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Interpregnancy weight change and adverse maternal outcomes: a retrospective cohort study

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Abstract

Purpose—Examine associations between interpregnancy BMI change and gestational diabetes mellitus (GDM), pre-eclampsia (PE), gestational hypertension (GHtn), primary cesarean delivery, and vaginal birth after cesarean delivery (VBAC).

Methods—Modified Poisson regression models estimated adjusted associations.

Results—Every one unit increase in interpregnancy BMI increased risks of GDM (RR: 1.09, 95%CI: 1.07–1.11), PE (RR: 1.06, 95%CI: 1.04–1.09), GHtn (RR: 1.08, 95%CI: 1.06–1.10), and primary cesarean delivery (RR: 1.03, 95%CI: 1.01–1.05) and decreased the risk of a successful VBAC (RR: 0.98, 95%CI: 0.97–0.997) in the second pregnancy. A BMI increase 3 units increased risks of GDM (RR: 1.71, 95%CI: 1.52–1.93), PE (RR: 1.60, 95%CI: 1.33–1.94), GHtn (RR: 1.66, 95%CI: 1.42–1.94), and primary cesarean delivery (RR: 1.29, 95%CI: 1.12–1.49) and decreased the risk of a successful VBAC (RR: 0.89, 95%CI: 0.80–0.99) compared to women with interpregnancy BMI change within –1 and +1 unit. GDM was also increased among women increasing their BMI by 2 but <3 units (RR: 1.40, 95%CI: 1.21–1.61) and among those gaining 1 but <2 units (RR: 1.23, 95%CI: 1.08–1.40).

Conclusion—An interpregnancy BMI increase 3 units is associated with an increased risk of all outcomes. These findings emphasize the importance of interpregnancy weight management.

MeSH Keywords

cesarean section; gestational diabetes; gestational hypertension; body mass index; pre-eclampsia; vaginal birth after cesarean

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INTRODUCTION

Nearly 56% of reproductive aged women (20–39 years old) are overweight or obese.¹ Obesity during pregnancy is associated with a high risk of adverse maternal outcomes.² Less is known about how weight change between two consecutive pregnancies, hereafter known as interpregnancy body mass index (BMI) or weight change, impacts subsequent risk of pregnancy complications. In 2012, 41.6% of 15–50 year old women in the US reported having at least two children.³ As such, investigating the association between interpregnancy weight change and pregnancy/delivery complications is important.

Seminal evidence for the impact of interpregnancy weight change on maternal health (pre-eclampsia (PE), gestational hypertension (GHtn), gestational diabetes mellitus (GDM), and cesarean delivery) comes from a study by Villamor and Cnattingius,² which utilized data from the Swedish Birth Register (n=151,025 women). Subsequent studies^{4–14} supported the findings from this study, showing a positive association between an increase in interpregnancy BMI and the risk of adverse maternal health outcomes. These studies have been conducted in the US utilizing vital records data from Missouri^{4–9} or Washington.^{10,11} Vital records, however, underreport the incidence of maternal complications compared to medical records.^{15–18} To our knowledge, only one US study from Northern California has been conducted using medical records to examine the association between interpregnancy weight change and GDM (n=22,351).¹² Other hospital-based cohort studies with larger sample sizes have been conducted in Belgium¹³ and Scotland.¹⁴

Given the limited number of US studies using medical record data, we examined the association between interpregnancy BMI change and adverse maternal outcomes including: GDM, PE, GHtn, primary cesarean delivery, and vaginal birth after cesarean delivery (VBAC) using data from the National Institute of Child Health and Human Development (NICHD) Consecutive Pregnancies Study, which captured women with at least two consecutive pregnancies.¹⁹

MATERIALS AND METHODS

Study population

The NICHD Consecutive Pregnancies Study enrolled 51,086 women, regardless of their parity, with at least two pregnancies (range 2–6 pregnancies) who delivered between 2002 to 2010 from 20 hospitals (Appendix Table 1) in Utah.¹⁹ This resulted in 114,679 pregnancies (livebirths or stillbirths > 20 weeks' gestation). Data sources included electronic medical records (EMR) and ICD-9 codes collected from maternal and newborn discharge summaries and linked to each delivery. Extensive information on maternal demographic, reproductive and medical history, pregnancy complications, labor and delivery information, and neonatal outcomes were available. All study sites had study approval and waiver of informed consent from their individual institutional review boards.

Data exclusions

We restricted our study sample to women delivering their first two singleton births (n=49,868) during the time of data collection regardless of baseline parity. We excluded

women with: inconsistencies in their hypertensive status, such as being prescribed hypertensive medications or having hypertension as a labor indication without a hypertension diagnosis (n=202); inconsistencies in their diabetes status, such as having an ICD-9 code for 'infant of a diabetic mother' with no diabetes recorded for the mother (n=23); chronic diseases in their first (n = 920) and/or second pregnancy (n=683) including diabetes mellitus, chronic hypertension, or superimposed PE; missing height or weight data in either pregnancy (n = 1,518); and implausible BMI values defined as BMI <11 kg/m² or BMI >70 kg/m² (n=1) resulting in 46,521 women for the current study (Figure 1). Some characteristics of those missing BMI data (3.0% of original sample) differed slightly from those with data (Appendix Table 2). Compared to those with BMI data, those missing BMI were less likely to be white, married or primiparous, have private insurance and were more likely to have shorter interpregnancy intervals and to be diagnosed with GDM in their second pregnancy.

Interpregnancy BMI change

The exposure, interpregnancy weight change, was calculated as the difference between the pre-pregnancy BMI of the first pregnancy and the pre-pregnancy BMI of the second pregnancy and was examined as both a continuous and a categorical variable as: difference in BMI <-1 unit (i.e. loss of more than 1 BMI unit (kg/m²)), -1 to less than 1 (reference group), 1 to less than 2, 2 to less than 3, and ≥3 BMI units (i.e. gain of 3 or more BMI units).

Maternal outcomes

Maternal outcomes in the second pregnancy were ascertained from electronic medical records (EMR) supplemented with ICD-9 codes and included: GDM, PE, GHtn, primary cesarean delivery, and VBAC. If the condition was coded in either source, then the woman was coded as having the diagnosis. During the study period, the definitions that were widely adopted in US clinical practice were utilized to identify the outcomes of interest. PE and GHtn were defined as systolic blood pressure ≥140 mmHg, a diastolic blood pressure ≥90 mmHg occurring after 20 weeks' gestation among previously normotensive women with and without proteinuria, respectively.^{20,21} Mode of delivery was determined via the EMR. For the primary cesarean delivery outcome, only those without a cesarean delivery in the prior pregnancy (n=38,142) were included. For VBAC outcome, data were restricted to women with a cesarean delivery in a previous pregnancy and to a trial of labor in the current pregnancy of interest (n=2,419). ICD-9 codes for the examined maternal outcomes are listed in Appendix Table 3.

Statistical analysis

We used Poisson regression models with robust variance estimators²¹ to examine the relative risks (RR) of maternal outcomes in the second pregnancy with interpregnancy BMI change adjusting for: maternal race/ethnicity (White, Hispanic, Black/Asian/Pacific Islander/other); maternal age; married (yes/no); smoking and alcohol use in the second pregnancy; interpregnancy interval (measured as days between delivery date of the first pregnancy and date of last menstrual period of the second pregnancy); GDM, PE, GHtn, and pre-pregnancy BMI in the first pregnancy. We decided on these variables based on literature review and directed acyclic graphs to determine an unbiased estimate of the effect of the exposure on

the outcomes. We report unadjusted and adjusted analyses for each outcome treating interpregnancy BMI change as either categorical or continuous. In a sub-analysis, we also examined whether first pre-pregnancy BMI modified the association between maternal outcomes and interpregnancy BMI change by examining the significance of the interaction term between first pre-pregnancy BMI (categorized as <25 and ≥25) and interpregnancy BMI change.

We also performed two sensitivity analyses. The first restricted the sample to nulliparous women at study entry (sample size for GDM, PE, and GHtn analyses: n=25,429; primary cesarean delivery: n=21,049; VBAC: n=1,104); the second excluded women who had GDM, PE or GHtn in the prior pregnancy (sample size for GDM, PE, and GHtn analyses: n=42,399; primary cesarean delivery: n=35,088; VBAC: n=2,195). Significance was evaluated at $\alpha = 0.05$. Statistical analyses were conducted using SAS software (version 9.4; SAS institute, Cary, NC).

RESULTS

On average, women gained 0.81 BMI units (median 0.46, interquartile range (IQR): -0.34, 1.77) over an average interpregnancy interval of 634 days (median 561, IQR: 373, 814). During the second pregnancy, 23% of women were overweight and 16% were obese; most women were married (90%); had private insurance (74%); identified as White (87%); and primiparous (55%). The average age of the women at the second delivery was 28 years (median 28, IQR: 25, 31). Table 1 describes the characteristics of the study participants and the change in BMI by these characteristics. Women who identified as not married had a higher mean BMI change (1.41 BMI units (standard deviation (SD): 3.03)) compared to women who identified as married. White women had lower mean change in BMI (0.74 (SD: 2.29) compared to women of other race/ethnicity (~1.3 BMI). Women who had pregnancy complications in the second pregnancy including GDM, PE, or GHtn gained on average 1.4 to 1.5 (SD: 2.9) BMI units. The incidence rates of maternal outcomes in the second pregnancy were: GDM: 3.5%, PE: 1.7%, GHtn: 2.3%, primary cesarean delivery: 4.2%, VBAC: 66.3%.

The highest frequencies of all the adverse outcomes were seen among women with the largest increase in interpregnancy BMI (i.e., +3 units; GDM 5.9%, PE 3.1%, GHtn 4.4%; primary cesarean delivery 5.4%; and no VBAC 44.4%) (Table 2).

After adjusting for potential confounders, every one unit increase in interpregnancy BMI increased the risks of GDM (RR: 1.09; 95% CI: 1.07–1.11), PE (RR: 1.06; 95% CI: 1.04–1.09), GHtn (RR: 1.08; 95% CI: 1.06–1.10), and primary cesarean delivery (RR: 1.03; 95% CI: 1.007–1.05) and decreased the risk of a successful VBAC (RR: 0.98; 95% CI: 0.97–0.997) in the second pregnancy (Table 3).

Compared to women who maintained their BMI between pregnancies (-1 BMI unit change <+1), women with a BMI ≥3 units increase were at a significantly increased risk of GDM (RR: 1.71; 95% CI: 1.52–1.93), PE (RR: 1.60; 95% CI: 1.33–1.94), GHtn (RR: 1.66; 95% CI: 1.42–1.94), and primary cesarean delivery (RR: 1.29; 95% CI: 1.12–1.49) and at a

significantly decreased risk of having a successful VBAC (RR: 0.89; 95% CI: 0.80–0.99) in the second pregnancy (Table 4). Women who increased their BMI by at least 2 but not more than 3 units showed only an increased risk of GDM in the second pregnancy (RR: 1.40; 95% CI: 1.22–1.61) while no significant differences were detected for the risks of other outcomes in comparison to those who maintained their interpregnancy BMI. Similarly, women who gained 1 BMI unit <2 were at a higher risk of GDM only in the second pregnancy (RR: 1.23; 95% CI: 1.08–1.40). Interpregnancy weight loss of more than one BMI unit was not significantly associated with any of the examined outcomes. The results of the sub-analysis differed only for the GHtn outcome. Women with a first pre-pregnancy BMI <25 kg/m² who gained 3 BMI units had a 2.20 (95% CI: 1.72–2.82) fold increased risk of developing GHtn in the second pregnancy compared to those who maintained their BMI between pregnancies while those who had a first pre-pregnancy BMI ≥25 Kg/m² and gained 3 BMI units had only a 1.40 (95% CI: 1.15–1.70) fold increased risk of developing GHtn in the second pregnancy compared to those who maintained their BMI.

Our results were robust in both sensitivity analyses when examining women who were nulliparous at baseline (Appendix Tables 4 & 5) and when excluding women who had GDM, PE or GHtn in the prior pregnancy (Appendix Tables 6 & 7). Only VBAC among women with BMI ≥3 units increase lost statistical significance (RR: 0.85; 95% CI: 0.71–1.02) when restricting the data to nulliparous women at study entry (Appendix Table 4).

DISCUSSION

In this large consecutive pregnancies study, we found that after accounting for pre-pregnancy BMI in the first pregnancy, a one unit increase in interpregnancy BMI significantly increased the risks of GDM, PE, GHtn, primary cesarean delivery, and an unsuccessful VBAC in the second pregnancy. Women who gained ≥3 BMI units had the highest magnitude of risk of these adverse outcomes. Women who gained more than 1 but less than 3 BMI units were still at an increased risk of GDM in their second pregnancy but not for other examined outcomes. First pre-pregnancy BMI only modified the association between interpregnancy BMI change and GHtn, with stronger impact of gain in BMI among women who were normal weight in their first pregnancy.

The incidence rates of the outcomes in the current study are less than the national estimates²³ reflecting the overall better health status of the Utah study population.²⁴ The main strengths of the current study were its large sample size and the usage of two data sources, including EMRs and ICD-9 codes, which allowed us to examine extensive demographic, diagnostic, and history information about the study participants. While our study population was mainly Caucasians, which limits generalizability to other races, the homogeneity of the study population reduced the potential for residual confounding of the associations of interest. We lacked information on lifestyle behaviors, such as diet and physical activity. BMI was also missing for 3% of women but we do not expect this to impact our findings. Weight was self-reported. However, this should not over or underestimate our exposure of interest which is the difference in weight measurement between two consecutive pregnancies..^{25,26} Other than interpregnancy weight change, waist-

to-hip ratio, waist circumference, and abdominal subcutaneous fat change might be better predictors of second pregnancy outcomes.²⁷

Similar to previous studies,^{2,8,12,13} we showed that as interpregnancy BMI increases, the risk of GDM in the second pregnancy also increases. However, while our results suggested that weight loss leading to more than 1 unit decrease in interpregnancy BMI would be protective of GDM risk, the association did not reach statistical significance (OR: 0.90; 95% CI: 0.79–1.02) as has been reported in two previous studies.^{8,12} One study⁸ classifying women based on their first-second BMI categories, showed that women in the underweight-underweight group (OR: 0.42; 95% CI: 0.19–0.92) and those in the normal weight-underweight group (OR: 0.69; 95% CI: 0.48–0.97) had significantly lower odds of developing GDM in the second pregnancy compared to those in the normal weight-normal weight group. While another study¹² showed this decrease only among women who were overweight/obese in their first pregnancy and either lost >2 BMI units (OR: 0.26; 95% CI: 0.14–0.47) or lost >1 but <2 BMI units (OR: 0.62; 95% CI: 0.39–0.98), compared to those who remained stable (± 1 BMI unit).

For PE and GHtn, similar to our study, four studies reported an increase in the risk as BMI increased;^{2,5,7,14} while one study⁶ did not find a significant association between an increase in BMI and a higher rate of GHtn. This study, however, had a small sample size ($n = 1,035$) and was only limited to women who were overweight in their first pregnancy.⁶ Moreover, we observed that a loss of weight among women who entered their first pregnancy as overweight/obese could potentially decrease their risk of GHtn (OR: 0.79; 95% CI: 0.62–0.99), which was not found in any of the previous studies.

Previous studies examining the association between interpregnancy weight change and the risk of cesarean delivery have also shown an increase in cesarean delivery with an increase in interpregnancy weight. Two studies^{9,13} reported an association between cesarean delivery, without differentiating between elective and emergency cesarean, and interpregnancy weight change. One study showed an association among overweight and obese women with weight gain of at least 2 BMI units (OR=2.04; 95% CI 1.41–2.95), compared to those with ± 1 BMI unit change.¹³ While, another study reported an association among those retaining 2 to <3 (OR=1.19; 95% CI: 1.09–1.29) and ≥ 3 BMI units irrespective of first pre-pregnancy BMI (OR=1.32; 95% CI 1.22–1.44).² Others examining only primary cesarean delivery reported elevated risks for normal weight women becoming obese (OR=1.41; 95% CI: 1.26–1.57) and obese women remaining obese (OR=1.75; 95% CI: 1.65–1.87)⁸, which was also supported by another study.⁴

Yet another study showed that weight gain of 1 to <3 (OR: 1.30, 95% CI: 1.03–1.66) and ≥ 3 BMI units (OR=1.78; 95% CI: 1.35–2.35) increased the odds of emergency cesarean section.¹⁴ In the current study, we only observed a significant association among those who gained at least 3 BMI units between pregnancies. We also did not find an interaction by previous BMI status. However, taken together, the evidence continues to point to the additional role of increased weight between pregnancies leading to additional risk of cesarean delivery.

Only one previous study¹¹ explored the association between interpregnancy BMI change and success of term VBAC among normal, overweight, and obese women. Women with normal BMI before their first pregnancy who had moderate (1 to <2 BMI units) (RR: 0.92; 95% CI: 0.87–0.98) or high weight gain (2 BMI units) (RR: 0.88; 95% CI: 0.83–0.93) decreased their risk of successful VBAC, compared to those who maintained their weight. While, those who were overweight (RR=1.12; 95% CI: 1.01–1.25) or obese (RR=1.24; 95% CI: 1.04–1.49) and had weight loss (1 BMI unit), compared to those who maintained their weight, increased their risk of successful VBAC¹¹. Our results only showed an effect at high weight gain of over 3 BMI units and not at other levels or by BMI status.

Normal pregnancy is characterized by progressive increases in serum glucose and lipids.^{28,29} Overweight and obese women, however, exhibit marked alterations in the trajectory of serum glucose and lipids in comparison to normal weight women.³⁰ Such changes in glucose and lipid metabolism, inflammation, as well as perturbances in adipokines seem to be involved in the underlying mechanisms that link maternal obesity with pregnancy-induced complications including GDM, GHtn and PE.³¹ Indications for the increased risk of primary cesarean delivery among women with high interpregnancy weight gain have been shown to be due to dystocia,⁴ fetal distress,⁴ or poor myometrial contractility followed by dysfunctional labor.³² Obese women are also more likely to give birth to macrosomic infants, a risk factor for cesarean delivery.³³ The mechanism underlying interpregnancy weight gain and the increased risk of unsuccessful VBAC is not clear; however, the proposed mechanisms for primary cesarean delivery can also apply to this outcome.

Interpregnancy weight gain is a combination of weight retained from pregnancy and postpartum weight gain. Particularly concerning is weight retained from pregnancy as it is associated with a centralized distribution of adipose tissue, with data suggesting preferential accumulation of adipose tissue in the visceral compartment.^{34–36} Regional fat distribution and visceral adipose tissue increase a woman's risk of developing major chronic diseases including type-2 diabetes and cardiovascular disease.^{37,38} Apart from weight gain, pregnancy complications can also manifest later in life as chronic conditions. Women with gestational diabetes for example have more than a seven fold increased risk of developing type 2 diabetes (RR=7.4; 95% CI: 4.8–11.5);³⁹ while new-onset gestational hypertension or preeclampsia increases future risk for cardiovascular disease, ischemic heart disease, and heart failure.^{40,41}

CONCLUSION

This retrospective US-based cohort study provides evidence that after accounting for first pre-pregnancy BMI, interpregnancy BMI gain particularly 3 units increases the risks of adverse maternal outcomes including: GDM, PE, GHtn, primary cesarean section, and unsuccessful VBAC. For women of average height (5'4"), a 3 unit increase in BMI would translate to about 20 pounds of weight gain between pregnancies. Given that we observed more than one in ten women reached weight gain at this level, these findings highlight the importance of weight management between pregnancies.

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Abbreviations and Acronyms

BMI	body mass index
PE	pre-eclampsia
GHtn	gestational hypertension
GDM	gestational diabetes mellitus
VBAC	vaginal birth after cesarean delivery
NICHD	National Institute of Child Health and Human Development
EMR	electronic medical records
ICD	International Classification of Diseases
kg	kilograms
m	meters
US	United States
RR	relative risk
IQR	interquartile range
SD	standard deviation
OR	odds ratio
CI	confidence interval

References

1. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA*. 2012; 307(5):491–497. [PubMed: 22253363]
2. Villamor E, Cnattingius S. Interpregnancy weight change and risk of adverse pregnancy outcomes: a population-based study. *Lancet*. 2006; 368(9542):1164–70. [PubMed: 17011943]
3. Monte, LM., Ellis, RE. Final Report. US Department of Commerce, Economics and Statistics Administration, US Census Bureau; 2014. Fertility of Women in the United States: 2012. Report No.: P20–575
4. Getahun D, Kaminsky LM, Elsassner DA, Kirby RS, Ananth CV, Vintzileos AM. Changes in prepregnancy body mass index between pregnancies and risk of primary cesarean delivery. *Am J Obstet Gynecol*. 2007; 197(4):376e1–7. [PubMed: 17904966]

5. Getahun D, Ananth CV, Oyelese Y, Chavez MR, Kirby RS, Smulian JC. Primary preeclampsia in the second pregnancy: effects of changes in prepregnancy body mass index between pregnancies. *Obstet Gynecol.* 2007; 110(6):1319–25. [PubMed: 18055727]
6. Hoff GL, Cai J, Okah FA, Dew PC. Pre-pregnancy overweight status between successive pregnancies and pregnancy outcomes. *J Womens Health (Larchmt).* 2009; 18(9):1413–7. [PubMed: 19698074]
7. Mostello D, Jen Chang J, Allen J, Luehr L, Shyken J, Leet T. Recurrent preeclampsia: the effect of weight change between pregnancies. *Obstet Gynecol.* 2010; 116(3):667–72. [PubMed: 20733450]
8. Whiteman VE, Aliyu MH, August EM, McIntosh C, Duan J, Alio AP, et al. Changes in prepregnancy body mass index between pregnancies and risk of gestational and type 2 diabetes. *Arch Gynecol Obstet.* 2011; 284(1):235–40. [PubMed: 21544736]
9. Whiteman VE, McIntosh C, Rao K, Mbah AK, Salihu HM. Interpregnancy BMI change and risk of primary caesarean delivery. *J Obstet Gynaecol.* 2011; 31(7):589–93. [PubMed: 21973129]
10. Paramsothy P, Lin YS, Kernic MA, Foster-Schubert KE. Interpregnancy weight gain and cesarean delivery risk in women with a history of gestational diabetes. *Obstet Gynecol.* 2009; 113(4):817–823. [PubMed: 19305325]
11. Callegari LS, Sterling LA, Zelek ST, Hawes SE, Reed SD. Interpregnancy body mass index change and success of term vaginal birth after cesarean delivery. *Am J Obstet Gynecol.* 2014; 210(4):330e1–7. [PubMed: 24215856]
12. Ehrlich SF, Hedderson MM, Feng J, Davenport ER, Gunderson EP, Ferrara A. Change in body mass index between pregnancies and the risk of gestational diabetes in a second pregnancy. *Obstet Gynecol.* 2011; 117(6):1323–30. [PubMed: 21606742]
13. Bogaerts A, Van den Bergh BR, Ameye L, Witters I, Martens E, Timmerman D, et al. Interpregnancy weight change and risk for adverse perinatal outcome. *Obstet Gynecol.* 2013; 122(5):999–1009. [PubMed: 24104777]
14. Wallace JM, Bhattacharya S, Campbell DM, Horgan GW. Inter-pregnancy weight change impacts placental weight and is associated with the risk of adverse pregnancy outcomes in the second pregnancy. *BMC Pregnancy Childbirth.* 2014; 14:40. [PubMed: 24450357]
15. DiGiuseppe DL, Aron DC, Random L, Harper DL, Rosenthal GE. Reliability of birth certificate data: a multi-hospital comparison to medical records information. *Matern Child Health J.* 2002; 6(3):169–79. [PubMed: 12236664]
16. Horon IL. Underreporting of maternal deaths on death certificates and the magnitude of the problem of maternal mortality. *Am J Pub Health.* 2005; 95(3):478–82. [PubMed: 15727980]
17. Dietz P, Bombard J, Mulready-Ward C, Gauthier J, Sackoff J, Borzicevic P, et al. Validation of selected items on the 2003 U.S. standard certificate of live birth: New York City and Vermont. *Public Health Rep.* 2015; 130(1):60–70. [PubMed: 25552756]
18. Roohan PJ, Josberger RE, Acar J, Dabir P, Feder HM, Gagliano PJ. Validation of birth certificate data in New York State. *J Community Health.* 2003; 28(5):335–46. [PubMed: 14535599]
19. Laughon SK, Albert PS, Leishear K, Mendola P. The NICHD Consecutive Pregnancies Study: recurrent preterm delivery by subtype. *Am J Obstet Gynecol.* 2014 Feb; 210(2):131.e1–8. [PubMed: 24036403]
20. Boghossian NS, Yeung E, Albert PS, Mendola P, Laughon SK, Hinkle SN, et al. Changes in diabetes status between pregnancies and impact on subsequent newborn outcomes. *Am J Obstet Gynecol.* 2014; 210(5):431e1–14. [PubMed: 24361790]
21. Boghossian NS, Albert PS, Mendola P, Grantz KL, Yeung E. Delivery blood pressure and other first pregnancy risk factors in relation to hypertensive disorders in second pregnancies. *Am J Hypertens.* 2015; 28(9):1172–9. [PubMed: 25673041]
22. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol.* 2004; 159:702–706.
23. Martin, JA., Hamilton, BE., Ventura, SJ., Osterman, MJK., Kirmeyer, S., Matthews, TJ., et al. National vital statistics reports. Vol. 60. Hyattsville, MD: National Center for Health Statistics; 2011. Births: Final Data for 2009.

24. Utah. America's Health Rankings. United Health Foundation; 2014. Available from: [URL: <http://cdnfiles.americashealthrankings.org/SiteFiles/StateSummaries/Utah-Health-Summary-2014.pdf>] [Accessed 11 June 2015]
25. Oken E, Taveras EM, Popoola FA, Rich-Edwards JW, Gillman MW. Television, walking, and diet: associations with postpartum weight retention. *Am J Prev Med.* 2007; 32:305–11. [PubMed: 17383561]
26. Pedersen P, Baker JL, Henriksen TB, Lissner L, Heitmann BL, Sørensen TI, et al. Influence of psychosocial factors on postpartum weight retention. *Obesity (Silver Spring).* 2011; 19:636–46.
27. Kennedy NJ, Peek MJ, Quinton AE, Lanzarone V, Martin A, Benzie R, et al. Maternal abdominal subcutaneous fat thickness as a predictor for adverse pregnancy outcome: a longitudinal cohort study. *BJOG.* 2016; 123(2):225–32. [PubMed: 26840907]
28. Catalano PM, Huston L, Amini SB, Kalhan SC. Longitudinal changes in glucose metabolism during pregnancy in obese women with normal glucose tolerance and gestational diabetes mellitus. *Am J Obstet Gynecol.* 1999; 180(4):903–916. [PubMed: 10203659]
29. Lippi G, Albiero A, Montagnana M, Salvagno GL, Scevarolli S, Franchi M, et al. Lipid and lipoprotein profile in physiological pregnancy. *Clin Lab.* 2007; 53(3–4):173–7. [PubMed: 17447654]
30. Scifres CM, Catov JM, Simhan HN. The impact of maternal obesity and gestational weight gain on early and mid-pregnancy lipid profiles. *Obesity (Silver Spring).* 2014; 22(3):932–8. [PubMed: 23853155]
31. Huda SS, Brodie LE, Sattar N. Obesity in pregnancy: prevalence and metabolic consequences. *Semin Fetal Neonatal Med.* 2010; 15(2):70–6. [PubMed: 19896913]
32. Zhang J, Bricker L, Wray S, Quenby S. Poor uterine contractility in obese women. *BJOG.* 2007; 114(3):343–8. [PubMed: 17261121]
33. Boulet SL, Alexander GR, Salihu HM. Secular trends in cesarean delivery rates among macrosomic deliveries in the United States, 1989–2002. *J Perinatol.* 2005; 25(9):569–76. [PubMed: 16079908]
34. Gunderson EP, Murtaugh MA, Lewis CE, Queensberry CP, West DS, Sidney S. Excess gains in weight and waist circumference associated with childbearing: The Coronary Artery Risk Development in Young Adults Study (CARDIA). *Int J Obes Relat Metab Disord.* 2004; 28(4):525–35. [PubMed: 14770188]
35. Gunderson EP, Sternfeld B, Wellons MF, Whitmer RA, Chiang V, Quesenberry CP Jr, et al. Childbearing may increase visceral adipose tissue independent of overall increase in body fat. *Obesity (Silver Spring).* 2008; 16(5):1078–84. [PubMed: 18356843]
36. Smith DE, Lewis CE, Caverny JL, Perkins LL, Burke GL, Bild DE. Longitudinal changes in adiposity associated with pregnancy. The CARDIA Study. *Coronary Artery Risk Development in Young Adults Study. JAMA.* 1994; 271(22):1747–51. [PubMed: 8196117]
37. Lemieux S, Prud'homme D, Nadeau A, Tremblay A, Bouchard C, Després JP. Seven-year changes in body fat and visceral adipose tissue in women. Association with indexes of plasma glucose-insulin homeostasis. *Diabetes Care.* 1996; 19(9):983–91. [PubMed: 8875093]
38. Rexrode KM, Carey VJ, Hennekens CH, Walters EE, Colditz GA, Stampfer MJ, et al. Abdominal adiposity and coronary heart disease in women. *JAMA.* 1998; 280(21):1843–8. [PubMed: 9846779]
39. Bellamy L, Casas JP, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet.* 2009; 373(9677):1773–9. [PubMed: 19465232]
40. Heida KY, Franx A, van Rijn BB, Eijkemans MJ, Boer JM, Verschuren MW, et al. Earlier age of onset of chronic hypertension and type 2 diabetes mellitus after a hypertensive disorder of pregnancy or gestational diabetes mellitus. *Hypertension.* 2015; 66(6):1116–22. [PubMed: 26459420]
41. Männistö T, Mendola P, Vääräsmäki M, Järvelin MR, Kartikainen AL, Pouta A, et al. Elevated blood pressure in pregnancy and subsequent chronic disease risk. *Circulation.* 2013; 127(6):681–90. [PubMed: 23401113]

APPENDIX

Table 1

Institutions included in NICHD Consecutive Pregnancies Study

Institution Name	City, State
Alta View Hospital	Sandy, UT
American Fork Hospital	American Fork, UT
Bear River Valley Hospital	Tremonton, UT
Cassia Regional Medical Center	Burley, ID
Cottonwood Hospital	Salt Lake City, UT
Delta Community Medical Center	Delta, UT
Dixie Regional Medical Center	St. George, UT
Fillmore Community Medical Center	Fillmore, UT
Heber Valley Medical Center	Heber City, UT
Intermountain Medical Center	Murray, UT
LDS Hospital	Salt Lake City, UT
Logan Regional Hospital	Logan, UT
Mckay-Dee Hospital Center	Ogden, UT
Orem Community Hospital	Orem, UT
Park City Medical Center	Park City, UT
Riverton Hospital	Riverton, UT
Sanpete Valley Hospital	Mount Pleasant, UT
Sevier Valley Medical Center	Richfield, UT
Utah Valley Regional Medical Center	Provo, UT
Valley View Medical Center	Cedar City, UT

Table 2

Comparison of the demographics of those missing BMI data and those not missing BMI data in the 2nd pregnancy

Characteristic	Missing BMI data (n=1518)	Not missing BMI data (n=46521)	p-value
Married, n (%)			<0.0001
Yes	1279 (84.31)	42063 (90.43)	
No	238 (15.69)	4454 (9.57)	
Insurance, n (%)			<0.0001
Private	928 (61.13)	34498 (74.16)	
Public	590 (38.87)	12023 (25.84)	
Maternal race, n (%)			<0.0001
White	1021 (67.35)	40457 (87.05)	
Hispanic	419 (27.64)	4691 (10.09)	
Black/Asian/Pacific Islander/Other	76 (5.01)	1328 (2.86)	
Smoking status, n (%)			0.0105
Yes	64 (4.23)	1427 (3.07)	

Characteristic	Missing BMI data (n=1518)	Not missing BMI data (n=46521)	p-value
No	1449 (95.77)	45053 (96.93)	
Alcohol use, n (%)			0.13
Yes	30 (1.99)	696 (1.50)	
No	1481 (98.01)	45705 (98.50)	
Gestational diabetes mellitus, n (%)			<0.0001
Yes	91 (5.99)	1646 (3.54)	
No	1427 (94.01)	44875 (96.46)	
Preeclampsia, n (%)			0.35
Yes	21 (1.38)	791 (1.70)	
No	1497 (98.62)	45730 (98.30)	
Gestational hypertension n (%)			0.74
Yes	37 (2.44)	1073 (2.31)	
No	1481 (97.56)	45448 (97.69)	
Delivery mode, n (%)			0.46
Vaginal birth	1178 (77.60)	36539 (78.54)	
Vaginal birth after cesarean in first delivery	69 (4.55)	1685 (3.62)	
Non-repeat cesarean in second delivery	52 (3.43)	1603 (3.45)	
Repeat cesarean in second delivery	219 (14.43)	6693 (14.39)	
Maternal age, years, n (%)			0.0037
< 35	1346 (88.67)	42268 (90.86)	
35	172 (11.33)	4253 (9.14)	
Maternal age, years, mean (SD)	27.84 (5.05)	27.97 (4.62)	0.31
Parity			0.0002
1	758 (49.93)	25429 (54.66)	
2	356 (23.45)	10624 (22.84)	
3	404 (26.61)	10468 (22.50)	
Interpregnancy interval			<0.0001
0 – 5 months	137 (9.03)	2402 (5.16)	
6 – 11 months	295 (19.43)	7536 (16.20)	
12 – 17 months	353 (23.25)	11065 (23.78)	
18 – 23 months	245 (16.14)	9630 (20.70)	
24 – 59 months	475 (31.29)	15332 (32.96)	
60 months	13 (0.86)	556 (1.20)	
Interpregnancy interval, months, mean (SD)	19.83 (12.67)	21.15 (12.31)	<0.0001

Excludes implausible BMI n=1

Missing BMI sample - Data were missing for: married n=1, maternal race n=1, smoke n=5, alcohol n=7. Not missing BMI sample - Data were missing for: maternal race n=45, smoke n=41, alcohol n=120, delivery mode n=1

Table 3

ICD-9 codes for maternal outcomes

Outcome	ICD-9 code	Definition
Gestational diabetes mellitus	648.8	Abnormal glucose tolerance of mother complicating pregnancy, childbirth, or the puerperium
Preeclampsia	642.4	Mild or unspecified PE
	642.5	Severe PE
Gestational hypertension	642.3	Transient hypertension of pregnancy
Chronic hypertension	401	Essential hypertension
	401.0	Malignant essential hypertension
	401.1	Benign essential hypertension
	401.9	Unspecified essential hypertension
	402	Hypertensive heart disease
	402.0	Malignant hypertensive heart disease
	402.1	Benign hypertensive heart disease
	402.9	Unspecified hypertensive heart disease
	403	Hypertensive chronic kidney disease
	403.0	Malignant hypertensive renal disease
	403.1	Benign hypertensive renal disease
	403.9	Unspecified renal disease
	404	Hypertensive heart and chronic kidney disease
	404.0	Malignant hypertensive heart and renal disease
	404.1	Benign hypertensive heart and renal disease
	404.9	Unspecified hypertensive heart and renal disease
	405	Secondary hypertension
	405.0	Malignant secondary hypertension
	405.1	Benign secondary hypertension
	405.9	Unspecified secondary hypertension
	642	Hypertension complicating pregnancy and childbirth and the puerperium
	642.0	Benign essential hypertension
	642.1	Hypertension secondary to renal disease
	642.2	Other pre-existing hypertension

Table 4

Relative risks (95% confidence intervals) of maternal outcomes in the 2nd pregnancy by interpregnancy BMI difference (continuous) among women who were nulliparous at baseline (n=25429)

Maternal Outcome in 2 nd Pregnancy	BMI difference (continuous)
Gestational diabetes mellitus	

Maternal Outcome in 2 nd Pregnancy	BMI difference (continuous)
Unadjusted	1.12 (1.09 – 1.14)
Adjusted	1.11 (1.08 – 1.13)
Preeclampsia	
Unadjusted	1.10 (1.06 – 1.13)
Adjusted	1.06 (1.03 – 1.09)
Gestational hypertension	
Unadjusted	1.12 (1.09 – 1.15)
Adjusted	1.08 (1.05 – 1.10)
Primary cesarean delivery ^a	
Unadjusted	1.04 (1.006 – 1.07)
Adjusted	1.03 (1.0004 – 1.06)
Vaginal birth after cesarean delivery ^b	
Unadjusted	0.97 (0.94 – 0.99)
Adjusted	0.97 (0.94 – 0.99)

Frequency of outcomes: gestational diabetes mellitus n=739 (2.9%), preeclampsia n=465 (1.8%), gestational hypertension n=599 (2.4%), primary cesarean delivery n=870 (4.1%), vaginal birth after cesarean delivery n=619 (56.1%)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI, gestational diabetes mellitus, preeclampsia, and gestational hypertension in the 1st pregnancy

^aDenominator n=21049

^bDenominator n=1104

Table 5

Relative risks (95% confidence intervals) of maternal outcomes in the 2nd pregnancy by interpregnancy BMI difference (categorical) among women who were nulliparous at baseline (n=25429) – Referent level: – 1 unit BMI change < 1 unit

Maternal Outcome in Second Pregnancy	BMI change < –1 unit	BMI change 1 to less than 2 units	BMI change 2 to less than 3	BMI change 3 units
Gestational diabetes mellitus				
Unadjusted	1.06 (0.83 – 1.35)	1.33 (1.06 – 1.66)	1.84 (1.45 – 2.33)	2.24 (1.87 – 2.69)
Adjusted	0.87 (0.71 – 1.07)	1.28 (1.05 – 1.56)	1.57 (1.26 – 1.95)	1.87 (1.58 – 2.22)
Preeclampsia				
Unadjusted	1.19 (0.89 – 1.59)	1.43 (1.08 – 1.87)	1.19 (0.84 – 1.69)	2.22 (1.77 – 2.80)
Adjusted	0.93 (0.70 – 1.24)	1.15 (0.88 – 1.51)	0.99 (0.70 – 1.41)	1.52 (1.19 – 1.95)
Gestational hypertension				
Unadjusted	0.96 (0.73 – 1.26)	1.27 (0.99 – 1.62)	1.37 (1.03 – 1.83)	2.30 (1.89 – 2.80)

Maternal Outcome in Second Pregnancy	BMI change < -1 unit	BMI change 1 to less than 2 units	BMI change 2 to less than 3	BMI change 3 units
Adjusted	0.75 (0.58 – 0.98)	1.03 (0.81 – 1.32)	1.10 (0.83 – 1.46)	1.52 (1.24 – 1.87)
Primary cesarean delivery ^a				
Unadjusted	1.14 (0.94 – 1.39)	1.27 (1.05 – 1.54)	0.94 (0.72 – 1.21)	1.41 (1.18 – 1.69)
Adjusted	1.02 (0.84 – 1.25)	1.19 (0.98 – 1.44)	0.87 (0.66 – 1.13)	1.25 (1.03 – 1.51)
Vaginal birth after cesarean delivery ^b				
Unadjusted	1.06 (0.92 – 1.22)	0.88 (0.74 – 1.04)	0.89 (0.73 – 1.09)	0.78 (0.65 – 0.93)
Adjusted	1.16 (1.01 – 1.34)	0.88 (0.75 – 1.04)	0.96 (0.78 – 1.17)	0.85 (0.71 – 1.02)

Frequency of outcomes: gestational diabetes mellitus n=739 (2.9%), preeclampsia n=465 (1.8%), gestational hypertension n=599 (2.4%), primary cesarean delivery n=870 (4.1%), vaginal birth after cesarean delivery n=619 (56.1%)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI, gestational diabetes mellitus, preeclampsia, and gestational hypertension in the 1st pregnancy

^aDenominator n=21049

^bDenominator n=1104

Table 6

Relative risks (95% confidence intervals) of maternal outcomes in the 2nd pregnancy by interpregnancy BMI difference (continuous) among women without any of gestational diabetes mellitus, preeclampsia or gestational hypertension in the first pregnancy (n=42399)

Maternal Outcome in 2 nd Pregnancy	BMI difference (continuous)
Gestational diabetes mellitus	
Unadjusted	1.16 (1.13 – 1.18)
Adjusted	1.13 (1.11 – 1.16)
Preeclampsia	
Unadjusted	1.11 (1.07 – 1.15)
Adjusted	1.08 (1.05 – 1.12)
Gestational hypertension	
Unadjusted	1.14 (1.11 – 1.18)
Adjusted	1.12 (1.09 – 1.15)
Primary cesarean delivery ^a	
Unadjusted	1.03 (1.005 – 1.06)
Adjusted	1.03 (1.004 – 1.05)
Vaginal birth after cesarean delivery ^b	
Unadjusted	0.98 (0.97 – 0.99)
Adjusted	0.98 (0.96 – 0.99)

Excludes women with gestational diabetes mellitus: n=864; preeclampsia: n=1516; gestational hypertension: n=1742; gestational diabetes mellitus and preeclampsia n=50; gestational diabetes mellitus and gestational hypertension n=42

Frequency of outcomes: gestational diabetes mellitus n=812 (1.9%), preeclampsia n=464 (1.1%), gestational hypertension n=587 (1.4%), primary cesarean delivery n=1417 (4.0%), vaginal birth after cesarean delivery n=1493 (68.0%)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI in the 1st pregnancy

^aDenominator n=35088

^bDenominator n=2195

Table 7

Relative risks (95% confidence intervals) of maternal outcomes by interpregnancy BMI difference (categorical) among women without any of gestational diabetes mellitus, preeclampsia or gestational hypertension in the first pregnancy (n=42399) – Referent level: – 1 unit BMI change < 1 unit

Maternal Outcome in Second Pregnancy	BMI change < –1 unit	BMI change 1 to less than 2 units	BMI change 2 to less than 3	BMI change 3 units
Gestational diabetes mellitus				
Unadjusted	1.09 (0.85 – 1.38)	1.62 (1.32 – 1.99)	2.09 (1.66 – 2.62)	2.94 (2.47 – 3.50)
Adjusted	0.83 (0.65 – 1.06)	1.43 (1.16 – 1.75)	1.75 (1.39 – 2.19)	2.26 (1.88 – 2.72)
Preeclampsia				
Unadjusted	1.13 (0.84 – 1.50)	1.11 (0.84 – 1.48)	1.04 (0.72 – 1.49)	2.24 (1.78 – 2.82)
Adjusted	0.84 (0.63 – 1.13)	0.98 (0.74 – 1.31)	0.87 (0.60 – 1.26)	1.64 (1.27 – 2.11)
Gestational hypertension				
Unadjusted	1.07 (0.81 – 1.40)	1.35 (1.05 – 1.72)	1.20 (0.87 – 1.65)	2.90 (2.38 – 3.53)
Adjusted	0.78 (0.59 – 1.03)	1.24 (0.97 – 1.59)	1.03 (0.75 – 1.42)	2.24 (1.82 – 2.76)
Primary cesarean delivery ^a				
Unadjusted	1.19 (1.02 – 1.39)	1.20 (1.03 – 1.40)	1.07 (0.88 – 1.30)	1.42 (1.22 – 1.64)
Adjusted	1.04 (0.89 – 1.22)	1.15 (0.99 – 1.34)	1.00 (0.82 – 1.22)	1.28 (1.09 – 1.49)
Vaginal birth after cesarean delivery ^b				
Unadjusted	1.01 (0.93 – 1.09)	0.99 (0.91 – 1.08)	0.94 (0.85 – 1.05)	0.82 (0.74 – 0.91)
Adjusted	1.09 (1.00 – 1.18)	1.00 (0.92 – 1.09)	0.96 (0.87 – 1.07)	0.89 (0.79 – 0.99)

Excludes women with gestational diabetes mellitus: n=864; preeclampsia: n=1516; gestational hypertension: n=1742; gestational diabetes mellitus and preeclampsia n=50; gestational diabetes mellitus and gestational hypertension n=42

Frequency of outcomes: gestational diabetes mellitus n=812 (1.9%), preeclampsia n=464 (1.1%), gestational hypertension n=587 (1.4%), primary cesarean delivery n=1417 (4.0%), vaginal birth after cesarean delivery n=1493 (68.0%)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI in the 1st pregnancy

^aDenominator n=35088

^bDenominator n=2195

Figure 1.
Data exclusions from the NICHD Consecutive Pregnancy Study that resulted in the final study sample

Table 1

Sample Characteristics of NICHD Consecutive Pregnancies Study from 20 hospitals in Utah, 2002–2010
(n=46521)

Characteristic	Second Pregnancy	Mean change in BMI (SD)
Pregnancy BMI kg/m ² category, n (%) ^a		
Underweight (BMI < 18.5)	2224 (4.78)	0.95 (1.64)
Normal (18.5 ≤ BMI < 25)	26117 (56.14)	0.77 (1.94)
Overweight (25 ≤ BMI < 30)	10772 (23.16)	0.97 (2.73)
Obese (BMI ≥ 30)	7408 (15.92)	0.74 (3.56)
Married, n (%)		
Yes	42063 (90.42)	0.75 (2.26)
No	4454 (9.57)	1.41 (3.03)
Private insurance, n (%)	34498 (74.16)	0.69 (2.18)
Public insurance, n (%)	12023 (25.84)	1.19 (2.76)
Maternal race, n (%)		
White	40457 (87.05)	0.74 (2.29)
Hispanic	4691 (10.09)	1.32 (2.73)
Black/Asian/Pacific Islander/Other	1328 (2.86)	1.28 (2.72)
Maternal age, years, n (%)		
< 35	42268 (90.86)	0.83 (2.37)
≥ 35	4253 (9.14)	0.68 (2.23)
Parity		
1	25429 (54.66)	0.90 (2.43)
2	10624 (22.84)	0.75 (2.26)
3	6461 (13.89)	0.68 (2.26)
4	2507 (5.39)	0.71 (2.24)
5	925 (1.99)	0.67 (2.27)
6+	575 (1.24)	1.18 (1.89)
Interpregnancy interval		
0 – 5 months	2402 (5.16)	1.03 (2.37)
6 – 11 months	7536 (16.20)	0.73 (2.24)
12 – 17 months	11065 (23.78)	0.57 (2.14)
18 – 23 months	9630 (20.70)	0.64 (2.23)
24 – 59 months	15332 (32.96)	1.07 (2.54)
≥ 60 months	556 (1.20)	1.88 (3.36)
Interpregnancy interval, months, mean (SD)	21.15 (12.31)	
Gestational diabetes mellitus, n (%)	1646 (3.54)	1.39 (2.85)
No gestational diabetes mellitus, n (%)	44875 (96.46)	0.79 (2.33)
Preeclampsia, n (%)	791 (1.70)	1.42 (2.92)
No preeclampsia, n (%)	45730 (98.30)	0.80 (2.34)
Gestational hypertension, n (%)	1073 (2.31)	1.54 (2.88)
No gestational hypertension, n (%)	45448 (97.69)	0.80 (2.34)

Characteristic	Second Pregnancy	Mean change in BMI (SD)
Primary cesarean in second delivery, n (%) ^b	1603 (4.20)	0.94 (2.64)
No primary cesarean in second delivery, n (%) ^b	36539 (95.80)	0.77 (2.23)
Vaginal birth after cesarean in second delivery, n (%) ^c	1604 (66.31)	0.67 (2.21)
No vaginal birth after cesarean in second delivery, n (%) ^c	815 (33.7)	1.00 (2.81)

Data were missing for: married n=4, maternal race n=45, smoke n=41, alcohol n=120, delivery mode n=1

^a BMI cutoffs for the first pregnancy: underweight (n=2738, 5.9%); normal (n=28591, 61.5%); overweight (n=9623, 20.7%); obese (n=5569, 12.0%)

^b n=38142; excluding women with a cesarean delivery prior to this pregnancy (vaginal birth after cesarean delivery n=904, cesarean n=5132, cesarean-repeat n=2321) and women with potential coding errors in the current second pregnancy (vaginal birth after cesarean delivery n=81, cesarean-repeat n=46)

^c n=2419; excluding women with a vaginal birth prior to this pregnancy (n=38164) and women who did not attempt labor in the current second pregnancy (n=5878) and women with potential coding errors in the current second pregnancy (vaginal delivery n=45, cesarean n=14, missing mode of delivery n=1)

Table 2

Outcomes in 2nd pregnancy by interpregnancy BMI difference regardless of parity at baseline (n=46521)

BMI unit change	Gestational diabetes mellitus N (%)	Preeclampsia N (%)	Gestational hypertension N (%)	Primary cesarean delivery ^a N (%)	Vaginal birth after cesarean delivery ^b
BMI unit change < -1	228 (3.48)	114 (1.74)	134 (2.04)	243 (4.57)	234 (67.44)
-1 BMI unit change < +1	609 (2.67)	304 (1.33)	408 (1.79)	714 (3.73)	821 (68.93)
+1 BMI unit change < +2	239 (3.55)	108 (1.60)	151 (2.24)	244 (4.42)	213 (66.98)
+2 BMI unit change < +3	196 (4.89)	66 (1.65)	100 (2.49)	137 (4.20)	148 (65.78)
BMI unit change +3	374 (5.87)	199 (3.12)	280 (4.39)	265 (5.40)	188 (55.62)
p-value ^c	<0.0001	<0.0001	<0.0001	<0.0001	0.0003

Frequency of outcomes: gestational diabetes mellitus n=1646, preeclampsia n=791, gestational hypertension n=1073, primary cesarean delivery n=1603, vaginal birth after cesarean delivery n=1604

BMI < -1 n=6560, -1 BMI < +1 n=22838, +1 BMI < +2 n=6737, +2 BMI < +3 n=4010, BMI +3 n=6376

^a n=38142; excluding women with a cesarean delivery prior to this pregnancy (vaginal birth after cesarean delivery n=904, cesarean n=5132, cesarean-repeat n=2321) and women with potential coding errors in the current second pregnancy (vaginal birth after cesarean delivery n=81, cesarean-repeat n=46)

^b n=2419; excluding women with a vaginal birth prior to this pregnancy (n=38164) and women who did not attempt labor in the current second pregnancy (n=5878) and women with potential coding errors in the current second pregnancy (vaginal delivery n=45, cesarean n=14, missing mode of delivery n=1)

^c Chi-square test

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Table 3

Relative risks (95% confidence intervals) of maternal outcomes in the 2nd pregnancy by interpregnancy BMI difference (continuous) (n=46521)

Maternal Outcome in 2 nd Pregnancy	BMI difference (continuous)
Gestational diabetes mellitus	
Unadjusted	1.10 (1.08 – 1.12)
Adjusted	1.09 (1.07 – 1.11)
Preeclampsia	
Unadjusted	1.10 (1.07 – 1.13)
Adjusted	1.06 (1.04 – 1.09)
Gestational hypertension	
Unadjusted	1.12 (1.09 – 1.14)
Adjusted	1.08 (1.06 – 1.10)
Primary cesarean delivery	
Unadjusted	1.03 (1.01 – 1.05)
Adjusted ^a	1.03 (1.01 – 1.05)
Vaginal birth after cesarean delivery	
Unadjusted	0.98 (0.97 – 0.99)
Adjusted ^b	0.98 (0.97 – 0.997)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI, gestational diabetes mellitus, preeclampsia, and gestational hypertension in the 1st pregnancy

^a n=38142

^b n=2419

Table 4

Relative risks (95% confidence intervals) of maternal outcomes in the 2nd pregnancy by interpregnancy BMI difference (categorical) (n=46521) – Referent level: – 1 unit BMI change < 1 unit

Maternal Outcome in 2 nd Pregnancy	BMI change < –1 unit	BMI change 1 to less than 2 units	BMI change 2 to less than 3	BMI change 3 units
Gestational diabetes mellitus				
Unadjusted	1.30 (1.12 – 1.51)	1.33 (1.15 – 1.54)	1.83 (1.57 – 2.15)	2.20 (1.94 – 2.49)
Adjusted – All women	0.90 (0.79 – 1.02)	1.23 (1.08 – 1.40)	1.40 (1.21 – 1.61)	1.71 (1.52 – 1.93)
Preeclampsia				
Unadjusted	1.31 (1.05 – 1.62)	1.20 (0.97 – 1.50)	1.24 (0.95 – 1.61)	2.34 (1.97 – 2.80)
Adjusted	0.97 (0.78 – 1.20)	1.03 (0.83 – 1.28)	1.00 (0.77 – 1.30)	1.60 (1.33 – 1.94)
Gestational hypertension				
Unadjusted	1.14 (0.94 – 1.39)	1.25 (1.04 – 1.51)	1.40 (1.12 – 1.73)	2.46 (2.12 – 2.85)
Adjusted	0.83 (0.69 – 1.01)	1.10 (0.91 – 1.31)	1.10 (0.89 – 1.36)	1.66 (1.42 – 1.94)
Adjusted ^a – BMI<25 Kg/m ² in first pregnancy	0.93 (0.66 – 1.30)	1.15 (0.88 – 1.51)	1.36 (0.99 – 1.86)	2.20 (1.72 – 2.82)
Adjusted ^a – BMI ≥ 25 Kg/m ² in first pregnancy	0.79 (0.62 – 0.99)	1.00 (0.78 – 1.27)	0.92 (0.70 – 1.22)	1.40 (1.15 – 1.70)
Primary cesarean delivery				
Unadjusted	1.22 (1.06 – 1.41)	1.18 (1.03 – 1.37)	1.13 (0.94 – 1.35)	1.45 (1.26 – 1.66)
Adjusted	1.06 (0.91 – 1.22)	1.13 (0.98 – 1.30)	1.04 (0.87 – 1.25)	1.29 (1.12 – 1.49)
Vaginal birth after cesarean delivery				
Unadjusted	0.98 (0.90 – 1.06)	0.97 (0.89 – 1.06)	0.95 (0.86 – 1.06)	0.81 (0.73 – 0.89)
Adjusted ^b	1.06 (0.97 – 1.15)	0.99 (0.91 – 1.08)	0.98 (0.89 – 1.09)	0.89 (0.80 – 0.99)

Adjusted for: maternal race; interpregnancy interval; maternal age, marital status, smoking, and alcohol use during the 2nd pregnancy; pre-pregnancy BMI, gestational diabetes mellitus, preeclampsia, and gestational hypertension in the 1st pregnancy

^aInteraction term between first pre-pregnancy BMI (categorized as <25 and ≥ 25) and interpregnancy BMI change was significant (p=0.048) and stratified results are reported

^bn=38142

^cn=2419