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ASSOCIATION BETWEEN PREPREGNANCY OBESITY AND HEALTH BEHAVIORS, ADVERSE CONDITIONS, AND BIRTH OUTCOMES IN SOUTH DAKOTA

BY

LILY SANDERSON

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Nutrition and Exercise Science

Specializing in Nutritional Sciences

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THESIS ACCEPTANCE PAGE

Lily Sanderson

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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CONTENTS

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LIST OF FIGURES

www.manaraa.com

LIST OF TABLES

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ABSTRACT

ASSOCIATION BETWEEN PREPREGNANCY OBESITY AND HEALTH BEHAVIORS, ADVERSE CONDITIONS, AND BIRTH OUTCOMES IN SOUTH DAKOTA

LILY SANDERSON

2021

Introduction: Prepregnancy obesity is associated with an increased risk for various adverse outcomes for mother and fetus. These adverse associations exist within the realms of preconception health, prenatal health, birth outcomes, and postnatal health.

Methods: This retrospective cohort study used data from the South Dakota Pregnancy Risk Assessment Monitoring System (SD PRAMS) survey, which is an ongoing state-based surveillance system of maternal behaviors, attitudes, and experiences before, during, and shortly after pregnancy. The 2017 and 2018 SD PRAMS sampled a total of 3,805 mothers who were randomly selected from birth certificate records to be representative of all South Dakota women who delivered a live-born infant. Logistic regression was used to determine whether prepregnancy obesity was associated with adverse health conditions after controlling for demographic factors.

Results: Women with prepregnancy obesity, compared to those who did not have obesity, were more likely to report an unintended pregnancy (45% vs. 39%), smoking three months before pregnancy (32% vs. 22%), delayed prenatal care (12% vs. 16%), hypertension during pregnancy (22% vs. 9%), gestational diabetes (19% vs. 8%), depression during pregnancy (21% vs. 14%), C-section delivery (35% vs. 22%), high

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birth weight (15% vs. 8%), and the infant hospitalized for 3 or more days (41% vs. 30%) (all, $p<0.05$). Of women with prepregnancy obesity, 37% had been talked to by health care providers about maintaining a healthy weight the 12 months before pregnancy compared to 13% of women without obesity.

Conclusions: Health care workers should be more intentional about stressing the potential risks of prepregnancy obesity to educate mothers and women of childbearing age.

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INTRODUCTION

Obesity is a growing epidemic worldwide, with women having a greater risk for developing obesity than men.[1] Roughly 40% of all-age adult women in the United States are classified as having obesity, and one-third of reproductive-age women are considered being overweight or having obesity.[2,3] Obesity is separated into three classes, which are based on body mass index (BMI) and are defined in Table 1. The term obesity, when used generally, refers to anyone with a BMI greater than 30, but it can be further divided into subcategories: Class I, Class II, and Class III. BMI is calculated using height and weight (weight in kg/height in m^2).

Table 1. Classification of body mass index	
Class	Body mass index (kg/m^2)
Underweight	>18.5
Normal	18.5-24.9
Overweight	25.0 – 29.9
Obese Obesity class I Obesity class II Obesity class III	≥30 30.0 – 34.9 35.0 – 39.9 ≥ 40.0

Some believe that BMI is not the best representation of health because it does not account for age, sex, bone structure, fat distribution, or muscle mass.[4] Prepregnancy obesity, defined using BMI, has been shown to increase the risk of numerous adverse health and birth outcomes that can affect the mother, fetus, and offspring later in life. It is also associated with different behaviors during and after pregnancy. The following review of literature related to prepregnancy obesity and increased risk for adverse pregnancy outcomes will dive into the findings of various research studies and

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demonstrate the association between prepregannncy obesity and adverse outcomes within the realms of preconception health, prenatal health, birth outcomes, and postnatal health.

While the exact cause of obesity is not completely known, it is likely a combination of factors such as lifestyle choices, diet, physical activity, certain health conditions, and genetics. Obesity can lead to an increased risk for developing a plethora of health conditions including hypertension, dyslipidemia, heart disease, stroke, type 2 diabetes, gallbladder disease, osteoarthritis, sleep apnea, respiratory problems, and certain types of cancer.[5] While BMI is used as an indicator of obesity, it is not the only indicator. Body fat distribution, whether visceral or subcutaneous, also affects the risks for certain health conditions. Visceral distribution is fat that is concentrated around the abdominal region, while subcutaneous fat is distributed throughout the rest of the body including the arms, legs, hips, thighs, and chest. Visceral body fat is more associated with the presence of adverse metabolic health conditions than subcutaneous body fat.[6]

Weight gain during pregnancy also has implications for the health of the mother and fetus. Table 2 shows the Institute of Medicine's (IOM) weight gain recommendations for pregnant women based on their BMI before pregnancy. These guidelines aim to optimize the outcomes for mother and baby. Regardless of prepregnancy BMI, reduced weight gain is associated with a low Apgar score. For normal-weight women, less weight gain than is recommended by the IOM is related to low birth weight, and excessive weight gain is associated with gestational hypertension and birth weight >4000 grams.[7,8] For pregnant women with obesity, there were additional adverse associations with excessive weight gain including neonatal metabolic abnormalities and tendency for a caesarian section delivery. However, when women across all BMI categories gain the

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recommended amount of weight or slightly less, there is a decreased likelihood of adverse outcomes.[8] There is some evidence to suggest that women who are overweight or have obesity before pregnancy and gain less than the recommended amount of weight experience less postnatal weight retention and do not see an increased rate of low birth weight infants.[9]

Table 2. Gestational weight gain guidelines in pounds based on Institute of Medicine recommendations[11010101010]

Prepregnancy BMI	Inadequate	Recommended	Excessive
Underweight (<18.5)	<28	28-40	>40
Normal weight (18.5-24.9)	<25	25-35	>35
Overweight (25-29.9)	<15	15-25	>25
Obese (>30)	<11	11-20	>20

1. *Pregnancy: Reexamining the Guidelines*, K.M. Rasmussen and A.L. YaktinEditors. 2009: Washington (DC).

i. Preconception health

Obesity not only affects the pregnancy, but also the period before becoming pregnant, referred to as preconception. Preconception care is a vital part of any pregnancy, regardless of maternal weight. It has been shown to reduce the risk of preterm birth, low birth weight, maternal complications, and fetal complications.[10] A large part of preconception care revolves around education about pregnancy and the best practices for a healthy pregnancy. A healthcare professional can identify biomedical, behavioral, and social risks that may affect the pregnancy negatively and find solutions or modifications to help lessen that risk. Adequate preconception care initiates early folic acid

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supplementation and addresses preexisting health problems that could affect the pregnancy. This could include health counseling where a healthcare professional asks a series of questions about pregnancy knowledge or lifestyle factors. A physician specializing in women's health and pregnancy is called an obstetrician gynecologist (OBGYN) and a physician specializing in high-risk pregnancies is a perinatologist. A health care provider will discuss the pregnancy with the patient and provide education on how to cultivate a safe environment for a healthy pregnancy. According to the South Dakota Pregnancy Risk Assessment Monitoring System, of women who gave birth, 16% of women reported speaking with a healthcare provider about a healthy pregnancy during the year before becoming pregnant.[11] In a separate study of only overweight women and women with obesity, 10% of women with a planned pregnancy reported going to a preconception care visit and talking to their healthcare provider about their weight during the visit. Because the percent is so low, it is possible that women who are overweight or have obesity planning to get pregnant are unaware of the risks specifically associated with prepregnancy obesity due to a lack of knowledge before becoming pregnancy.[12]

In women of childbearing age, only 18% of pregnant women reported receiving diet or physical activity counseling during any preconception care visit.[13] Additionally, women who were seen by an OBGYN were 44% less likely to receive diet or physical activity counseling than those who met with a non-OBGYN provider.[13] This may seem counterintuitive, but it could be due to the fact that the majority of appointments with an OBGYN are dedicated to education on the pregnancy rather than topics not directly related to pregnancy such as general health counseling. However, at a non-OBGYN visit, healthy lifestyle practices may be a more common topic because the visits are typically

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centered around the health of the woman first rather than pregnancy. One study found that 67% of women saw a OBGYN before their pregnancy.[14] Most women trying to get pregnant choose to see an OBGYN, so they may be less likely to receive counseling on diet and physical activity. This poses a risk for women who are overweight or have obesity that could benefit from healthy lifestyle counseling, as they are at an increased risk for adverse pregnancy outcomes.

ii. Prenatal health

Prepregnancy obesity has a sizable effect on the mother throughout all stages of pregnancy, starting with the ability to conceive. As body mass index (BMI) rises above 29 kg/m^2, the likelihood of becoming pregnant decreases.[1] As BMI increases, the lower the chance of sperm implantation and pregnancy and the higher the chance of ectopic pregnancy and miscarriage.[15] Because the exact mechanism of how obesity affects the reproductive system is quite complex and multifactorial, it is still being studied, but some theories exist. Women with obesity experience hyperandrogenemia from insulin resistance and increased leptin release, which leads to augmented male sex hormone release, such as testosterone, in those women.[16] Additionally, anovulation, changes in adipokine levels, and the deterioration of the hypothalamic-pituitary-gonadal axis due to hormonal and some substrate changes all play an important role in reproductive development and regulation, which ultimately affect the likelihood of pregnancy.[16]

Risky health behaviors such as smoking, drinking, and drug use increase the risk of health complications for mother and baby during pregnancy including preterm birth, still birth, miscarriage, maternal mortality, neonatal abstinence syndrome, low birth weight, birth defects of the mouth and lip, sudden infant death syndrome (SIDS), and

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fetal alcohol spectrum disorders.[17,18] Women with obesity are not reportedly more likely to smoke, drink alcohol, or use drugs during pregnancy than those without obesity. While there is an association with smoking and lower BMI in non-pregnant women, this is not reported in pregnant women.[19,20]

Various maternal complications during pregnancy increase when combined with being overweight or having obesity such as hypertensive disorders of pregnancy, which include high blood pressure, preeclampsia, and eclampsia. Obesity is strongly associated with the risk of developing preeclampsia.[21-26] This is potentially due to the presence and location of excess adipose tissue. These are important factors to consider because cardiovascular complications are more often associated with abdominal or visceral obesity rather than peripheral obesity.[27] Visceral fat which is stored in the abdominal cavity and contributes to central obesity, produces more CRP and inflammatory cytokines and contributes more to oxidative stress than subcutaneous fat, which is typically found in the hips, arms and legs.[21] Measuring body composition rather than BMI is a more accurate indicator for the risk of developing preeclampsia because BMI does not take into account several factors such as distribution of adipose tissue, muscle mass, or bone mass.[5] However, even though higher muscle mass is not associated with an increased risk for hypertensive disorders during pregnancy, it does increase BMI. But, because there is a such a strong association between generalized obesity and the risk of developing hypertensive disorders during pregnancy, the ease of using BMI may outweigh the proposed increased accuracy of measuring body composition.

Along with hypertensive disorders during pregnancy, women with obesity are at increased risk of developing gestational diabetes mellitus (GDM). When a person has

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obesity, their body naturally releases more pro-inflammatory cytokines than a person of normal weight due to the increased inflammation caused by the presence of excess adipose tissue. The insulin resistance we see with diabetic disorders is associated with the abnormal secretion of pro-inflammatory cytokines and decreased secretions of anti-inflammatory cytokines, and because proinflammatory cytokines interfere with insulin signaling, the body's natural ability to self-regulate blood glucose levels may be impaired.[28] This could be why various studies have found that women who are overweight or have obesity have an increased risk of developing GDM.[22-26] As BMI increases through the stages of obesity, the likelihood of developing gestational diabetes also increases.[23] GDM heightens the risk for several adverse health and birth outcomes including premature birth, birth trauma, macrosomia, respiratory distress, impaired glucose tolerance in mother and offspring, development of maternal type 2 diabetes mellitus after pregnancy, and increased adiposity in offspring during childhood.[28-30]

Physical complications are not the only adverse effect associated with prepregnancy obesity. In the general population, obesity is associated with multiple mental disorders, including depression, compared to those without obesity.[31] While obesity and major depressive disorder are independently associated with a lower quality of life, major depressive disorder combined with obesity is associated with an even lower mental and physical quality of life than the conditions separately.[32] Depression during and after pregnancy are more common among mothers with obesity than mothers without.[24,26] Perinatal and postnatal depression can make pregnancy more stressful and negatively impact the mother's experience throughout and following the pregnancy. Postnatal depression can lead to a decrease in self-care, poor nutrition, breastfeeding

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cessation, weight gain, relationship problems, and trouble bonding or forming an emotional connection with her baby.[33,34] Breastfeeding cessation can reduce the likelihood of receiving the various benefits of breastfeeding for infant and mother.[35]

iii. Birth outcomes

Various adverse birth outcomes are associated with maternal prepregnancy obesity. Obesity adversely influences the likelihood of a healthy, normal, full-term birth. While not as common as is with underweight mothers, the prevalence of preterm birth and very-preterm birth increases, especially within the highest BMI categories.[24,36] Preterm and very preterm births negatively affect the health of an infant. The baby has not gone through the full gestational period and may not have developed enough to function properly after being born without further assistance and/or monitoring.

One birth complication associated with obesity is the need for a manual placental extraction. While this typically does not cause any direct issues, it does increase the risk of postpartum hemorrhage, which can cause further maternal complications.[22] Another adverse birth outcome associated with prepregnancy obesity is the increased risk for a caesarian section delivery. While it is a common procedure, a caesarian section delivery is a major surgery and should be treated as such. The risk for a c-section delivery increases significantly with the presence of prepregnancy obesity.[22-25] There are greater risks, especially for the mother, with this type of delivery. The risk of maternal mortality is 3 times greater with a caesarian section delivery compared to a vaginal delivery. The most common causes of maternal death are complications of anesthesia, puerperal infection, or venous thromboembolism.[37] Women with obesity, especially those categorized with class III obesity, are also at an increased risk of problems with wound

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healing and wound infection following a c-section delivery.[23,38] Additionally, the mother is not the only one at a greater risk for adverse outcomes resulting from c-section delivery. There is evidence suggesting that children who were born by caesarian section delivery, planned or unplanned, are more likely to have obesity and type 2 diabetes later in life compared to those who were born vaginally.[39,40] It is unclear exactly why women with obesity have caesarian section deliveries more often than those without obesity, but it may be related to the higher proportion of large-for-gestational age babies born to women with prepregnancy obesity, which are generally harder to birth vaginally than those with a normal birth weight.

Prepregnancy obesity does not only increase the risk for maternal complications but can also affect the fetus and infant. One of the most strongly associated conditions related to maternal obesity is macrosomia, which is defined as an abnormally large infant who weighs more than 4000g at birth.[22-24] All classes of obesity increase the likelihood of a macrosomic birth, but there is a linear relationship with the likelihood of a macrosomic birth as BMI increases above 29.9 kg/m^2.[36] A macrosomic birth is associated with an increased maternal risk for prolonged labor, instrumental delivery, failed instrumental delivery, emergency c-section, postpartum hemorrhage, and obstetrical anal sphincter injuries. A macrosomic birth is also associated with increased neonatal risks for shoulder dystocia, obstetrical brachial plexus injury, birth fractures, asphyxia, and hypoglycemia.[41] The specific mechanisms by which obesity is associated with abnormal birth is unknown, but there is some evidence to support the theory that chronic inflammation, oxidative stress, insulin resistance, and blood glucose levels related to maternal obesity create an environment that can lead to abnormal fetal growth.[42]

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Low birth weight (<2500g, LBW) and very low birth weight infants (<1500g, VLBW) are also associated with prepregnancy obesity, however, this may be largely due to preterm birth.[24,36] Many complications of LBW and VLBW are similar to complications of preterm birth. Small-for-gestational-age (SGA), however, is not affected by preterm birth because it is already accounted for in this variable. There is no strong evidence to suggest that SGA is associated with prepregnancy obesity, but that is not true of intrauterine growth retardation (IUGR). Some health professionals believe that SGA and IUGR are interchangeable terms, but they are different. SGA assesses development based on birth weight, whereas IUGR analyzes measurements during the gestational period without considering birth weight to assess fetal development. IUGR has been found to be associated with maternal obesity and can increase the risk for various complications.[43] Perinatal and postnatal complications associated with IUGR include prenatal mortality, c-section delivery, abnormal fetal heart rate, oligohydramnios, periventricular leukomalacia, meconium obstruction, and convulsions. Several long-term outcomes also associated with IUGR include neurodevelopmental impairment, mild disability, severe disability (including cerebral palsy), motor, speech, cognition, and vision impairments, and growth delay.[44]

While the risks linked to abnormal birth weight are typically manageable, prepregnancy obesity is also associated with more serious adverse fetal outcomes. The risk of stillbirth increases with the presence of maternal obesity and continues to increase linearly as BMI rises to and past the severe obesity classification (>34.9 kg/m^2), regardless of the timing or specific cause of stillbirth. Prepregnancy obesity is also associated with stillbirth accompanied by various conditions or anomalies including

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maternal hypertension, placental disease, fetal, genetic, or structural defects, umbilical cord abnormalities, and antepartum infection.[45]

iv. Postnatal health:

Breastfeeding an infant presents many benefits including improved ability to fight infections and reduced risk of adverse health conditions later in life. More specifically, evidence suggests that exclusive breastfeeding compared to exclusive formula feeding reduces the risk of several conditions for the infant including ear infection, atopic dermatitis, eczema, respiratory tract infections, SIDS, gastrointestinal tract infections, asthma, celiac disease, and type 1 diabetes.[35,46] It is also associated with beneficial outcomes later in life including decreased childhood, adolescent, and adult obesity rates, reduced risk of certain cancers, and favorable neurodevelopmental outcomes.[46] After birth, mothers with prepregnancy obesity are less likely to initiate and continue breastfeeding than mothers with a normal BMI.[23,35,47-51] Various proposed reasons exist for the reduced prevalence of breastfeeding initiation and continuation in mothers with obesity compared to those without obesity such as physical difficulties like enlarged areolas and excess breast tissue, discomfort with breastfeeding in public because of poor body image, delayed onset of lactation, and hormone imbalances due to the presence of obesity.[50-53]

Maternal prepregnancy obesity is also related to adverse outcomes for offspring after birth and throughout their lifetime. Maternal obesity is associated with an increased prevalence of obesity in childhood, adolescent, and adult offspring.[54,55] Childhood obesity is a precursor and early modifiable risk factor to various metabolic health conditions such as type 2 diabetes and metabolic syndrome.[56] It also greatly affects a

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child's ability to have a healthy, normal childhood by negatively influencing physical, social and emotional wellbeing, self-esteem, academic performance, and overall quality of life.[57] Children with obesity are also at an increased risk for developing impaired glucose tolerance before adulthood, which is a risk factor for type 2 diabetes,.[58]

Along with obesity, there is an association between maternal prepregnancy obesity and the development respiratory conditions including diagnosed asthma and wheezing.[59] As previously discussed, the release of the hormone leptin is increased in those with obesity, and it is thought that excess leptin interferes with respiratory function and could be associated with various respiratory diseases.[59] It is unclear if the excessive release of this hormone in women with prepregnancy obesity independently affects the secretion in offspring. However, because mothers with prepregnancy obesity are more likely to have offspring that develop obesity, they may be more prone to a higher release of leptin because of the presence of obesity compared to offspring whose mother did not have prepregnancy obesity.

Because women are at a greater risk for obesity than men, the relationship between obesity and pregnancy must be given special attention.[3] The purpose of the following analysis is to determine the prevalence of obesity before pregnancy among South Dakota women who gave birth in 2017-2018, determine the association between prepregnancy obesity and various health behaviors and conditions during and after pregnancy, and determine how often mothers reported that their health care providers had talked to them about appropriate weight.

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METHODS

Data from the 2017 and 2018 South Dakota Pregnancy Risk Assessment Monitoring System (PRAMS) surveys were used in the current analysis. PRAMS is a population-based surveillance system from the Centers for Disease Control and Prevention (CDC) that was implemented in South Dakota in conjunction with the South Dakota Department of Health and the EAM Program at South Dakota State University. The methodology for the CDC PRAMS is described elsewhere.[60] In South Dakota, American Indian mothers and mothers of other races are oversampled in order to obtain prevalence estimates within these race strata. Mothers are asked to complete a survey about experiences and maternal behaviors before, during, and after pregnancy to learn more about the health of women and infants in South Dakota. In the 2017 PRAMS, 2,028 mothers were sampled with a weighted response rate of 67%, whereas in the 2018 PRAMS, 1,777 mothers were sampled with a weighted response rate of 64%.

Obesity was defined as having a BMI equal to or greater than 30 kg/m^2. BMI prior to pregnancy was obtained through information provided on the mother's birth certificate. Various demographic factors, also obtained from the birth certificate, that may be associated with the prevalence of obesity were taken into consideration including maternal age, race/ethnicity, education, and marital status. Health behaviors included substance use, prenatal care, emotional abuse, and breastfeeding and were obtained from the survey. Health outcomes, obtained from birth certificates, included gestational hypertension and diabetes, depression, c-section delivery, birthweight, preterm birth, and NICU admission. Topics covered by a health care provider included improving health

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before pregnancy, maintaining a healthy weight before pregnancy, and weight gain during pregnancy.

Data were analyzed using procedures for complex survey analyses within the SAS® software (SAS® Institute, Cary, NC), which incorporates the sampling design, non-response, and non-coverage weights. Weighting allows for the calculation of population-based statewide and race-specific rates representing live births to eligible South Dakota mothers in 2017 and 2018. A further description of weighting can be found elsewhere.[61] The significance of factors associated with prepregnancy obesity was calculated using the Rao-Scott chi-square test. Logistic regression was used to determine the association between prepregnancy obesity and outcomes after controlling for demographic factors (age, race/ethnicity, education, marital status) and adjusted odds ratios (adjOR) were determined. IRB approval was obtained through the South Dakota State University Institutional Review Board, and participation in the survey was voluntary.

RESULTS

According to the SD PRAMS data, 24.7% of South Dakota women who had obesity before pregnancy (Table 3). American Indian mothers had higher obesity rates than white, non-Hispanic mothers and other races. There was no difference in the obesity rates between white, non-Hispanic women and women of other races. No other demographic factors were significantly associated with obesity prior to pregnancy. Although age was not significantly associated with obesity, those who were less than 20 years old had the lowest rate.

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Table 3. Obesity rates by demographic characteristics of mothers responding to the survey

	N	Obese	Non-obese	P-value*
Statewide	2,124	24.7 (22.6-26.8)	75.3 (73.2-77.4)	
Race				<0.001
White, non-Hispanic [a]	886	23.1 (20.3-25.8)	76.9 (74.2-79.7)	
American Indian [ab]	675	34.1 (30.6-37.6)	65.9 (62.4-69.4)	
Other races [b]	563	20.6 (17.6-23.6)	79.4 (76.4-82.4)	
Age (years)				0.15
Less than 20	132	18.1 (10.6-25.5)	81.9 (74.5-89.4)	
20-24	437	22.8 (18.1-27.4)	77.3 (72.6-81.9)	
25-29	702	27.2 (23.4-31.0)	72.8 (69.0-76.6)	
30-34	611	22.8 (19.1-26.4)	77.2 (73.6-80.9)	
Greater than 35	242	28.6 (22.3-34.9)	71.4 (65.1-77.7)	
Education				0.27
Less than high school	419	24.7 (19.9-29.5)	75.3 (70.5-80.1)	
High school	511	27.8 (23.1-32.4)	72.2 (67.6-76.9)	
Greater than high school	1,183	23.6 (20.9-26.2)	76.4 (73.8-79.1)	
Marital Status				0.19
Married	1,199	23.6 (21.0-26.3)	76.4 (73.7-79.0)	
Not married	925	26.6 (23.2-30.0)	73.4 (70.0-76.8)	

Prepregnancy BMI not available for 24 mothers (2,148 completed surveys in 2017 & 2018, but only 2,124 included in these analyses).
Data are weighted percentages (95% confidence intervals). Similar superscripts indicate significant difference between categories.
*Trend analysis also was completed for age and education and the conclusions did not differ.

Mothers who had obesity prior to pregnancy, were more likely to report smoking three months before pregnancy and never breastfeeding, and less likely to have delayed or no prenatal care compared to mothers without obesity (all, $p<0.05$; Table 4). A slightly higher percent of mothers with obesity, compared to mothers without obesity, had unintended or mistimed pregnancy and illicit drug use the month before pregnancy but these were not statistically significant (both, $p=0.06$). Increased occurrence of health conditions and birth outcomes among mothers who had prepregnancy obesity included hypertension and depression during pregnancy, gestational diabetes, C-section delivery, high birth weight, and their infant being hospitalized for three or more days. After

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controlling for race, almost all associations remained significant (Figure 1), except never breastfeeding which was no longer associated with obesity (adj OR=1.33, 95% confidence interval 0.90-1.96; p=0.16) and women who had obesity prior to pregnancy had higher odds of reporting an unintended or mistimed pregnancy (adj OR=1.27, CI 1.00-1.62, p =0.05). Interpretation of the results for all behaviors and outcomes did not change when logistic regression analyses were repeated including all demographic characteristics.

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Table 4. Weighted Percentages for Risk Behavior or Outcome by Obesity Status Prior to Pregnancy

	Mother Obese Prior to Pregnancy			
Behavior or Outcome	No	Yes	P-Value*	P-Value**
Health Behaviors				
Unintended or mistimed pregnancy[1]	38.9 (36.2-41.8)	44.6 (39.7-49.5)	0.06	0.05
Not insured before pregnancy[1]	11.8 (10.1-13.7)	13.2 (10.3-16.8)	0.47	0.47
Smoke 3-months before pregnancy[1]	21.5 (19.3-23.9)	31.5 (27.2-36.2)	<0.001	0.007
Smoke last 3-months of pregnancy[1]	9.4 (7.9-11.3)	10.9 (8.3-14.2)	0.40	0.88
Alcohol 3-months before pregnancy[1]	65.2 (62.6-67.8)	64.7 (60.1-69.1)	0.86	0.11
Alcohol last 3-months of pregnancy[1]	8.3 (6.8-10.1)	8.1 (5.8-11.3)	0.89	0.97
Illicit drugs the month before pregnancy[1]	7.7 (6.4-9.2)	10.7 (8.1-13.8)	0.06	0.31
Delayed or no prenatal care[2]	16.0 (14.1-18.2)	11.9 (9.3-15.0)	0.04	0.01
Attended <80% of prenatal care visits[2]	15.5 (13.7-17.4)	16.3 (13.4-19.8)	0.66	0.46
Emotional abuse during pregnancy[1]	6.2 (5.0-7.7)	6.9 (5.0-9.5)	0.63	0.74
Never breastfed[1]	8.5 (7.2-10.1)	12.3 (9.5-15.9)	0.03	0.16
Health Conditions				
Hypertension during pregnancy[1]	9.3 (7.7-11.2)	21.8 (17.9-26.2)	<0.001	<0.001
Depression during pregnancy[1]	14.0 (12.1-16.2)	21.0 (17.3-25.2)	0.001	<0.001
Gestational diabetes[1]	7.9 (6.5-9.5)	18.6 (15.2-22.6)	<0.001	<0.001
Symptoms of postpartum depression[1]	13.3 (11.5-15.2)	14.8 (11.8-18.5)	0.44	0.75

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Birth Outcomes				
C-Section delivery[2]	21.5 (19.2-23.9)	35.4 (30.9-40.2)	<0.001	<0.001
Low birth weight (<2500 g)[2]	5.7 (4.6-7.1)	5.0 (3.3-7.5)	0.60	0.61
High birth weight (>4000 g)[2]	7.9 (6.5-9.7)	14.8 (11.8-18.5)	<0.001	<0.001
Preterm birth[1]	8.0 (6.6-9.6)	8.8 (6.5-11.7)	0.62	0.75
NICU admission[2]	8.6 (7.1-10.4)	8.1 (5.9-10.9)	0.73	0.69
Infant in hospital 3 days or longer[1]	30.0 (27.5-32.7)	40.8 (36.1-45.7)	<0.001	<0.001
* P-value based on Rao-Scott chi-square test; ** p-value based on logistic regression controlling for maternal race.[1] Based on data obtained from PRAMS survey; [2]obtained from vital records				

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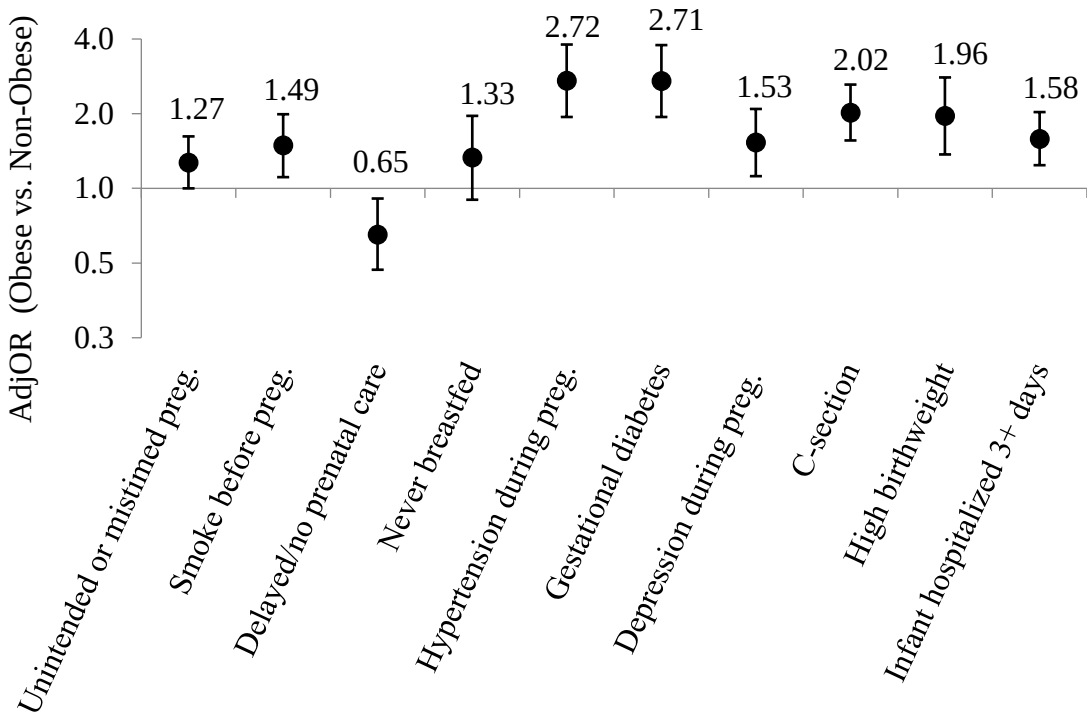
Figure 1. Health Behaviors and Outcomes Among Women Who Had Obesity Prior to Pregnancy Compared to Women Who Did Not Have Obesity After Controlling for Race



Scatter plot of adjusted odds ratios (AdjOR) and 95% confidence interval of different health behaviors and outcomes among women who had obesity prior to pregnancy compared to women without obesity after controlling for race. All had p-values < 0.05.

Twelve months before pregnancy, a greater percent of women with obesity reported being talked to by a health care provider about maintaining a healthy weight compared to women without obesity (37% vs. 13%, respectively; $p<0.05$), but only 18% of mothers with obesity and 16% of mothers without obesity reported being talked to about how they could improve their health before pregnancy (not significant). During prenatal visits, 66% of mothers who had obesity prior to pregnancy reported being talked to by a health care provider about how much weight they should gain during pregnancy which did not differ from the 64% of mothers without obesity (Figure 2).

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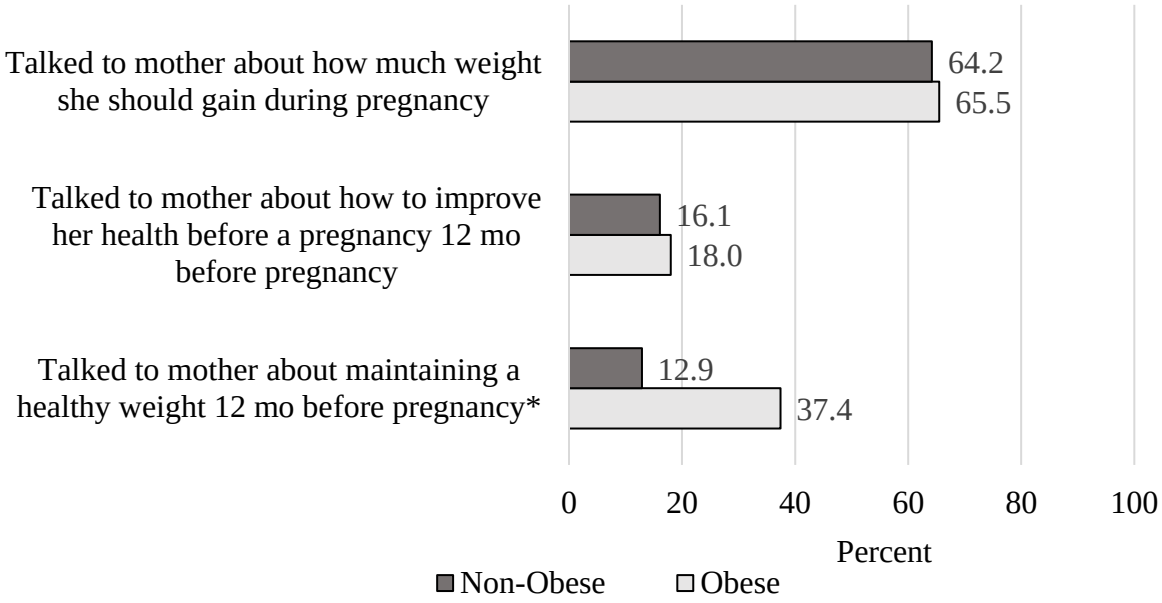
Figure 2. Women Who Talked with a Health Care Provider About Topics Related to Health and Weight Before and During Pregnancy by Prepregnancy Obesity Status



Percent of women who talked with a health care provider about topics related to health and weight before and during pregnancy by prepregnancy obesity status. *p ≤ 0.05 based on Rao-Scott chi-square

DISCUSSION

One quarter of South Dakota mothers delivering an infant in 2017 and 2018 had obesity prior to pregnancy. This report demonstrated several relationships between prepregnancy obesity and adverse health behaviors or outcomes for these mothers. Mothers with prepregnancy obesity, compared to mothers who did not have obesity, had greater odds of maternal behaviors such as unintended or mistimed pregnancy and smoking during pregnancy. Alternately, we found lesser odds of delayed or no prenatal care. This could be due to an increase in comorbidities that already exist or because these women are at an increased risk for adverse health conditions during pregnancy. Health

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conditions or birth outcomes that had greater odds for mothers who had prepregnancy obesity included hypertension and depression during pregnancy, gestational diabetes, c-section delivery, macrosomia, and infant hospitalization of three days or longer. Hypertension during pregnancy, gestational diabetes, and C-section delivery were all outcomes that were more than twice as likely to occur among mothers who had obesity prior to pregnancy compared to mothers who were not.

Our findings confirm previous research. Prepregnancy obesity has been shown to be associated with a higher risk for preeclampsia/hypertension during pregnancy, gestational diabetes,[22-24,26,62] depression during pregnancy,[24,26] C-section delivery,[22-24,36,62] fetal macrosomia,[22-24,36] prolonged hospital stay,[23] and never breastfeeding.[45] Other factors we analyzed that were not associated with prepregnancy obesity included lack of insurance before pregnancy, smoking during pregnancy, alcohol use before or during pregnancy, emotional abuse during pregnancy, low birth weight, preterm birth, NICU admission, and postpartum depression. Other studies found significant relationships with several of those outcomes including smoking during pregnancy,[62] alcohol use during pregnancy,[26] preterm birth,[24,36,62] low birth weight,[24] and NICU admission.[23,24,45] A significant relationship between smoking three months prior to pregnancy and prepregnancy obesity was unique to our analysis. Differences in findings may be due to sampling or analysis procedures, population differences, number of participants, or study location.

Obesity prior to pregnancy leads to an increased risk of maternal and fetal adverse birth outcomes. The metabolic changes that are associated with obesity affect both the mother and growing fetus. These changes most likely influence the development or

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prevalence of adverse pregnancy and birth outcomes. The exact mechanism by which obesity affects a fetus is unknown, but there are several theories. Oxidative stress related to obesity can damage cells, tissue, or organs. Increased inflammation, blood glucose levels, and blood pressure among women with obesity are believed to affect a woman and her fetus during pregnancy to some extent.[63] Pro-inflammatory cytokines related to obesity interfere with insulin signaling, which can increase insulin resistance. Insulin resistance plays a role in the increased risk of preeclampsia and gestational diabetes development.[21,28] The presence and location of excess adipose tissue has been linked to a higher risk of adverse health outcomes. Adipose tissue produces leptin, which is proposed to increase blood pressure. Increased blood pressure during pregnancy increases the risk for adverse health outcomes. Some investigators propose that adipose tissue distribution is a stronger determinant of adverse effects during pregnancy than its presence alone, with central adiposity presenting a much higher risk for adverse outcomes than peripheral adiposity.[21]

To decrease the prevalence of prepregnancy obesity-related complications, preconception care should stress the importance of having a healthy BMI prior to pregnancy and educating women on the risks associated with having obesity prior to pregnancy. Because the rate of unintended pregnancy is 44% for South Dakota women, all reproductive-age women, regardless of intent, should be aware of the pregnancy-related risks associated with having obesity. Health care providers can offer education on these risks to women. Health care providers in South Dakota talked to some women about the importance of maintaining a healthy weight before pregnancy, improving health before pregnancy, and healthy weight gain during pregnancy. Our study found that

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women who had obesity prior to pregnancy were more likely to talk with a health care provider 12 months before pregnancy about maintaining a healthy weight compared to women without obesity. Table 2 shows the Institute of Medicine's recommendations for healthy weight gain during pregnancy by BMI. Women with obesity should gain between 11-20 pounds for a singleton birth, yet only 66% of South Dakota women who had obesity prior to their pregnancy reported talking to a health care professional about how much weight they should gain during pregnancy. This illustrates an area where education on the part of the health care provider could be improved for all pregnant women, with obesity or without. Based on the results of this paper, including a section related to the maternal and fetal risks associated with prepregnancy obesity in the Department of Health's "Adult Obesity Provider Toolkit" would offer an additional tool for health care providers to educate women further about the risks associated with prepregnancy obesity. Increased patient education could reduce the occurrence of associated comorbidities and improve the overall health of women and babies in South Dakota. Updating the toolkit also would provide an opportunity for follow-up research regarding the effect of increased patient education on the prevalence of adverse health conditions or birth outcomes related to prepregnancy obesity.

There are several limitations to this study. The SD PRAMS response rates were 67% in 2017 and 64% in 2018. These are relatively high response rates and currently the CDC PRAMS sets the cut-off for inclusion of state survey results in the national data base at a 50% response rate. Additionally, methods are employed to weight the data for non-response in order to minimize potential bias. Data from the PRAMS survey were self-reported, so recall bias or self-reporting bias may exist. The surveys are sent to the

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mothers at two months postpartum and could be completed between two and six months, so recall of previous actions or behaviors is necessary. This is especially true for recalling topics that were discussed at health visits both before and during pregnancy. It is likely that recall becomes more difficult the further from the birth of the infant the survey is completed. Symptoms of postpartum depression is estimated based on how often the mother felt down, depressed or hopeless and whether they had interest or pleasure in doing things in life that they usually enjoy since the birth of their infant, rather than on a clinical diagnosis of postpartum depression.

This study highlights the various risks associated with prepregnancy obesity among South Dakota mothers delivering an infant in 2017 and 2018. These findings emphasize the need for obesity education and prevention in women of child-bearing age, and we will be able to anecdotally determine whether there is a change in health behaviors and outcomes following changes in state-provided educational materials. An opportunity for future research includes further separating obesity into categories of increasing BMI, because the risk of some adverse outcomes increases as BMI increases. Ratnasiri et al. concluded that as BMI progressed through obesity classes I, II, and III, the risk of those outcomes increased almost linearly[36]. With more years of data collection, South Dakota PRAMS should be able to investigate these types of relationships in greater detail, as well as investigate trends over time.

CONCLUSION

Based on current research, maternal prepregnancy obesity is a relevant health risk to mothers, infants, and offspring later in life, especially with the increasing rate of obesity in the United States. Various studies found that prepregnancy obesity increases

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the risks for adverse maternal and fetal outcomes, while concurrently being associated with a higher likelihood of less desirable maternal behaviors and poor childhood outcomes. The unique research in this thesis concurs with most previous findings including an increased risk for preeclampsia/hypertension during pregnancy, gestational diabetes, depression during pregnancy, C-section delivery, fetal macrosomia, prolonged hospital stay, and never breastfeeding. An association present in this study that was not apparent in others was smoking before pregnancy. This study also identified an increased likelihood that a mother with prepregnancy obesity was more likely to have been talked to by their healthcare provider about maintaining a healthy weight before pregnancy. More specifically, this study identified a relationship between prepregnancy obesity and the need for research and intervention practices to help decrease the number of those who have obesity when becoming pregnant which is vital to the health and wellbeing of mothers, infants, and children across the nation. Working to educate women of child-bearing age more effectively about the risks of prepregnancy obesity may help reduce the prevalence of adverse health and birth outcomes for women and infants.

Conflict of Interest: None of the authors have a conflict of interest.

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