREME OBESITY

Abstract

Objective: To estimate the overall risk of maternal obstetric complications during labor and delivery for obese and extremely obese women. **Methods:** A retrospective cohort study was conducted using electronic medical records for 6,799 women enrolled in a large HMO. Obesity was defined as BMI 30 – 39.9 kg/m^2 and extreme obesity as BMI ≥ 40 kg/m^2. Obstetric complications were assessed using *ICD-9-CM* codes from labor and delivery hospitalizations and included a broad range of complications that are included in the *Healthy People 2010* index on maternal morbidity. Multiple characteristics were assessed as possible confounding exposures. **Results:** 1,447 obese and 344 extremely obese women were identified. The risk of having at least one obstetric complication was higher among obese and extremely obese women (34.2% and 39.8%) compared to normal weight women (26.3%). After adjusting for age, parity, number of live born infants, and tobacco use, the odds ratios (OR, 95% CI) were 1.15 (1.01-1.31) for women who were overweight, 1.56 (1.36-1.80) who were obese, and 1.99 (1.57-2.51) for women who were extremely obese, relative to normal weight women. Interactions between BMI category and both age and tobacco use status were statistically significant. Among women age 30 and older, adjusted OR were 1.13 (1.06-1.62) for overweight, 2.04 (1.63-2.56) for obese, and 2.31 (1.60-3.32) for extremely obese. Among tobacco users, the adjusted OR were 1.91 (1.37-2.67) for obese women and 2.58 (1.51-4.41) for extremely obese women. **Conclusions:** Obesity and extreme obesity are associated with a significant excess risk of obstetric complications during labor and delivery, particularly for women age ≥ 30 years and women who are smokers. Studies

evaluating clinical strategies to optimally manage obese women before and during pregnancy are needed and must evaluate risks and benefits for both the mother and fetus.

Background

Over one million women annually are estimated to experience some type of maternal morbidity during hospitalized labor and delivery in the United States, representing over 30% of women giving birth (Danel, 2003). Most maternal deaths and serious complications occur during labor and delivery (Berg, 1996) and reducing maternal morbidity during this stage of pregnancy is a new national maternal health goal in *Healthy People 2010* (USDHHS, 2000). The vast majority of maternal morbidity during labor and delivery is due to obstetric complications, which are conditions that are caused by pregnancy or the management of the pregnancy and occur among 29% of women giving birth (Danel, 2003). Identifying modifiable risk factors related to multiple obstetric complications will be important for designing national strategies to prevent overall maternal morbidity for women in the United States.

Obesity, or excess adipose tissue, is associated with an increased risk of numerous adverse health consequences in non-pregnant individuals such as cardiovascular disease, type 2 diabetes mellitus, and hypertension. Epidemiological studies commonly measure obesity using the body mass index (BMI), a measure of relative weight for height that is correlated with total body fat content. According to national estimates, the prevalence of obesity, defined as having a BMI $\geq$ 30 kg/m^2, rose from 25.4% to 33.2% between the periods 1988-1994 and 1999-2002 among women $\geq$ 20 years (Flegal, 2002; Hedley, 2004). Extreme obesity is defined as having a BMI $\geq$ 40 kg/m^2 and the prevalence of this condition rose from 4.0% to 6.4% among women $\geq$ 20 years over the same time periods (Flegal, 2002; Hedley, 2004).

Obesity during pregnancy has been consistently found to be associated with an increased risk of two of the more commonly occurring obstetric complications, gestational diabetes mellitus and pregnancy-induced hypertension and the relationships are discussed in depth in several recent reviews (O'Brien, 2003; Linne, 2004; Nuthalapaty, 2004). Increased resistance to insulin occurs in normal pregnancies due to hormonal changes including increased levels of human placental lactogen, progesterone, and cortisol (Landon, 2002). Women who develop gestational diabetes have an exaggerated insulin resistance for reasons that are not completely understood. Excess abdominal adipose tissue is associated with increased tissue resistance to insulin in non-pregnant individuals and this is a possible mechanism through which obesity increases risk for gestational diabetes among pregnant women (Gabbe, 2003).

Pregnancy-induced hypertension is a multi-organ systems disease for which the etiology is still poorly understood. Solomon and Seely have hypothesized that in some women, pregnancy-induced hypertension may be a manifestation of the insulin resistance syndrome, or "metabolic syndrome", that has been described among obese, non-pregnant individuals (Solomon, 2001). Hyperinsulinemia may contribute to increased risk of pregnancy-induced hypertension through the same mechanisms implicated in essential hypertension, including increased activity of the sympathetic nervous system, increased renal tubular re-absorption of sodium, increased cation transport, and associated endothelial dysfunction (Solomon, 2001).

Obesity during pregnancy could lead to an excess risk of other types of maternal obstetric complications mediated through other pathophysiological effects of insulin resistance such as depressed immune system functioning. However, few studies have

evaluated maternal outcomes other than pregnancy-induced hypertension and gestational diabetes and none have estimated the magnitude of overall risk of obstetric complications associated with obesity. Furthermore, few previous studies have had adequate sample size to assess maternal health risks in extremely obese pregnant women separately. Demonstrating a dose-response relationship between excess adiposity and risk of obstetric complications provides stronger evidence of causality. In addition, because the prevalence of extreme obesity is growing among women of reproductive age, clinicians need to know what types of complications they are more likely to have in order to counsel and manage them appropriately during pregnancy.

In the present study, the overall risk of maternal obstetric complications associated with obesity and extreme obesity is described for a group of 6,799 women who were members of a large health maintenance organization during 1998-2001. A broadly inclusive spectrum of obstetric complications is considered using methods developed for the new *HP 2010* index on maternal health during labor and delivery. Age, race, parity, gravidity, multi-fetal gestation, smoking status, Medicaid enrollment, substance abuse, and history of infertility or polycystic ovarian syndrome are evaluated as possible confounding exposures. Obese women have a higher prevalence of chronic medical conditions and are at increased risk for giving birth by cesarean delivery, each of which could mediate additional overall risk of obstetric complications. In the present study, we evaluate the role of pre-existing medical conditions and cesarean delivery as possible mediators of increased risk of obstetric complications due to obesity. If they contribute to a large portion of an increase in risk, then interventions to reduce morbidity could target management of these conditions. Our results allow us to estimate the

overall impact of obesity and extreme obesity on women's health during pregnancy, independent of important possible confounding exposures, and provide a basis for designing future national strategies to reduce maternal morbidity for women.

Methods

A retrospective cohort study was conducted using electronic medical record data from 1998 to 2001 for women who were members of Kaiser Permanente Northwest (KPNW), a large prepaid non-profit group practice health maintenance organization. Pregnant women were identified through a complex computer software algorithm that was designed to describe maternal morbidities before, during, and after pregnancy using automated medical record data among women with all types of pregnancy outcomes (Hornbrook, 2005). The pregnancy-identifying computer algorithm was highly valid when compared to medical record review and is described in Chapter I.

Women were included in the present study if they were identified by the computer algorithm as having had a pregnancy that resulted in giving birth to a live or stillborn infant during 1998-2001 and were ages 18-55 years old at the time of giving birth. For women who had more than one identified pregnancy during 1998-2001 meeting these criteria, the first eligible pregnancy per woman was selected for inclusion in this study. Women were excluded if they had insufficient data to calculate a body mass index, if their first prenatal weight was recorded after 20 weeks of gestation, or if they had biologically implausible values for height, weight, or gestational age. Women were also excluded if they had insufficient data to calculate gestational weight gain.

The maternal body mass index (BMI, weight in kilograms divided by the square of height in meters) was calculated for each woman using her first prenatal weight recorded in the electronic medical record. The height closest to the estimated time of conception (before or after) was used. BMI categories were specified based on guidelines from the National Institutes of Health (NIH) as follows: < 18.5 kg/m^2 (underweight), 18.5 kg/m^2 to 24.9 kg/m^2 (normal weight), 25 kg/m^2 to 29.9 kg/m^2 (overweight), 30 kg/m^2 to 39.9 kg/m^2 (obese), and 40 kg/m^2 or greater (extremely obese) (NIH, 1998). BMI of 18.5 kg/m^2 to 24.9 kg/m^2 was used as the referent group for all comparisons in which BMI was treated as a categorical variable.

Obstetric complications, the main outcome in the present study, are conditions caused by the pregnancy or management of the pregnancy such as pregnancy-induced hypertension, and do not include pre-existing medical conditions alone or cesarean delivery alone. As described in chapter I, maternal obstetric complications were assessed using *International Classification of Diseases - 9 -Clinical Modification (ICD-9-CM)* discharge diagnoses codes developed for the new *Healthy People 2010* index "Maternal complications during hospitalized labor and delivery" (**Table 1**). A woman was considered to have had an obstetric complication if she had at least one of these *ICD-9-CM* codes in the inpatient discharge record for the hospitalization during which her labor and delivery occurred.

Other conditions that are associated with any of the specific obstetric complications included in our outcome could potentially confound the relationship between obesity and risk of having any obstetric complication if they are also associated with obesity and are not in the causal pathway between these two variables. Most

previously published studies evaluating the relationship between maternal obesity and gestational diabetes or pregnancy-induced hypertension have evaluated maternal age, race, parity and multi-fetal gestation as potential confounding factors (Bowers, 1999; Thadhani, 1999; Michlin, 2000; Seibre, 2001; Bodnar, 2005). Nulliparity is a well-established risk factor for preeclampsia and Chesley has estimated that approximately 75% of women with preeclampsia are nulliparous (Chesley, 1984). Among nulliparous women, number of previous miscarriages or abortions may be associated with increased risk of preeclampsia (Sibai, 1995) however data describing this relationship are conflicting and most previous studies of obesity and obstetric complications have not evaluated history of previous early losses as a possible confounder. Increasing maternal age and multi-fetal gestation are risk factors for pregnancy-induced hypertension (Dekker, 2001) and age is also a risk factor for gestational diabetes (Kjos, 1999). Race and ethnicity are known risk factors for gestational diabetes (Kjos, 1999).

Baeten et al and Rosenberg et al have used birth certificate data and found that obesity remained associated with higher risk of pregnancy-induced hypertension and gestational diabetes after adjusting for socioeconomic status (e.g., marital status, education), adequacy of prenatal care, and payer of prenatal care (Baeten, 2001; Rosenberg, 2003). Rosenberg also used history of tobacco use, alcohol use, or illegal substance use during pregnancy as markers of "social risk".

Researchers who have evaluated the relationship between maternal obesity and infectious or thrombotic obstetric complications have adjusted for tobacco use history (Bianco, 1998; Seibre, 2001), which is known to be associated with these complications among non-pregnant individuals. Smoking has also been associated with a decreased risk

of preeclampsia and warrants consideration for this reason as well (Dekker, 2001). Infertility and polycystic ovarian syndrome are associated with obesity in women and could potentially have a confounding effect as well (Solomon, 2001) but have not been considered in previous studies.

In the present study, the following variables were assessed for possible confounding effect on the relationship between obesity and risk of obstetric complications: age, race/ethnicity, enrollment in Medicaid or Washington Basic Health Plan, parity, history of previous early pregnancy losses, number of live born infants for current pregnancy (i.e., twins or triplets), tobacco use, and substance abuse. Maternal obesity is associated with a higher risk of both pre-existing chronic medical conditions and giving birth by cesarean delivery. Pre-existing hypertension, and pre-existing diabetes mellitus are both risk factors for pregnancy-induced hypertension (Dekker, 2001). Cesarean delivery could mediate some increased risk of obstetric complications such as anesthesia-related complications, wound complications, post-operative infections and thrombosis. In the present study, we evaluate pre-existing medical conditions and cesarean delivery as conditions that may mediate an increased risk of obstetric complications.

Data on age, race, parity, gravidity, number of live born infants (resulting from the pregnancy included in the study), gestational age at time of labor and delivery, and the length of labor and delivery hospitalization were available from the database for the parent study on maternal morbidities and were originally assessed for each woman from automated inpatient hospitalization discharge records. Gravidity is the number of prior pregnancies a woman has had, including the in-study pregnancy, all prior pregnancies

that ended in early losses (e.g., spontaneous abortions), and any previous births to live or stillborn infants. Parity includes only prior births to live or stillborn infants, excluding the in-study pregnancy and prior early pregnancy losses. History of previous early losses (≥ 1) was calculated for each woman using these two available variables (number of previous early losses = Gravidity – (parity +1)).

Tobacco use history was assessed using a variable based on a "tobacco use" field in the outpatient electronic medical record for which possible values were "never", "yes", "infrequent", "quit", "passive", or "not asked". KPNW medical providers routinely ask patients about tobacco use status during outpatient visits and record each patient's self-reported answer in the electronic medical record using this field. Typically, this information is available from multiple time points during a pregnancy. For the present study, the last value for this field during the pregnancy was used. A value of "quit" indicates that a woman has reported that she quit using tobacco, but does not differentiate between whether or not she quit before or during pregnancy or for how long she quit.

Alcohol dependence, drug dependence, non-dependent abuse of drugs, polycystic ovarian syndrome, and female infertility were assessed based on the presence of at least one *ICD-9-CM* diagnosis code in the medical record at any time during the pregnancy, including both outpatient and inpatient medical records (**Table 4**). Substance abuse was defined as the presence of an *ICD-9-CM* code for either alcohol dependence, drug dependence, or non-dependent use of drugs. Information regarding enrollment in Medicaid or Washington Basic Health Plan and eligibility for KPNW medical coverage was assessed based on whether a woman was enrolled or eligible during the entire

pregnancy and was available from the database for the parent study on maternal morbidities.

Cesarean delivery and pre-existing medical complications, including pre-existing hypertension, pre-existing diabetes mellitus, asthma, cardiac disease, and renal disease, were assessed using *ICD-9-CM* diagnosis codes as described in Chapter I (Table 1). Both variables were assessed from the *ICD-9-CM* codes from the labor and delivery hospitalization records.

Data analysis

Descriptive graphical and statistical analyses and assessment for outliers or possible data errors were conducted for each variable. Characteristics of included and excluded women were compared using Pearson Chi-squared tests or independent sample t-tests to assess for differences in any possible confounding exposures. Among women included in the final study population, characteristics of women in each BMI category were compared using Pearson Chi-squared tests or one-way ANOVA to see if women in the various BMI categories differed with respect to other important risk factors for obstetric complications. Simple logistic regression models were used to calculate crude odds ratios with 95% confidence intervals for the risk of having at least one obstetric complication for women in BMI categories, using normal weight (BMI 18.5 to 24.9 kg/m^2) as the referent group.

The following variables were assessed for possible confounding or effect modification: age (< 30 or ≥ 30), race/ethnicity (white or non-white), enrollment in Medicaid or Washington Basic Health Plan (yes/no), parity (0, 1 or greater), history of

previous early pregnancy losses (yes/no), number of live born infants for current pregnancy (1 or > 1), tobacco use (Never, yes, quit, or other), and substance abuse (yes/no). If information was not available for any women for a particular covariate, a missing data category was created. Preliminary categories of each covariate were developed based on the distribution of the data and considering biological appropriateness of cut points and combining categories.

For each possible confounding or effect modifying exposure, the relationship between BMI and obstetric complications was assessed within each stratum of categories of the covariate. The stratum-specific odds ratios were examined for indication of difference in magnitude across all strata compared to the overall crude odds ratios (to evaluate for evidence of possible confounding effects) or for differences among the individual strata (to evaluate for possible effect modification). Categories were combined for variables if patterns of the ORs were similar across the initial categories.

A multiple logistic regression model was built to evaluate whether obesity was independently associated with risk of obstetric complications when adjusted for other potential confounding variables. Variables were selected using methods described by Hosmer and Lemeshow (Hosmer, 2000). First, univariable analyses were conducted to assess the relationship of each variable with risk of obstetric complications using contingency tables and Pearson chi-square tests. Covariates were entered into a preliminary multivariate logistic regression model with the main exposure variable if they were 1) biologically important (age, parity, number of live born infants) or 2) had a $p < 0.25$ based on the Chi-squared test. Hosmer and Lemeshow recommend using the $p <$

0.25 level because the more traditional levels (i.e., $p < 0.05$) have been shown to fail in identifying variables known to be important.

Variables that were no longer significant in this preliminary multivariate model at the $p < 0.05$ level (based on the Wald statistic) were removed individually and the significance of all of the remaining covariates were evaluated until only variables significant at the $p < 0.05$ were remaining in the model. All variables that were not included in the original multivariate model were subsequently added back one at a time to assess for any statistical significance ($p < 0.05$). For variables that demonstrated evidence of effect modification in stratified analyses, interaction with BMI categories was tested.

Formal evaluation was conducted to test for possible confounding effects of other variables on the relationship between obesity and risk of obstetric complications. For these analyses, BMI was used as a categorical variable. Odds ratios for the relationship between BMI categories and risk of obstetric complication, adjusted for all variables in the main effect model, were compared to odds ratios adjusted after removing one variable (evaluated for each individual variable in main effect model), or adding back those not included in the final main effect model. The percent change in the odds ratios were evaluated for each BMI category. A change of $\geq 10\%$ for the OR for any individual BMI category was used to determine if any individual covariate had a confounding effect on the relationship between BMI and risk of obstetric complications.

To evaluate for possible mediating effects by presence of pre-existing medical conditions or cesarean delivery, the relationship between BMI categories and risk of obstetric complications was evaluated after stratifying by these two variables. The

relationship between each of these variables and risk of obstetric complications was also evaluated in univariate analyses using Chi-squared tests and OR's and 95% CI were calculated using simple logistic regression models. These variables were added to the final multivariate model to assess for any change in the magnitude of the adjusted odds ratio for the relationship between each BMI category and risk of obstetric complications.

In order to assess for possible selection bias due to women being excluded due to missing height data or first prenatal weight measurement after 20 weeks of gestation, BMI categories were re-calculated for all women who had a prenatal weight measured at any time during pregnancy using 1) BMI from the first time point during pregnancy for women who had height available and 2) absolute weight categories for women who had missing height data, thus allowing most women to be included in analyses. The following weight categories were used: ≤ 150 lbs (assigned to normal weight group), 151-200 lbs (overweight group), 201 – 250 lbs (obese category), ≥ 250 (extremely obese category). Absolute weight categories have been used previously to assess the impact of maternal obesity when height data were unavailable (Carroll, 2003; Chauhan, 2001; Ehrenberg, 2002), typically using ≥ 200 lbs to define obesity and ≥ 250 lbs to define extreme obesity. The cut points of 200 and 250 lbs do categorize women into the appropriate BMI category (> 30 kg/m^2 or > 40 kg/m^2) unless their height is at the upper or lower distributions of height ($< 5'$ or $\geq 5'7"$). Among women who met all other inclusion and exclusion criteria, the correlation between BMI category assigned by absolute weight categories and actual BMI values was assessed using Spearman correlation. The relationship between BMI categories, referent to the normal weight category, and risk of

obstetric complications was reassessed, adjusting for other significant covariates in the multivariate model.

Analyses were also conducted to assess possible misclassification bias of maternal BMI. Among women who had a pre-pregnancy weight during the 60 days before pregnancy and met all other study inclusion and exclusion criteria, BMI was calculated using the pre-pregnancy weight. The correlation between the BMI using weights from these two time periods were calculated using Pearson correlation and the mean difference was calculated using a paired t-test. Pre-pregnancy BMI categories were assigned using the same categories that were used for the main study analyses. Adjusted odds ratios estimating the relative risk of obstetric complications for women in each pre-pregnancy BMI category, referent to normal weight were re-calculated and compared to results using the BMI from the first 20 weeks of pregnancy.

Institutional Review Board

The study protocol was approved the institutional review board (IRB) at Kaiser Foundation Research Institute (KFRI; FWA 00002344 –IRB 00000405). The protocol was also reviewed by the IRB at Oregon Health and Science University and authority was waived to KFRI.

Results

The computer algorithm identified 15,088 women who had a pregnancy eligible for inclusion. 6,799 women had adequate height and weight data for further analyses and are described in **Table 5**. 8,289 women were excluded from analyses, most commonly because they had no measured height recorded (**Table 6**). Excluded women were younger, more likely to have given birth previously, and were less likely to have pre-existing medical conditions, although differences among these characteristics were small (Table 5). Excluded women were less likely to have had continuous eligibility for KPNW coverage during pregnancy, to have had their first prenatal weight recorded during the first 20 weeks of pregnancy (an exclusion criterion), and were more likely to have missing data for race or tobacco use status.

The distribution of women among BMI categories is presented in **Figure 1**. 1,447 women were obese (BMI 30 – 39.9 kg/m^2) and 344 were extremely obese (BMI $\geq$ 40 kg/m^2). Women in the higher BMI categories were different from normal weight women in terms of several characteristics under consideration as possible confounding exposures (**Table 7**).

The risk of having $\geq$1 obstetric complication during the labor and delivery hospitalization was lowest among normal weight women and increasingly higher among women in higher BMI categories (**Figure 2**, **Table 8**). BMI (kg/m^2) was also a significant predictor of obstetric complications when assessed as a continuous variable (Crude OR 1.03, 95% CI 1.02-1.04). However, the relationship between BMI and obstetric complications did not appear to be linear because underweight women showed a trend for

having a higher risk of obstetric complications. In an adjusted multivariate model, BMI, age, parity, and number of live born infants were significant independent covariates associated with risk of obstetric complications.

Other potential confounding variables were also associated with risk of obstetric complications and these relationships are described in Table 8. Stratified univariate analyses indicated that age and tobacco use status might modify the relationship between BMI categories and risk of obstetric complications (**Tables 9 & 10**). When added to a multivariate model including BMI, age, parity, number of live born infants, and smoking status, two-way interaction terms for tobacco use*BMI category and age category*BMI category were significant additions ($p < 0.01$ and $p < 0.05$). Adjusted odds ratios and 95% confidence intervals describing the risk of obstetric complications among women in higher BMI categories compared to normal weight women are presented in **Table 11**. Results are presented for all women and stratified by age and smoking status.

Parity had a negative confounding effect on the relationship between BMI categories and risk of obstetric complications. When parity was removed from the model, the adjusted OR was reduced by 4 % among overweight women (OR_{adj} 1.11), 8 % among obese women (OR_{adj} = 1.45) and 11 % among extremely obese women (OR_{adj} 1.81). Adjustment for all other potential confounding variables caused less than a 2% change in the odds ratio for any BMI category.

Pre-existing medical conditions and cesarean delivery were evaluated as potential mediating factors between the relationship between BMI status and risk of obstetric complications. Stratified analyses are presented in **Table 12**. When these variables were added to the multivariate model including all 6,799 eligible women, the magnitude of the

odds ratio describing the relationship between BMI categories and obstetric complication changed < 5% for any individual BMI category.

Results of analyses assessing for bias are presented in **Table 13**. The magnitude of the relationship between BMI categories and risk of obstetric complications was similar among pregnant women who had continuous eligibility during pregnancy compared to main study findings with < 5% change in the magnitude of the OR for any BMI category.

1786 women who met other inclusion and exclusion criteria also had a weight recorded during the 60 days before the start of the pregnancy. The BMI using the first weight recorded during the first 20 weeks of pregnancy and BMI calculated using the pre-pregnancy weight were highly correlated ($R = 0.975$, $p < 0.001$, Pearson Correlation) and the mean difference in BMI was 0.34 $kg/m^2 \pm 1.52$ kg/m^2 ($p < 0.001$, paired-samples t-test). When BMI categories were assigned using pre-pregnancy weight, results followed the same pattern as findings in the main analyses but the odds ratio was 6% lower for obese women and 18% higher for extremely obese women (Table 13).

At least one prenatal weight during pregnancy was available for 14,433 women who met other inclusion criteria. When BMI category was estimated using absolute weight categories for women excluded from main analyses due to missing height, the distribution among BMI categories was similar to the distribution when excluding women without height data. The correlation between BMI using both methods was $R = 0.817$ (Spearman's rho, $p < 0.001$). The magnitude of the association between BMI categories and obstetric complication was similar to main study findings with 5% or less change for any BMI category (Table13).

Discussion

In the present study, we have estimated the increase in total obstetric complications due to obesity in a large sample of pregnant women enrolled in a managed care health plan. 34% of obese women and 40% of extremely obese women had at least one obstetric complication during labor and delivery, compared to 26% of women who had a normal weight during early pregnancy. After adjusting for parity and other measured confounders, the overall increase in risk of obstetric complications was 60% for obese women and 100% for extremely obese women relative to the risk among normal weight women.

Previous studies of obese pregnant women have typically found an incidence of 9-14% for preeclampsia (Edwards, 1996; Sibai, 1997; Bianco, 1998; Baeten, 2001) and 6-14% for gestational diabetes (Baeten, 2001; Edwards, 1996; Bianco, 1998), but the total burden of obstetric complications among obese women has not been previously described. Few previous studies have evaluated extremely obese women separately and these have evaluated a limited number of maternal obstetric complications, excluding the majority of those that make up the *HP 2010* index for maternal morbidity that we used in the present study. Bianco and colleagues evaluated medical records of 613 women in the USA who had a BMI > 35 and found that compared to normal weight women, they had an increased risk of gestational diabetes and preeclampsia, with an incidence of 14% each, and placental abruption with an incidence of 2% (Bianco, 1998). Kumari et al evaluated 188 women with BMI > 40 delivering singleton pregnancies in Abu Dhabi and found statistically significant associations with gestational diabetes and pregnancy-

induced hypertension which occurred in 23% and 29% of women, respectively (Kumari, 2001). Cedergren assessed 3,480 extremely obese women with singleton pregnancies (BMI > 40) using data from the Swedish Medical Birth registry and found these women had an increased risk of pre-eclampsia, although only 3.5% of extremely obese women in their sample developed the condition (Cedergren, 2004). These women also had an increase in anal sphincter lacerations and major postpartum hemorrhage, which each occurred in 6% of their extremely obese women.

In our study, we have identified clinical subgroups in which obesity may be of particular concern. Among women older than thirty, the increase in risk due to obesity and extreme obesity were 100 and 130% relative to normal weight after adjusting for confounders. Among women who reported smoking during pregnancy, the relative increases in risk were 90% and 160% compared to normal weight smokers (who had a similar level of risk as normal weight non-smokers). Future studies evaluating pre-pregnancy weight loss may want to target these clinical subgroups.

We were able to evaluate and adjust for important measured confounders. Maternal age, parity, multi-fetal gestation, and race are risk factors for specific obstetric complications included among those that were part of our outcome (Dekker, 2001; Kjos, 1999) and smoking is a known risk factor for infection and thrombosis in non-pregnant individuals. Among these variables, only parity had a measurable confounding effect in our data. Although we did not measure marital status or education, adjustment for payer of medical care or substance abuse during pregnancy, which has been used as a marker of social risk in previous studies of obese pregnant women (Rosenberg, 2003), did not change our results. Previous studies that have adjusted for multiple socioeconomic factors

using birth certificate data found that obesity remained associated with a higher risk of pregnancy-induced hypertension and gestational diabetes (Baeten, 2001; Rosenberg, 2003).

We did not measure any genetic factors that could potentially be associated with both obesity and risk of obstetric complications. Studies exploring the heritability of obesity among family members suggest that 25-40% of individual differences may depend on genetic factors and some studies in identical twins reared apart suggest that the genetic contribution to obesity may be 70% (NIH, 1998). It is possible such factors could be associated with a predisposition to develop gestational diabetes or pregnancy-induced hypertension.

Weight gain during pregnancy is possibly another unmeasured confounder. However, the role of weight gain in the relationship between maternal obesity and obstetric complications is not yet clearly defined. Most of the current data describing optimal weight gain during pregnancy are based on optimizing infant birth weight and much less is known about the relationship between gestational weight gain and maternal obstetric complications (IOM 1991). Some have found that gestational weight gain is associated with a higher risk of preeclampsia. However, this relationship is complicated by the fact that preeclampsia is accompanied by excessive extra-vascular fluid increase and thus reverse causality is possible. Recent studies that have evaluated weight gain among obese pregnant women have failed to find an independent association with maternal obstetric complications (Edwards, 1996; Bianco, 1998). Further studies clarifying the relationship between gestational weight gain and maternal obstetric complications are warranted. Baeten et al previously adjusted for gestational weight

gain and found that obesity remained associated with increased risk of gestational diabetes and pregnancy-induced hypertension (Baeten, 2001).

Some residual confounding is also possible in our study. Characterization of race and ethnicity was based on hospitalization discharge records and was missing for 14% of included women. Some of our confounders were measured using *ICD-9-CM* codes, which may have misclassified women's exposure status for those variables. In addition, the measurement of tobacco use was based on a self-reported value for one point during pregnancy. Frequency or duration of smoking were not assessed nor was self-reported quitting validated in any way.

In the present study, maternal BMI was measured using the first weight in the medical record during the first 20 weeks of pregnancy. Our intention was to measure obesity early during pregnancy and not precisely at the time of conception, which would be necessary if one were interested in events that occur early during pregnancy such as possible teratogenicity or early pregnancy loss. The maternal health outcomes we considered in the present study occur during the end of pregnancy, during labor and delivery, or during the immediate postpartum period and could be influenced by excess adiposity at any earlier point during pregnancy.

However, weight gain during pregnancy could have potentially caused women to be misclassified into higher BMI categories than appropriate for their actual percent body fat. 1,786 women in our study had a pre-pregnancy weight recorded during the 60 days prior to the start of their pregnancies. When BMI category was calculated using this weight, the effect size was reduced by 6% for obese women and increased by 18% for extremely obese women. This difference may have occurred because when BMI was

assessed using a weight during the first 20 weeks of pregnancy, gestational weight gain may have misclassified some women who were obese as extremely obese, thus blunting the measured effect size in the extremely obese women and increasing it among the obese women. These results indicate that the risk of obstetric complications among extremely obese women may actually be130% higher relative to the risk among normal weight women, which is higher than the 100% relative increase in risk that we measured using the prenatal weight during the first 20 weeks of pregnancy.

Because this was a retrospective study using available medical record data, only women who had complete medical records to characterize BMI could be included. Although 55% of women eligible for inclusion were excluded from analyses, most commonly because they did not have any height data available during 1998 – 2001 (48% of women), this does not appear to have caused bias in our estimation of effect size of obesity on risk of obstetric complications. In analyses in which excluded women were assigned a BMI category based on absolute weight values, the magnitude of the association between obesity or extreme obesity and risk of obstetric complications was similar to the main study findings (<5% change in ORs). Although estimation of relative adiposity using absolute weight categories is less precise than adjusting for height, this method allowed us to estimate the association of obesity and obstetric complications among 14,433 women (96%) with eligible pregnancies. The cut points of 200 and 250 lbs were accurate for predicting appropriate BMI category for 85% of women for whom both classification systems could be compared. Women who were excluded generally had less complete health care coverage and less complete medical records than included women. In order to measure the effect of obesity on the risk of obstetric complications among

these types of women, this study could be replicated using electronic medical record data from a more recent time period, during which height may be more likely to be measured due to the growing concern among clinicians about obesity.

Obesity is associated with both chronic medical conditions and cesarean delivery, both of which could theoretically mediate some increased risk for obstetric complications. In our study population, 96% of the population did not have any recorded pre-existing medical conditions (pre-existing hypertension, asthma, pre-existing diabetes mellitus, cardiovascular disease, or renal disease). Among these women, obesity and extreme obesity were associated with an increased risk of obstetric complications and the magnitude of the odds ratios were similar to the main study findings (45% and 90% higher relative risk for obese and extremely women, respectively, compared to normal weight women). When adjusting the overall results among all eligible women for pre-existing medical conditions (in addition to adjusting for age, parity, number of live born infants, and tobacco use status), the magnitude of the association between obesity or extreme obesity and risk of obstetric complications changed by $\leq 2\%$. Most of the excess risk of obstetric complications associated with obesity does not appear to be mediated by pre-existing medical conditions.

4% of women we studied had a pre-existing medical condition. Among these women, obesity was not significantly associated with an increased risk of obstetric complications. It is possible that we could not detect a significant effect due to the small number of women who had pre-existing medical conditions. It is also possible that among these women, obesity is not associated with increased risk of obstetric complications. Pre-existing medical conditions are not prevalent among women of

childbearing age, and therefore management of these conditions may not have a significant impact on reducing maternal morbidity in the nation.

In our population, 30% and 42% of obese and extremely obese women respectively, gave birth by cesarean delivery compared to 18% of normal weight women. Cesarean delivery could mediate increased risk of post-partum obstetric complications, such as anesthesia-related complications, infections, or thrombotic events. In our study population, 35% of women who gave birth by cesarean delivery had obstetric complications compared to 28% of women who gave birth vaginally. Among the women who had cesarean deliveries, extreme obesity was associated with 60% relative increase in risk of obstetric complications. Among women who gave birth vaginally, obesity and extreme obesity were associated with 46% and 77% relative increase in risk. The addition of cesarean delivery to adjusted multivariate regression model reduced the risk estimate by 4%. These results indicate that only a small portion of the overall increased risk of obstetric complications associated with obesity may be mediated by the increased risk of complications due to having had a cesarean delivery. Interventions that target labor management strategies to reduce rates of cesarean delivery may not reduce the overall risk of obstetric complications among obese women significantly. Further studies evaluating what specific obstetric complications are associated with obesity among women who have given birth vaginally or by cesarean will be useful to determine how to best manage obese women who give birth by cesarean delivery. Specifically, it will be useful to know if they are experiencing complications that occur prior to giving birth (e.g., pregnancy-induced hypertension) or those that occur during the postpartum period and are a complication of cesarean delivery (e.g., wound complications).

Reducing the maternal death ratio and reducing overall maternal morbidity remain national health goals in the United States. Although the maternal mortality ratio in the United States declined from the 1930's through 1970's, it has remained between seven and eight deaths per 100,000 live births since 1982. One approach to reducing maternal death may be to reduce the overall percentage of women who experience maternal morbidities during labor and delivery. Although the goal of this study was not to build a model to best predict the occurrence of maternal morbidities, we have identified body mass index, age, parity, and number of live born infants (i.e., multiple gestations), as variables that are independently associated with risk of maternal morbidity at the time of labor and delivery. Prevention strategies that target women in higher risk groups may be useful for reducing overall maternal morbidity.

Obesity is a potentially modifiable risk factor that has been increasing in prevalence in all subgroups of the US population over the last two decades. Lu et al retrospectively studied the prevalence of obesity among 53,080 women with singleton pregnancies in Jefferson County Alabama during 1980 and 1999 and found that the prevalence of obesity doubled in pregnant women during this time period (Lu, 2001). Obesity is one of the 10 Leading Health Indicators identified in *HP 2010* and the goal among women is to reduce the prevalence 15% for obesity and extreme obesity combined (USDHHS, 2000). Reducing and treating obesity were also the focus of a recent Surgeon General's report in which he called for collaborative action by a wide range of professionals and organizations to take action to promote physical activity and healthy diet (USDHHS, 2001).

The US Preventive Services Task Force, which makes evidence-based recommendations for primary care clinicians, has recently recommended that clinicians screen all adults for obesity using the BMI (USPSTF, 2003). They found fair to good evidence that high-intensity counseling, about diet or exercise or both, combined with behavioral interventions, produces modest, sustained weight loss (3-5 kg for 1 year or more) in adults who are obese (BMI $\geq$ 30 kg/m^2). Although the USPSTF did not find evidence that this level of weight loss was directly linked to improved health outcomes, they concluded that changes in intermediate health outcomes such as improved glucose metabolism, lipid levels, and blood pressure that are associated with modest weight loss (NIH, 1998), providing indirect evidence of health benefits.

Weight loss programs have been studied for obese women who have infertility problems and have been recommended in a recent review as the first choice of treating obese women to achieve conception (Linne, 2004). Compared to induced pregnancy attempts, weight loss programs have been shown to be effective for achieving conception and reducing medical costs (Linne, 2004).

Although preventing obesity should remain the focus of national efforts to reduce obesity-related maternal morbidity, clinical approaches to managing women who are already obese need to be evaluated. Interventions that target women who are planning to conceive, such as weight loss reduction programs, could potentially reduce the risk these women have for developing obstetric complications. Future observational studies should evaluate maternal and fetal health outcomes among obese women who have lost weight prior to becoming pregnant. If observational studies indicate that weight loss prior to pregnancy may be beneficial for maternal and infant health, then interventional studies

should be developed targeting obese women planning conception. Obese women older than 30 years or who are also smokers may be subgroups that could benefit the most. Any preconceptual weight loss programs would need to ensure that women were meeting nutritional recommendations for micro and macronutrients for all women planning conceptions (Institute of Medicine, 1992). During pregnancy, obese women are recommended to gain at least 15 lbs (Institute of Medicine 1992). These recommendations are based primarily on optimizing infant birth weight and studies that evaluate optimal weight gain for obese pregnant women are needed. However, until better data are available, clinicians should continue to follow existing recommendations on weight gain when counseling obese pregnant women.

OVERALL SUMMARY AND CONCLUSIONS

Maternal morbidities are common for pregnant women at the time of labor and delivery and identifying modifiable risk factors will be important for developing strategies to reduce overall maternal morbidity. In the present study, we assessed maternal morbidities during labor and delivery using automated medical records in a 15,088 pregnant women who were enrolled in a group practice health maintenance organization. 27% of women had at least one type of obstetric complication, 4% had a pre-existing medical condition, and 21% gave birth by cesarean delivery. Among 6,799 women who had adequate medical records to calculate a maternal body mass index during the first 20 weeks of pregnancy, 21% were obese (BMI 30 – 39.9 kg/m^2) and 5% were extremely obese (BMI $\geq$ 40 kg/m^2). The risk of having at least one obstetric complication during the labor and delivery hospitalization was 34% for obese women and 40% for extremely obese women, compared to 26% for women who had a normal weight. After adjusting for measured confounding exposures, the overall relative increase in risk of obstetric complications was 60% for obese women and 100% for extremely obese women, compared to normal weight women. Women who were older than thirty years of age or who smoked during pregnancy had an even higher risk of obstetric complications associated with obesity. Obesity was also associated with an increased risk of having pre-existing medical conditions and giving birth by cesarean delivery. However adjustment for these exposures had little impact on the magnitude of the measured association between obesity and risk of obstetric complications.

During the last two decades, the prevalence of obesity has been increasing in all subgroups of the US population, including women of childbearing age. Obesity is associated with multiple adverse health consequences in non-pregnant women and is one of the leading health indicators identified in *Healthy People 2010*. High-intensity behavioral weight loss counseling has been shown to produce modest, sustained weight loss (3-5 kg for 1 year or more) for non-pregnant obese adults and these changes are associated with improvements in intermediate health outcomes such as improved glucose metabolism, lipid levels, and blood pressure. Moderate weight loss has also been successful for treating infertility in obese women. Weight loss prior to conception could also potentially reduce the risk of developing obstetric complications during pregnancy among obese women and should be evaluated for effects on maternal complications and fetal health. Most women who are obese do not return to a normal weight even after intensive behavioral weight loss counseling programs, and obesity prevention efforts should therefore remain the priority of national efforts to reduce obesity-related maternal morbidity.

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TABLES

Table 1. *ICD-9-CM* codes used to assess maternal morbidities during hospitalized labor and delivery using automated medical record data[a]

Morbidity Description	ICD-9 Codes
Obstetric complications	
Hemorrhage	
Antepartum hemorrhage (excluding hemorrhage in early pregnancy)	641.1-641.3, 641.8-641.9
Postpartum hemorrhage	All 666
Preeclampsia and eclampsia	
All (Pregnancy-induced hypertension, preeclampsia, and eclampsia, including either preeclampsia or eclampsia that is superimposed on preexisting HTN)	642.3-642.7
Severe preeclampsia	642.5
Eclampsia	642.6
Transient hypertension of pregnancy	642.3
Obstetric trauma	
Major perineal laceration (third and fourth degree perineal lacerations; vulval and perineal hematoma)	664.2, .3, .5
Other obstetrical trauma; (includes inversion of uterus, cervical laceration, high vaginal laceration, other injury to pelvic organs, joints or ligaments, pelvic hematoma)	665.2 - 665.9
Ruptured uterus	665.0 - 665.1
Infection	
GU infection (pyelonephritis, UTI)	646.6, Any 590, 599.0
Amnionitis	658.4
Other infection (unspecified pneumonia, unspecified bacterial infection, abscess)	041,486, 682
Fever (maternal pyrexia during labor, unspecified)	659.2
Major puerperal infection (includes endometritis, sepsis, cellulitis, peritonitis, salpingitis)	All 670, All 615
Pyrexia of unknown origin in the puerperium	All 672

Morbidity Description	ICD-9 Codes
Sepsis (generalized infection during labor, septicemia during labor)	659.3
Other	
Other major puerperal conditions (includes hepatorenal syndrome, postpartum cardiomyopathy, sudden death, fluid/electrolyte abnormality, purpura)	674.8-674.9, All 276, All 287
Other major complications of labor and delivery (includes maternal distress, shock, hypotension, arrest)	669.0 - 669.4,All 518, All 998
Anesthetic complications	All 668, All 349
Wound complication	674.1 - 674.3
Deep venous thrombosis	671.3 - 671.4
Gestational liver disease	646.7
Late vomiting of pregnancy	643.2
Obstetrical pulmonary embolism (includes blood clot embolism, amniotic fluid embolism, air embolism)	All 673
CVA (includes cerebral venous thrombosis, thrombosis of intracranial venous sinus)	671.5, 674.0
Gestational diabetes (abnormal GTT)	648.8
Preexisting medical conditions	
Chronic hypertension	642.0-642.2, 642.7, 642.9, All 401
Cardiac disease (includes congenital diseases; excludes cerebral, venous complications)	648.5-648.6, All 424, All 425
Asthma	All 493
Preexisting diabetes mellitus (does not include abnormal GTT)	648.0, All 250
Renal disease (unspecified renal disease in pregnancy without mention of hypertension)	646.2
Cesarean delivery	74.0-74.2, 74.4, 74.99, 669.70-669.71

[a]Codes were provided by Isabella Danel (personal communication; Danel, 2004)

Table 2: Characteristics of pregnant women enrolled in Kaiser Permanente Northwest during 1998 - 2001 (N= 15,088)

Characteristic	N (%)
Age	
18-24 yrs	5227 (34.6)
25-29 yrs	4490 (29.8)
30-34 yrs	3454 (22.9)
35-39 yrs	1539 (10.2)
≥ 40 yrs	378 (2.5)
Race[a]	
Asian	925 (6.1)
Black	527 (3.5)
Hispanic	882 (5.8)
Native American	82 (0.5)
Other	74 (0.5)
White	9311 (61.7)
Missing data	3287 (21.8)
Parity	
0	5689 (37.7)
1	5076 (33.6)
2	2309 (15.3)
3 or greater	1490 (9.9)
Missing data	524 (3.5)
> 1 live born infant[b]	253 (1.7)
Stillborn infant	87[c] (0.6)
Medicaid or Washington Basic Health Plan	949 (6.3)
Eligible for KPNW coverage during entire pregnancy	11,230 (74.4)

[a] Among women who had data available for race/ethnicity, 21% were non-white.
[b] For current pregnancy; data are missing for 532 women.
[c] 7/87 women had both a stillborn and a live born infant
Abbreviations: L & D = Labor and delivery; KPNW = Kaiser Permanente Northwest

Table 3. Maternal morbidities during hospitalized labor and delivery among pregnant women enrolled in Kaiser Permanente Northwest during 1998 – 2001 (N = 15,088)

Type of Morbidity	KPNW, 1998-2001 N (%)	NHDS 1993-1997[a] (%)
Obstetric complications		
Hemorrhage		
• Antepartum	211 (1.4)	1.6
• Postpartum	515 (3.4)	2.0
Preeclampsia and eclampsia		
• All	1219 (8.1)	3.0
• Severe preeclampsia	123 (0.8)	0.6
• Eclampsia	8 (0.1)	0.1
• Transient hypertension of pregnancy	682 (4.5)	2.1
Obstetric trauma		
• $3^{rd}/4^{th}$-degree laceration or hematoma	674 (4.5)	5.0
• Other obstetric trauma	571 (3.8)	3.8
• Ruptured uterus	12 (0.1)	0.1
Infection		
• Genitourinary infection	148 (1.0)	2.7
• Amnionitis	391 (2.6)	1.9
• Other infection	66 (0.4)	1.5
• Fever	229 (1.5)	1.1
• Major puerperal infection	47 (0.3)	0.8
• Postpartum fever of unknown origin	26 (0.2)	0.3
• Sepsis	1 (0.0)	<0.1
Other		
• Other puerperal complication	134 (0.9)	0.9
• Other major obstetric complication	72 (0.5)	0.4
• Anesthesia complication	108 (0.7)	0.4
• Wound complication	73 (0.5)	0.3
• Deep venous thrombosis	7 (0.0)	< 0.1
• Gestational liver disease	11 (0.1)	< 0.1
• Late vomiting	2 (0.0)	< 0.1
• Pulmonary or amniotic embolism	0 (0.0)	< 0.1
• Cerebrovascular accident	1 (0.0)	< 0.1
Gestational diabetes (abnormal GTT)	530 (3.5)	2.8

Type of Morbidity	KPNW, 1998-2001 N (%)	NHDS 1993-1997[a] (%)
Preexisting medical conditions		
• Chronic hypertension	208 (1.4)	1.5
• Cardiac disease	64 (0.4)	0.9
• Asthma	172 (1.1)	0.7
• Diabetes (excluding abnormal GTT)	78 (0.5)	0.6
• Renal disease	22 (0.1)	0.1
Obstetric complications, total[b]	**4120 (27.3)**	**28.6**
Preexisting medical conditions, total[b]	**521 (3.5)**	**4.1**
Any morbidity, excluding cesarean[b, c]	**4458 (29.5)**	**30.7**
Cesarean delivery	**3207 (21.3)**	**21.8**
Any morbidity, including cesarean[b]	**6496 (43.1)**	**43.0**

[a]Data from Danel et al 2003.
[b]percentage of women with at least 1 reported morbidity within a given category.
[c] A goal of *HP 2010* is to reduce the percentage of women experiencing any morbidity, excluding cesarean, to 24% of women giving birth
Abbreviations: KPNW = Kaiser Permanente Northwest; NHDS = National Hospital Discharge Survey; GTT = Glucose tolerance test

Table 4. ***ICD-9-CM*** **codes used to assess possible confounding exposures during pregnancy**

Exposure	*ICD-9-CM* Code
Alcohol dependence	303[a]
Drug dependence	304[a]
Non-dependent abuse of drugs	305[a]
Polycystic ovarian syndrome	256.4
Female infertility	628 or V23.0

[a] With any 4th *ICD-9-CM* digit

Table 5. Characteristics of pregnant women enrolled in Kaiser Permemante Northwest during 1998-2001 who were included and excluded[a] in obesity analyses

Characteristic	Included N = 6,799	Excluded N = 8,289	p-value[b]
Age, n (%)			
18-24 yrs	2173 (32.0)	3054 (36.8)	
25-29 yrs	2032 (29.9)	2458 (29.7)	
30-34 yrs	1657 (24.4)	1797 (21.7)	< 0.001
≥ 35 yrs	937 (13.8)	980 (11.8)	
Race, n (%)[c]			
White	4556 (67.0)	4755 (57.4)	< 0.001
Asian	497 (7.3)	428 (5.2)	
Black	285 (4.2)	242 (2.9)	
Hispanic	419 (6.2)	463 (5.6)	
Native American	41 (0.6)	41 (0.5)	
Other	29 (0.4)	45 (0.5)	
Data missing	972 (14.3)	2315 (27.9)	
Medicaid or Washington Basic Health Plan, n (%)	408 (6.0)	541 (6.5)	0.19
Eligible for KPNW coverage during entire pregnancy, n (%)	5741 (84.4)	5489 (66.2)	< 0.001
First prenatal weight recorded during first 20 weeks of gestation[d], n (%)	6799 (100)	6555 (79.1)	< 0.001
Gravidity, n (%)			
1	1876 (27.6)	2187 (26.4)	0.42
2	1919 (28.2)	2358 (28.4)	
3	1277 (18.8)	1571 (19.0)	
4	731 (10.8)	893 (10.8)	
5 or greater	765 (11.3)	957 (11.5)	
Data missing	231 (3.4)	323 (3.9)	
Parity, n (%)			
0	2685 (39.5)	3004 (36.2)	<0.001
1	2270 (33.4)	2806 (33.9)	
2	1024 (15.1)	1285 (15.5)	
3 or greater	603 (8.9)	887 (10.7)	
Data missing	217 (3.2)	307 (3.7)	

Characteristic	Included N = 6,799	Excluded N = 8,289	p-value[b]
Tobacco use history, n (%)			
Never	4195 (61.7)	4858 (58.6)	< 0.001
Yes	1142 (16.8)	1521 (18.3)	
Infrequent	20 (0.3)	13 (0.2)	
Quit	1388 (20.4)	1382 (16.7)	
Passive	7 (0.1)	5 (0.1)	
Not asked	14 (0.2)	62 (0.7)	
Data missing	33 (0.5)	448 (5.4)	
Alcohol dependence or drug abuse/dependence, n (%)	120 (1.8)	156 (1.9)	0.59
Female infertility, n (%)	153 (2.3)	111 (1.3)	<0.001
Polycystic ovarian syndrome, n (%)	6 (0.1)	3 (0.0)	0.19
Pre-existing chronic medical condition, n (%)	298 (4.4)	223 (2.7)	< 0.001
Gestational age < 37 weeks at time of L & D, n (%)	569 (8.4)	650 (7.8)	0.24
Pregnancy outcome, n (%)			
Live infant	6759 (99.4)	8242 (99.4)	0.86
Stillborn infant[e]	40 (0.6)	47 (0.6)	
Number of live born infants, n (%)			
1	6458 (95.0)	7845 (94.6)	0.30
> 1	118 (1.7)	135 (1.6)	
Data missing	223 (3.3)	309 (3.7)	
Cesarean delivery, n (%)	1549 (22.8)	1658 (20.0)	< 0.001
Length of hospitalization for L & D, n (%)			
0-2 days	3841 (56.5)	5172 (62.4)	< 0.001
3-5 days	2741 (40.3)	2912 (35.1)	
≥ 6 days	217 (3.2)	205 (2.5)	
Source of outcome date, n (%)			
ADT	6766 (99.5)	8142 (98.2)	<0.001
OSCAR	33 (0.5)	147 (1.8)	

Characteristic	Included N = 6,799	Excluded N = 8,289	p-value[b]
Absolute weight			
≤ 200 lbs	5734 (84.3)	6500 (85.0)	0.09[f]
201 – 250 lbs	797 (11.7)	895 (11.7)	
> 250 lbs	268 (3.9)	249 (3.3)	
Any obstetric complication recorded in L & D discharge record, n (%)	1993 (29.3)	2127 (25.7)	<0.001

[a] Excluded due to insufficient height or prenatal weight records
[b] Calculated using Pearson Chi-squared test
[c] Among women who had data available for race or ethnicity, 22% were non-white.
[d] An exclusion criteria
[e] 7 excluded women had both a live and a stillborn infant
[f] Excluding 645 women with missing data for prenatal weight
Abbreviations: KPNW = Kaiser Permanente Northwest, L & D = Labor and Delivery, ns = not statistically significant

Table 6. Reasons for excluding women from analyses of the relationship between obesity and maternal obstetric complications

Exclusion criteria	Total number of women meeting each exclusion criteria, N (%)[a]
Missing data	
Height unavailable during 1998-2001	7,285 (48.3)
Prenatal weight not available	645 (4.3)
Gestational age when first prenatal weight recorded ≥ 20 weeks	1,525 (10.1)
Difference between gestational age at last prenatal visit and time of delivery > 30 days[b]	843 (5.6)
Suspected data errors due to biologically implausible values:	
Gestational age at time of delivery (≤ 20 weeks)	7 (< 0.01)
Height outlier (outside of 3 sd of mean; < 44.26" or > 85.22")	19 (0.1)
Weight < 37.62 lbs	5 (< 0.01)
Any of exclusion criteria listed above	**8,289/15,088 (54.9)**

[a]Number of women within each category (not mutually exclusive)
[b]Excluded for calculating gestational weight gain

Table 7. Characteristics of pregnant women enrolled in Kaiser Permanente Northwest during 1998 – 2001, stratified by maternal body mass index categories

Characteristic	Under-weight (< 18.5 kg/m^2) N=169	Normal weight (18.5–24.9 kg/m^2) N=3075	Overweight (25-29.9 kg/m^2) N=1764	Obese (30-39.9 kg/m^2) N=1447	Extremely Obese (≥ 40 kg/m^2) N=344	p-value[a]
Age, n (%)	59 (34.9)	1010 (32.8)	543 (30.8)	468 (32.3)	93 (27.0)	0.05
18-24 yrs	50 (29.6)	911 (29.6)	502 (28.5)	464 (32.1)	105 (30.5)	
25-29 yrs	38 (22.5)	758 (24.7)	442 (25.1)	321 (22.2)	98 (28.5)	
30-34 yrs	22 (13.0)	396 (12.9)	277 (15.7)	194 (13.4)	48 (14.0)	
≥ 35 yrs						
Race, n (%)						
White	88 (52.1)	2008 (65.3)	1184 (67.1)	1023 (70.7)	253 (73.5)	< 0.001
Asian	48 (28.4)	335 (10.9)	88 (5.0)	23 (1.6)	3 (0.9)	
Black	3 (1.8)	108 (3.5)	71 (4.0)	77 (5.3)	26 (7.6)	
Hispanic	4 (2.4)	156 (5.1)	134 (7.6)	104 (7.2)	21 (6.1)	
Native American	1 (0.6)	13 (0.4)	17 (1.0)	7 (0.5)	3 (0.9)	
Other	0 (0.0)	17 (0.6)	5 (0.3)	7 (0.5)	0 (0.0)	
Data missing	25 (14.8)	438 (14.2)	265 (15.0)	206 (14.2)	38 (11.0)	
Medicaid or Washington Basic Health Plan, n (%)	7 (4.1)	151 (4.9)	108 (6.1)	116 (8.0)	26 (7.6)	0.001

Characteristic	Under-weight (< 18.5 kg/m^2) N=169	Normal weight (18.5–24.9 kg/m^2) N=3075	Overweight (25-29.9 kg/m^2) N=1764	Obese (30-39.9 kg/m^2) N=1447	Extremely Obese (≥ 40 kg/m^2) N=344	p-value[a]
Eligible for KPNW coverage during entire pregnancy, n (%)	144 (85.2)	2619 (85.2)	1491 (84.5)	1192 (82.4)	295 (85.8)	0.17
Gravidity, n (%)						
1	56 (33.1)	966 (31.4)	437 (24.8)	343 (23.7)	74 (21.5)	< 0.001
2	64 (37.9)	898 (29.2)	492 (27.9)	379 (26.2)	86 (25.0)	
3	25 (14.8)	531 (17.3)	364 (20.6)	289 (20.0)	68 (19.8)	
4	11 (6.5)	304 (9.9)	199 (11.3)	171 (11.8)	46 (13.4)	
5 or greater	10 (5.9)	279 (9.1)	199 (11.3)	220 (15.2)	57 (16.6)	
Data missing	3 (1.8)	97 (3.2)	73 (4.1)	45 (3.1)	13 (3.8)	
Parity, n (%)						
0	83 (49.1)	1340 (43.6)	671 (38.0)	487 (33.7)	104 (30.2)	< 0.001
1	56 (33.1)	1015 (33.0)	567 (32.1)	520 (35.9)	112 (32.6)	
2	19 (11.2)	418 (13.6)	283 (16.0)	238 (16.4)	66 (19.2)	
3 or greater	8 (4.7)	209 (6.8)	174 (9.9)	162 (11.2)	50 (14.5)	
Data missing	3 (1.8)	93 (3.0)	69 (3.9)	40 (2.8)	12 (3.5)	

Characteristic	Under-weight (< 18.5 kg/m^2) N=169	Normal weight (18.5–24.9 kg/m^2) N=3075	Overweight (25-29.9 kg/m^2) N=1764	Obese (30-39.9 kg/m^2) N=1447	Extremely Obese (≥ 40 kg/m^2) N=344	p-value[a]
History of early pregnancy loss, n (%)						
No	112 (66.3)	1927 (62.7)	1021 (57.9)	840 (58.1)	198 (57.6)	< 0.01
Yes	53 (31.4)	1044 (34.0)	660 (37.4)	555 (38.4)	131 (38.1)	
Data missing	4 (2.4)	104 (3.4)	83 (4.7)	52 (3.6)	15 (4.4)	
Tobacco use history, n (%)[b]						
Never	108 (63.9)	2018 (65.6)	1081 (61.3)	807 (55.8)	181 (52.6)	< 0.001
Yes	30 (17.8)	488 (15.9)	277 (15.7)	278 (19.2)	69 (20.1)	
Infrequent	0 (0.0)	9 (0.3)	3 (0.2)	6 (0.4)	2 (0.6)	
Quit	28 (16.6)	541 (17.6)	388 (22.0)	341 (23.6)	90 (26.2)	
Passive	1 (0.6)	2 (0.1)	1 (0.1)	1 (0.1)	2 (0.6)	
Not asked	0 (0.0)	8 (0.3)	3 (0.2)	3 (0.2)	0 (0.0)	
Data missing	2 (1.2)	9 (0.3)	11 (0.6)	11 (0.8)	0 (0.0)	
Alcohol dependence or drug abuse/dependence	2 (1.2)	51 (1.7)	29 (1.6)	31 (2.1)	7 (2.0)	0.73
Female infertility	0 (0.0)	67 (2.2)	33 (1.9)	36 (2.5)	17 (4.9)	< 0.01
Polycystic ovarian syndrome	0 (0.0)	1 (0.0)	0 (0.0)	3 (0.2)	2 (0.6)	< 0.01

Characteristic	Under-weight (< 18.5 kg/m^2) N=169	Normal weight (18.5–24.9 kg/m^2) N=3075	Overweight (25-29.9 kg/m^2) N=1764	Obese (30-39.9 kg/m^2) N=1447	Extremely Obese (≥ 40 kg/m^2) N=344	p-value[a]
Pre-existing medical condition, n (%)	4 (2.4)	86 (2.8)	69 (3.9)	91 (6.3)	48 (14.0)	< 0.001
Gestational age at labor and delivery < 37 weeks, n (%)	10 (5.9)	231 (7.5)	147 (8.3)	140 (9.7)	41 (11.9)	< 0.05
Pregnancy outcome, n (%)						
Livebirth	168 (99.4)	3060 (99.5)	1750 (99.2)	1437 (99.3)	344 (100.0)	0.39
Still birth	1 (0.6)	15 (0.5)	14 (0.8)	10 (0.7)	0 (0.0)	
Number of live born infants, n (%)						
1	165 (97.6)	2935 (95.4)	1669 (94.6)	1370 (94.7)	319 (92.7)	< 0.05
>1	0 (0.0)	40 (1.3)	32 (1.8)	34 (2.3)	12 (3.5)	
Data missing	4 (2.4)	100 (3.3)	63 (3.6)	43 (3.0)	13 (3.8)	
Cesarean delivery, n (%)	26 (15.4)	553 (18.0)	393 (22.3)	433 (29.9)	144 (41.9)	< 0.001

Characteristic	Under-weight (< 18.5 kg/m^2) N=169	Normal weight (18.5–24.9 kg/m^2) N=3075	Overweight (25-29.9 kg/m^2) N=1764	Obese (30-39.9 kg/m^2) N=1447	Extremely Obese (≥ 40 kg/m^2) N=344	p-value[a]
Length of hospitalization for L & D, n (%)						
0-2 days	107 (63.3)	1864 (60.6)	1001 (56.7)	723 (50.0)	146 (42.4)	< 0.001
3-5 days	56 (33.1)	1129 (36.7)	708 (40.1)	671 (46.4)	177 (51.5)	
≥ 6 days	6 (3.6)	82 (2.7)	55 (3.1)	53 (3.7)	21 (6.1)	

[a]p-value calculated by Pearson Chi-squared test.
[b]Based on self-reported tobacco use status to healthcare provider at the latest point available during the pregnancy. "Quit" includes self-report of quitting either before or during pregnancy.
Abbreviations: L & D = Labor and delivery; KPNW = Kaiser Permanente Northwest

Table 8. Risk of obstetric complications among pregnant women enrolled in Kaiser Permanente Northwest during 1998 – 2001, stratified by body mass index categories and other covariates (N = 6,799)

Characteristic	Total population N	Any obstetric complication N (%)	p-value[a]
Total population	6799	1993 (29.3)	N/A
Body Mass Index			
Underweight	169	49 (29.0)	< 0.001
Normal weight	3075	808 (26.3)	
Overweight	1764	504 (28.6)	
Obese	1447	495 (34.2)	
Extremely obese	344	137 (39.8)	
Age			
< 30 years	4205	1187 (28.2)	< 0.05
≥ 30 years	2594	806 (31.1)	
Race			
White	4556	1336 (29.3)	0.77
Non-white	1271	380 (29.9)	
Data missing	972	277 (28.5)	
Medicaid or Washington Basic Health Plan			
No	6391	1891 (29.6)	< 0.05
Yes	408	102 (25.0)	
Gravidity			
1	1876	693 (36.9)	< 0.001
2	1919	562 (29.3)	
3	1277	304 (23.8)	
4	731	179 (24.5)	
5 or greater	765	190 (24.8)	
Data missing	231	65 (28.1)	

Characteristic	Total population N	Any obstetric complication N (%)	p-value[a]
Parity			
0	2685	964 (35.9)	< 0.001
1	2270	604 (26.6)	
2	1024	223 (21.8)	
3 or greater	603	139 (23.1)	
Data missing	217	63 (29.0)	
Previous early pregnancy loss	4098	1248 (30.5)	< 0.05
No	2443	674 (27.6)	
Yes	258	71 (27.5)	
Data missing			
Tobacco use history			
Never	4195	1233 (29.4)	0.375
Yes	1142	318 (27.8)	
Quit	1388	424 (30.5)	
Data missing or other[b]	74	18 (24.3)	
Alcohol dependence or drug abuse/dependence			
No	6679	1953 (29.2)	0.329
Yes	120	40 (33.3)	
Female infertility			
No	6646	1930 (29.0)	0.001
Yes	153	63 (41.2)	
Polycystic ovarian syndrome			
No	6793	1992 (29.3)	0.68[c]
Yes	6	1 (16.7)	
Pre-existing medical conditions			
No	6501	1887 (29.0)	<0.05
Yes	298	106 (35.6)	

Characteristic	Total population N	Any obstetric complication N (%)	p-value[a]
Number of live born infants			
1	6458	1866 (28.9)	<0.001
>1	118	59 (50.0)	
Data missing	223	68 (30.5)	
Cesarean delivery			
No	5250	1444 (27.5)	<0.001
Yes	1549	549 (35.4)	

[a]p-value calculated using Pearson Chi-squared test, [b]Infrequent, Passive, Not asked
[c]p-value calculated using Fisher's exact test; Abbreviations: N/A = not applicable

Table 9. Risk of having ≥ 1 obstetric complications among women in body mass index categories among pregnant women enrolled in Kaiser Permanente Northwest during 1998 –2001

	Normal weight		Overweight		Obese		Extremely obese	
	N	%	N	%	N	%	N	%
All women	808/3075	26.3	504/1764	28.6	495/1447	34.2	137/344	39.8
Age								
< 30	509/1921	26.5	286/1045	27.4	287/932	30.8	75/198	37.9
≥ 30	299/1154	25.9	218/719	30.3	208/515	40.4	62/146	42.5
Tobacco use								
Never	555/2018	27.5	319/1081	29.5	273/807	33.8	57/181	31.5
Yes	113/488	23.2	70/277	25.3	97/278	34.9	29/69	42.0
Quit	138/541	25.5	108/388	27.8	119/341	34.9	50/90	55.6
Data missing or other[a,b]	2/28	N/A	7/ 18	N/A	6/21	N/A	1/4	N/A

[a]infrequent or passive tobacco exposure or not asked by clinician about tobacco use
[b]74 women were in this category, including 3 underweight women.

Table 10. Crude odds ratios for risk of obstetric complications among overweight, obese, and extremely obese pregnant women who were enrolled in Kaiser Permanente Northwest during 1998 - 2001

	Crude Odds Ratio (95% CI)		
	Overweight	**Obese**	**Extremely obese**
All women	1.12 (0.99 – 1.28)	1.46 (1.28 – 1.67)	1.86 (1.48 – 2.34)
Age			
< 30	1.05 (0.88 – 1.24)	1.23 (1.04 – 1.47)	1.69 (1.25 – 2.29)
≥ 30	1.24 (1.01 – 1.53)	1.94 (1.56 – 2.41)	2.11 (1.48 – 3.01)
Tobacco use[a]			
Never	1.10 (0.94 – 1.30)	1.35 (1.13 – 1.61)	1.21 (0.87 – 1.68)
Yes	1.12 (0.80 – 1.58)	1.78 (1.29 – 2.46)	2.41 (1.43 – 4.06)
Quit	1.13 (0.84 – 1.51)	1.57 (1.17 – 2.10)	3.65 (2.31 – 5.77)

[a]Results are not shown for 74 women in the "Data missing or other" category which includes women who reported infrequent or passive tobacco exposure, were not asked by clinician about tobacco use, or had missing data on tobacco use.

Table 11. Adjusted odds ratios for risk of obstetric complications among overweight, obese, and extremely obese pregnant women who were enrolled in Kaiser Permanente Northwest during 1998 – 2001

	Adjusted Odds Ratio (95% CI)		
	Overweight	**Obesity**	**Extreme Obesity**
All women[a]	1.15 (1.01 – 1.31)	1.56 (1.36 – 1.80)	1.99 (1.57 – 2.51)
Age[b]			
< 30	1.06 (0.90 – 1.26)	1.32 (1.11 – 1.57)	1.83 (1.34 – 2.49)
≥ 30	1.13 (1.06 – 1.62)	2.04 (1.63 – 2.56)	2.31 (1.60 – 3.32)
Tobacco use[c,d]			
Never	1.15 (0.98 – 1.36)	1.44 (1.20 – 1.72)	1.30 (0.93 – 1.81)
Yes	1.10 (0.78 – 1.55)	1.91 (1.37 – 2.67)	2.58 (1.51 – 4.41)
Quit	1.14 (0.84 – 1.53)	1.63 (1.21 – 2.20)	3.81 (2.38 – 6.09)

[a] Adjusted for age, parity , number of live born infants, tobacco use
[b] Adjusted for parity , number of live born infants, tobacco use
[c] Adjusted for age, parity , number of live born infants
[d] Results are not shown for 74 women in the "Data missing or other" category which includes women who reported infrequent or passive tobacco exposure, were not asked by clinician about tobacco use, or had missing data on tobacco use.

Table 12. Crude odds ratios for risk of obstetric complications, stratified by history of pre-existing medical conditions, and cesarean delivery

	Crude Odds Ratio (95% CI)		
	Overweight	**Obese**	**Extremely obese**
Pre-existing medical condition			
Yes	1.04 (0.53 – 2.03)	1.36 (0.73 – 2.51)	1.14 (0.54 – 2.39)
No	1.12 (0.98 – 1.28)	1.45 (1.26 – 1.67)	1.93 (1.51 – 2.47)
Cesarean delivery			
Yes	1.11 (0.84 – 1.45)	1.27 (0.98 – 1.66)	1.63 (1.12 – 2.36)
No	1.10 (0.95 – 1.28)	1.46 (1.24 – 1.71)	1.77 (1.31 – 2.39)

Table 13. Analyses assessing for bias in the relationship between body mass index category and the risk of obstetric complications during labor and delivery among pregnant women enrolled in Kaiser Permanente Northwest during 1998 - 2001

Population	N	Adjusted Odds Ratio (95% CI) [a]		
		Overweight	Obesity	Extreme Obesity
Women in main analyses[b]	6,799	1.15 (1.01 – 1.31)	1.56 (1.36 – 1.80)	1.99 (1.57 – 2.51)
Women in main analyses who were continuously eligible for KPNW coverage during pregnancy[b]	5741	1.11 (0.96 – 1.29)	1.53 (1.31 – 1.78)	1.92 (1.49 – 2.47)
Women in main analyses who have a pre-pregnancy weight ≤ 60 days before pregnancy[c]	1786	0.90 (0.69 – 1.17)	1.46 (1.12 – 1.89)	2.35 (1.51 – 3.64)
All women with a prenatal weight value[d]	14,433	1.14 (1.04 – 1.24)	1.52 (1.37 – 1.69)	1.89 (1.58 – 2.26)

[a] adjusted for age, parity , number of live born infants, tobacco use
[b] BMI calculated using first prenatal weight during first 20 weeks of pregnancy
[c] BMI calculated using the latest pre-pregnancy weight for women who have a weight recorded during the 60 days prior to pregnancy
[d] BMI calculated using first prenatal weight for all women with height data and BMI category was imputed for women with no height data based on absolute weight categories

FIGURES

Figure 1. Prevalence of overweight, obesity, and extreme obesity among pregnant women enrolled in a large health maintenance organization in 1998 - 2001

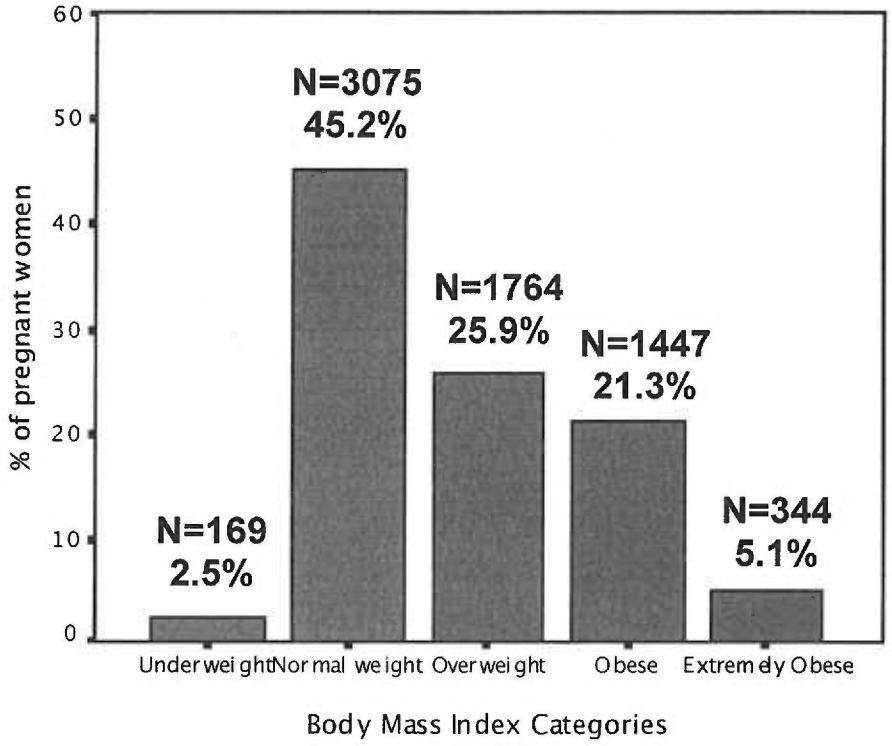

Figure 2. Proportion of women with ≥ 1 obstetric complications during labor and delivery