Published in final edited form as:

Obstet Gynecol Clin North Am. 2009 June ; 36(2): 317–ix. doi:10.1016/j.ogc.2009.04.001.

Childbearing and Obesity in Women: Weight Before, During, and After Pregnancy

Erica P. Gunderson, PhD

Kaiser Foundation Research Institute, Kaiser Permanente Northern California, Division of Research, 2000 Broadway, Oakland, CA 94612, USA epg@dor.kaiser.org

Keywords

Pregnancy; Postpartum period; Puerperium; Gestational weight gain; Obesity; Parity; Epidemiology; Women

The childbearing years are an important life stage for women that may result in substantial weight gain leading to the development of obesity. When compared with other age groups, US women aged 35 to 44 years have experienced the greatest increase in obesity prevalence in the past 45 years.¹ Furthermore, 45% of women begin pregnancy overweight or obese, up from 24% in 1983.² Gestational weight gain is also higher than ever before, with 43% of pregnant women gaining more than is recommended.²

Maternal overweight and obesity is the most common high-risk obstetric condition and is associated gestational diabetes mellitus, hypertensive disorders, and newborn macrosomia, among other perinatal complications.³ Women who are already over-weight or obese before a first pregnancy tend to retain or gain more weight after pregnancy than average weight women^{4–7} despite larger newborns⁸ and wider variability in gestational weight gain. Weight gain before, during, and after pregnancy not only affects the current pregnancy but may also be a primary contributor to the future development of obesity in women during midlife and beyond.^{9–11}

Two types of prospective study designs have examined persistent weight changes related to pregnancy in women: (1) pregnancy cohort studies using self-reported pre-pregnancy weight, and (2) longitudinal cohorts of women of reproductive age that measured weights before and after pregnancies and controlled for secular trends by accounting for weight gain in non-parous women. The pregnancy cohort studies rely almost exclusively on self-report of pregravid weight, and estimates of postpartum weight retention may be inflated by weight gain from secular trends.^{4,5,12} Moreover, pregnancy cohort studies have rarely obtained serial measurements of postpartum weight to differentiate net retention of gestational weight gain from subsequent post-partum weight gain or loss. By contrast, studies focusing on women of reproductive age more accurately estimate weight gain related to childbearing because body weight is measured before and after pregnancy. In addition, these studies remove weight gain due to secular trends and aging by estimating net weight gain for parous women relative to non-parous or nulliparous women during the same time interval.

Three outcome measures have been examined: (1) average weight change (retention), (2) substantial postpartum weight retention (ie, ≥ 5 kg above pregravid weight), and (3) the incidence of overweight or obesity after pregnancy (body mass index [BMI] > 26). Mean weight change or “retention” from preconception to postpartum is subject to high interindividual variability. Substantial weight retention (≥ 5 kg above pregravid weight) at 1 to 2 years postpartum may be a more useful clinical measure for identifying women who experience

significant weight shifts after pregnancy.^{4,13,14} The most clinically relevant health measure, the incidence of becoming overweight or obese after pregnancy, has rarely been assessed.^{15,16}

The evidence^{13,17-19} consistently shows that excessive gestational weight gain contributes to higher postpartum body weight; however, higher maternal body size before pregnancy and biologic factors are also important. For example, the age at menarche and a short interval from menarche to first birth may be as important as high gestational weight gain to the development of overweight after pregnancy.¹⁶ Being heavy before a first pregnancy has important implications for long-term persistent weight changes. Most studies have examined the independent relationships of pregravid body size, gestational weight gain, and parity to postpartum weight retention with conflicting results. These traits were first proposed in the 1950s and again in the 1970s as important correlates of weight changes after pregnancy;^{5,20} however, the joint influences of parity and pregravid body size on long-term weight changes have been examined in only a few large epidemiologic studies with sufficient numbers of primiparas across all BMI groups.⁵⁻⁷ This article examines the evidence suggesting that gestational weight gain, primiparity, and maternal body size before pregnancy jointly influence long-term postpartum weight retention and the development of over-weight and obesity among women of childbearing age.

GESTATIONAL WEIGHT GAIN AND LONG-TERM WEIGHT STATUS

Specifically, overweight and obese women are two to six times more likely to exceed the weight gain recommendations during pregnancy²¹⁻²³ than other BMI groups (Table 1). These women are also predisposed to higher postpartum weight gain (Fig. 1) and retention after pregnancy. Moreover, the incidence of high birth weight increases with higher gestational weight gain among average and high maternal BMI groups.²⁴ Obese women are also more likely to give birth to macrosomic infants, even with lower average pregnancy weight gain^{8,21,25} and normal glucose tolerance.²⁶ Some evidence indicates that gestational weight gain below 15 lbs in obese women may lower the risk of large-for-gestational age infants.²⁷

Gestational weight gain is strongly positively correlated with maternal weight change from preconception to beyond 6 months postpartum and exerts long-term effects on maternal body weight.^{12,28-31} In multiple linear regression models, total gestational gain has accounted for 20% to 35% of the variability in the weight change.^{4,12,28-31} Gunderson and colleagues¹⁶ reported that gestational gain above the recommended levels was associated with a threefold higher risk of becoming overweight after pregnancy (BMI ≥ 26) among women who were under or average weight before pregnancy in a large, multi-ethnic cohort.

Although gestational weight gain is linked to postpartum weight retention, primiparity and larger body size before pregnancy exert important influences. Findings on pre-gravid body size and primiparity have been inconsistent. Women who are overweight or obese before pregnancy are generally more likely to have excessive as well as inadequate gestational weight gains.^{8,21} Their accelerated pregravid weight gain trajectories and other factors may make overweight women more susceptible to substantial weight gain related to pregnancy, as well as more severe levels of obesity in midlife.

Postpartum Weight Retention: Pregnancy Cohort Studies

In observational epidemiologic studies, the average weight change from preconception to the first year postpartum is referred to as “postpartum weight retention.” Postpartum weight retention includes the weight gain during gestation (preconception through gestation), early postpartum weight loss (delivery to 6 weeks postpartum), and later postpartum weight changes

(after 6 weeks postpartum). Few studies have obtained serial measurements during the 12 to 24 months postpartum to assess patterns of weight change (ie, weight loss versus gain).

Average postpartum weight retention (preconception to 6–18 months postpartum) is relatively small, ranging from 0.5 to 1.5 kg based on self-reported pregravid weights,^{12,19,29,30,32,33} and has little impact on body weight for most women.³⁴ Nevertheless, the variability in postpartum weight change is large; 13% to 20% of women are 5 kg or more above their preconception weight by 1 year postpartum (Table 2).^{12,29,30,32} Limitations of pregnancy cohort studies include the lack of control for secular trends in body weight changes, self-reported pre-pregnancy weight, and short-term postpartum weight retention (ie, 1 year or less).⁴ The weight increases observed among black women versus white women in surveys may reflect differences in social, cultural, and behavioral factors rather than pregnancy itself. Long-term postpartum weight retention (beyond 1 to 2 years postpartum) has been examined in relatively few studies.^{5,25,35} Some evidence indicates that both gestational weight gain and weight retention at 1 year postpartum are directly associated with maternal body weight and overweight status decades after pregnancy.^{9,36}

Both primiparity and maternal pregravid body size are directly associated with high gestational weight gain, which, in turn, is highly correlated with postpartum weight retention. Given this evidence, characterization of the interrelationships of these maternal attributes is essential to an understanding of postpartum weight changes and obesity.

HIGH PREGRAVID BODY SIZE

Pregravid body size exerts a strong influence on weight changes during and after pregnancy. As previously discussed, women who are overweight before pregnancy experience greater and more variable increases in body weight during and after pregnancy.⁸ In 1957, McKeown and colleagues reported that weight change during the 12 months postpartum was largely influenced by the woman's weight before pregnancy; the heavier the woman, the larger amount of weight "retained."²⁰ Similarly, Aberdeen primiparas (1950s to 1960s) who were overweight in the first pregnancy were heavier by the middle of the subsequent pregnancy than other primiparas of average body size even after adjusting for weight increments related to age and secular trends.⁵ The 1988 National Maternal and Infant Health Survey (NMIHS) found that women who were overweight before pregnancy were more likely to experience substantial weight retention at 10 to 18 months postpartum than underweight and average weight groups.³²

Several pregnancy cohort studies from developed countries have reported independent direct associations between pregravid weight or BMI and postpartum weight retention based on multivariable models,^{18,28,29,34,37} although studies from a 1980s cohort reported no association.^{12,38} A study of Brazilian women found an inverse association.³¹ One explanation for the disparate findings is that studies with null findings included only white women, of whom only 7% were overweight before pregnancy (see Table 2), which limited the variation in gestational weight gain and pregravid BMI.

The bias in self-reported pregravid weight is greater for high pregravid body size groups and may inflate estimates of postpartum weight retention. In pregnancy cohort studies that utilized self-reported pregravid weight, substantial bias may be introduced because high BMI groups may underreport body weight by up to 5 kg versus 1 kg for other groups.^{39,40} Gestational weight gain and postpartum weight retention are affected to a greater extent for high versus low BMI groups due to reporting bias. An underestimate of 5 kg may overestimate gestational weight gain by almost 50%, and an error of 1 kg may overestimate postpartum weight change by more than 100% to 200%. Measured weights at preconception, delivery, and postpartum provide more accurate estimates of average weight change as well as gestational weight gain,

especially for overweight or obese women. Similarly, first trimester weight measurements may underestimate both gestational weight gain and postpartum weight retention because maternal fat deposition begins early in pregnancy, which has been estimated at 1.5 kg by 7 weeks' gestation.⁴¹

The pattern of postpartum weight changes has been assessed in relatively few studies and rarely according to pregravid body size groups. Gunderson and colleagues²⁵ examined the impact of pregravid body size on the pattern of weight changes during the early postpartum (delivery to 6 weeks' postpartum) and long-term postpartum (from 6 weeks' postpartum to a median 2 years) periods (see Fig. 1). Weight loss from delivery to 6 weeks' postpartum did not differ by pregravid BMI group,²⁵ but high BMI groups were three to five times more likely to gain more than 2 kg in the long-term than the average BMI group (see Fig. 1). The group difference in long-term weight change was 4 kg on average (-0.3 kg for obese versus -4.3 kg for average weight women).²⁵ Early postpartum weight loss generally consists of the placenta and amniotic fluid and contraction of maternal blood volume and other body components, and largely represents the loss of nonadipose tissue accumulated during gestation; therefore, early postpartum weight loss is similar among BMI groups despite BMI group differences in gestational weight gain. Later postpartum weight changes may differ by BMI because they involve fat mass. Obese women may tend to gain rather than lose weight after 6 weeks postpartum.

Other studies report lower gestational fat mass gains among overweight and obese women when compared with underweight and average weight women (6.0 ± 2.6 , 3.8 ± 3.4 , 3.5 ± 4.1 , and -0.6 ± 4.6 kg, respectively)⁴² and much higher postpartum weight gains among heavier women.³⁷ The higher weight retention from preconception to postpartum observed among high BMI groups may be due to postnatal weight gain, particularly because these women have lower average gestational gains with greater variability when compared with women of average and low BMI.²³ These data suggest that retention of gestational gain is unlikely to explain the higher weight levels after pregnancy among obese women and to some extent among overweight women. Given that gestational gain is strongly correlated with higher postpartum weight, pregravid BMI is an important modifier of this relationship. For example, average size women may be more likely to retain gestational weight gain, and over-weight or obese women may tend to lose less weight or to gain weight beyond the 6-week postpartum period.

Pregnancy Cohort Studies: Substantial Postpartum Weight Retention, Risk of Overweight

Substantial postpartum weight retention—Approximately 13% to 20% of pregnant women experience substantial weight retention by 1 year postpartum (see Table 2), defined as body weight at least 5 kg above preconception weight. Correlates of substantial postpartum weight retention based on epidemiologic studies include high gestational weight gain, pregravid overweight, primiparity, black race, low socioeconomic status, smoking cessation, and fewer than 5 hours of sleep per day.^{4,13,19} The most important independent risk factors for not returning to within 5 kg of pre-pregnancy body weight are maternal overweight or obesity before pregnancy and excessive gestational weight gain.

Risk of becoming overweight after pregnancy: maternal characteristics—

Approximately 6% to 14% of women are likely to become overweight within 1 year after delivery.^{4,15} In the 1988 NMIHS, 8.2% of average weight white women were heavier by more than 9 kg at 10 to 18 months after delivery versus 22% of black women.³²

Among pregnant women who were not overweight before pregnancy, Gunderson and colleagues¹⁶ examined the racial and ethnic differences in becoming overweight after pregnancy. In this 1980 to 1990 multi-ethnic pregnancy cohort, overall, 6.4% became overweight by 1.5 years (median follow-up time) after the index pregnancy. Black women

were about 40% more likely to become overweight within a median of 2 years after delivery when compared with white women (10% versus 7%). Although the adjusted risk estimate for black women was not statistically significant, it was comparable in magnitude to estimates from a population-based sample of women aged 30 to 55 years in which black women were 50% more likely than white women to gain 10 kg or more over 10 years.⁴³ Asian women had a greatly reduced risk of becoming overweight (2% versus 7%) when compared with white women, whereas Hispanic women had no increased risk when compared with white women. Although these women did not become overweight, approximately 40% more Asians shifted from a BMI below 19.8 (underweight) to a BMI between 19.8 and 26.0 (normal weight), indicating that significant weight increments occurred among Asian women.

A higher prevalence of overweight and obesity for black women has been reported in population-based epidemiologic studies of US women.⁴³ In a 10-year prospective study of women aged 18 to 30 years at baseline, black women were three times more likely to become overweight than white women when controlling for age, parity, smoking, sociodemographics, and other risk factors.¹⁶ The higher risk of becoming overweight among black women was not related to childbearing but to differences in secular trends in weight gain trajectories for black women versus white women.

Moreover, other studies found that maternal characteristics independently associated with a twofold to threefold higher risk of becoming overweight after pregnancy included gestational weight gain exceeding the Institute of Medicine (IOM) recommendations, age at menarche of less than 12 years, less than 8 years between menarche and first birth, first birth between age 24 to 30 years,¹⁶ and short sleep duration (<5 hours per 24-hour period) at 6 months' postpartum.¹³ These risk factors may indirectly represent genetic or biologic influences on adult body weight before pregnancy, socioeconomic differences in maternal age when childbearing begins, or postpartum changes. Although the strengths of associations were similar to total gestational weight gain, their lower prevalence in a population may result in relatively lower attributable risk from these factors for postpartum weight retention.

CHILDBEARING AND LONG-TERM WEIGHT GAIN: PRIMIPARITY AND PREGRAVID BODY SIZE

Among women of reproductive age, high pregravid body size and primiparity predispose women to substantial weight gain related to childbearing (paras versus nulliparas). Studies of weight gain related to childbearing (Table 3) are designed to estimate weight change due to pregnancy and its aftermath relative to weight changes that would normally occur among women of similar reproductive age who did not give birth during the same time interval (ie, removes weight gain due to secular trends and aging). Only four longitudinal studies have measured weight before and after pregnancy during fixed intervals and obtained estimates of weight gain attributed to childbearing by comparing changes among parous women with those among nulliparous or nonparous women.^{6,44-46} A fifth study relied on survey methodology to estimate weight changes based on self-reported body weight associated with childbearing.⁷ The evidence from these studies, as summarized herein, is consistent, except for one study⁴⁶ in which fewer than 27% of women were primiparas.

Specifically, population-based longitudinal studies, the NHANES I Epidemiologic Follow-up Study (NHEFS), the Coronary Artery Risk Development in Young Adults (CARDIA) Study, and the Black Women's Health Study (BWHS), prospectively estimated net weight changes from before to after pregnancy relative to the weight changes related to secular trends and aging in the population (see Table 3).^{6,7,45,46} Two studies that measured body weight before and after pregnancy reported an average weight gain of 2 to 3 kg associated with a single birth versus no pregnancy in a biracial cohort (black and white women)⁴⁵ and a 1.7-kg weight

increase per birth among white women.⁴⁶ These studies included fewer than 90 primiparas, limiting their ability to examine whether pregnancy-related weight gain varied by pregravid BMI.

In the larger study cohorts, the CARDIA study and the BWHS, weight gain due to childbearing was greatest after the first birth (primiparas versus nulliparas), and this association depended on body size before pregnancy. The estimates from these two studies were remarkably similar; the average gain associated with having a first child was 3 to 6 kg among women who were overweight before pregnancy (BMI ≥ 25) and about 1 kg among women who were average weight (BMI < 25) before pregnancy (Fig. 2), accounting for secular trends, aging, and changes in lifestyle versus nulliparas.^{6,7}

The CARDIA data also provided evidence that weight gain attributed to childbearing did not differ between black women and white women⁶ when weight changes were examined separately within pregravid body size categories and within parity groups (see Fig. 2). Among women nulliparous at baseline, black women gained more weight overall than white women during the 10-year follow-up period regardless of the number of births (0, 1, or 2+ birth groups); however, weight gain attributed to a first birth was similar by race (1 kg for normal BMI, and 3–6 kg for overweight BMI). Cultural as well as biologic and behavioral factors may influence the predisposition of overweight women to gain weight associated with childbearing. Similar gains in central adiposity (waist circumference) by race were linearly associated with the number of births during follow-up.⁶

In prospective longitudinal studies in women of reproductive age, the evidence indicates that persistent weight gain attributed to pregnancy occurs primarily after the first birth (ie, cumulative increases do not occur with subsequent births), and that weight gain is greater with increasing maternal body size. Steeper weight gain trajectories after pregnancy observed within certain race groups may be actually due to secular trends or differences in the prevalence of women who are overweight or obese before pregnancy.

Childbearing and Risk of Becoming Overweight (Parous versus Nulliparous Women)

Childbearing is associated with the development of overweight in women of reproductive age.¹¹ A longitudinal study of US women aged 25 to 45 years at baseline found a 60% to 110% greater risk of becoming overweight among women with one birth when compared with women with no births during the 10-year follow-up period.⁴⁶ Limitations of this study included the relatively small number of parous women and the inclusion of peri- and postmenopausal women in the nongravid comparison group.

Another longitudinal study of women aged 18–30 years found that the risk of becoming overweight after pregnancy depended on smoking habits in women.¹⁵ Among never smokers, those who bore children were twice as likely to become overweight as those who never gave birth (odds ratio [OR] = 2.66 [95%CI, 1.80–3.93] for one birth and 2.10 [95%CI, 1.24–3.56] for two or more births). Among current smokers, those who bore children were half as likely to become overweight as those who never gave birth (OR = 0.41 [95%CI, 0.17–0.96] for one birth and 0.36 [95%CI, 0.08–1.65] for two or more births).¹⁵

Other characteristics associated with becoming overweight among women of reproductive age (18–30 years at baseline) independent of parity included a higher risk for black versus white race (OR = 3.49 [95%CI, 2.59–4.69]), frequent weight cycling versus none (OR = 1.45 [95%CI, 1.03–2.04]), and a high school diploma or less versus 4 years of college (OR = 2.21 [95%CI, 1.50–3.26]). High versus low physical activity (OR = 0.62 [95%CI, 0.43–0.90]) was associated with a reduced risk of becoming overweight.¹⁵ These findings are consistent with previous studies of postpartum weight changes.

Pregnancy and regional fat distribution and central adiposity—During pregnancy, fat is preferentially deposited in the femoral and abdominal regions. In a prospective study of 557 healthy women, subcutaneous body fat was measured via skinfold thicknesses before, during, and 6 weeks after pregnancy.⁴⁷ Central body fat gains in the subscapular area were relatively high during pregnancy but mobilized (or reduced) to a lesser extent than in triceps and thigh regions within the first 6 weeks' postpartum. Moreover, primiparas gained more at both thigh and subscapular locations than multiparas.⁴⁷ Another study using MRI tomographs found that 68% of gestational fat gain was deposited in the trunk, and that excess fat gain remaining at 1 year postpartum tended to be localized centrally.⁴⁸

Regional fat distribution may differ for women already overweight or obese before pregnancy. Obese women experience more variable changes, including lower or higher gestational weight gains²³ and lower or similar gestational fat gains,⁴² but have greater increases in central adiposity and fat deposition during the postpartum period when compared with lower BMI groups.⁴⁹ Body fat assessed via skinfold thicknesses and waist and hip circumferences in parous women (n = 47) showed that obese women developed more central obesity by 6 months' postpartum.⁴⁹ Women who are overweight before pregnancy accumulate excessive fat stores in response to pregnancy that continue into the postpartum period, or experience patterns of postpartum fat deposition that differ from those who are not overweight.

In population-based, cross-sectional studies, multiparity correlated positively with abdominal girth in women for whom childbearing ended many years earlier, and with larger waist-hip ratios (WHR) in both pre- and postmenopausal women.^{50–52} Similarly, longitudinal studies of women of reproductive age reported greater increments in WHR⁴⁵ and waist circumference from preconception for up to several years postpartum associated with an increasing number of births independent of age, secular trends, preconception BMI, weight gain, education, and selected behavioral attributes.⁶ Parity-related increases in central adiposity were also similar for blacks and whites.

Longitudinal changes in visceral and overall adiposity from preconception to postpartum were examined in 122 premenopausal women (50 black, 72 white), of whom 14 gave birth and 108 did not give birth between 1995 and 2000.⁵³ Adipose tissue compartments were measured via CT and dual energy x-ray absorptiometry in 1995 to 1996 and again in 1999 to 2000. In multiple linear regression models adjusted for age, race, and changes in total and subcutaneous adiposity, visceral adipose tissue levels increased by 40% and 14% above initial levels for the 1 birth and 0 birth groups, respectively; the visceral fat level was 18.0 cm² (4.8–31.2) higher for 1 birth versus 0 births groups controlling for gain in total body fat and covariates ($P < .01$) (Fig. 3). There was a borderline greater increase in waist girth of 2.3 cm (0–4.5) ($P = .05$), a gain of 6.3 cm (4.1–8.5) versus 4.0 cm (3.2–4.8). This study provides evidence that pregnancy may be associated with preferential accumulation of adipose tissue in the visceral compartment for similar gains in total body fat.

SUMMARY

Epidemiologic studies that measure weight before and after pregnancy in primiparas and that control for secular trends and aging have consistently found that primiparity is associated with higher weight gain among women already overweight before pregnancy.^{6,25} Furthermore, these findings consistently show that weight gain does not differ across racial and ethnic groups after controlling for pregravid body size groups.^{6,25} Findings from pregnancy cohort studies in developed countries are some-what mixed, but most report that higher postpartum weight retention is associated with high BMI before pregnancy. Bias in self-reported weight and a limited sample size (including a low percentage of overweight primiparas) may explain the conflicting findings. It is unclear whether becoming overweight after pregnancy is primarily

due to high gestational gain, altered lifestyle habits during the postpartum period, or a combination of influences. Overall, the evidence supports the conclusion that substantial weight gain associated with childbearing is an important risk factor for the development of overweight and obesity in women during midlife.¹¹

Further investigation is needed to confirm the links among primiparity, sleep duration, age at menarche, and young age at first birth in relation to becoming overweight after pregnancy, as well as the relative importance of these risk factors. More information regarding the influence of socioeconomic factors and culture practices, smoking cessation, lactation, and other behaviors on weight changes during or after pregnancy is also needed.

Within this context, future studies should identify women most likely to benefit from interventions that modify body size before conception, weight gain during pregnancy, or lifestyle during the postpartum period. Women who are most likely to benefit from interventions during one or more of these critical time periods are primiparas who are overweight or obese before pregnancy, and women who have excessive gestational weight gain regardless of parity or pregravid BMI. Morbidly obese women may be advised to gain very little during pregnancy and may benefit from intensive interventions postpartum to lose weight or slow their pre-pregnancy weight gain trajectory. Similarly, women who are moderately overweight before a first pregnancy may be advised to lose weight several months before pregnancy and to carefully control gestational weight gain from early gestation within IOM recommendations. Over-weight and obese women who have modest gestational weight gain, as well as average weight women who have excessive gestational weight gain, may benefit primarily from interventions during the postpartum period to promote weight loss. Clinicians can identify women who are susceptible to substantial postpartum weight retention, to becoming obese, or to increased central adiposity after pregnancy. These women may require subsequent evaluation for primary prevention of midlife obesity and chronic diseases.

Weight gain and overweight during midlife are strong independent predictors of cardiovascular disease, particularly among women,⁵⁴ as well as the metabolic syndrome, type 2 diabetes, and early mortality.⁵⁵⁻⁵⁷ Changes in body fat distribution and central obesity as a consequence of childbearing require further investigation. As a modifiable risk factor, weight gain during prenatal and postpartum periods may provide the critical window for conducting interventions to prevent substantial weight gain as well as the development of overweight and obesity in young women.

Acknowledgments

This article was supported by a Career Development Award, grant K01 DK059944 from the National Institute of Diabetes, Digestive and Kidney Diseases, grant R01 HD050625 from the National Institute of Child Health and Human Development, and a Clinical Research Award from the American Diabetes Association.

REFERENCES

1. Flegal KM, Carroll MD, Ogden CL, et al. Prevalence and trends in obesity among US adults, 1999–2000. *JAMA* 2002;288:1723–7. [PubMed: 12365955]
2. Centers for Disease Control & Prevention. Pediatric & pregnancy nutrition surveillance system. [Accessed April 27, 2009]. 2009 Available at: http://www.cdc.gov/pednss/pnss_tables/tables_health_indicators.htm
3. Catalano PM. Increasing maternal obesity and weight gain during pregnancy: the obstetric problems of plentitude. *Obstet Gynecol* 2007;110:743–4. [PubMed: 17906003]
4. Gunderson EP, Abrams B. Epidemiology of gestational weight gain and body weight changes after pregnancy. *Epidemiol Rev* 1999;21:261–75. [PubMed: 10682262]

5. Billewicz WZ. Body weight in parous women. *Br J Prev Soc Med* 1970;24:97–104. [PubMed: 5431074]
6. Gunderson EP, Murtaugh MA, Lewis CE, et al. 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;28:525–35. [PubMed: 14770188]
7. Rosenberg L, Palmer JR, Wise LA, et al. A prospective study of the effect of child-bearing on weight gain in African-American women. *Obes Res* 2003;11:1526–35. [PubMed: 14694218]
8. Institute of Medicine. Nutrition during pregnancy. National Academy of Sciences; Washington, DC: 1990.
9. Rooney BL, Schauburger CW, Mathiason MA. Impact of perinatal weight change on long-term obesity and obesity-related illnesses. *Obstet Gynecol* 2005;106:1349–56. [PubMed: 16319262]
10. Linne Y, Dye L, Barkeling B, et al. Weight development over time in parous women: the SPAWN study—15 years follow-up. *Int J Obes Relat Metab Disord* 2003;27:1516–22. [PubMed: 14634683]
11. Gunderson EP, Sternfeld B, Wellons MF, et al. Childbearing may increase visceral adipose tissue independent of overall increase in body fat. *Obesity* 2008;16(5):1078–84. [PubMed: 18356843]
12. Ohlin A, Rossner S. Maternal body weight development after pregnancy. *Int J Obes* 1990;14:159–73. [PubMed: 2341224]
13. Gunderson EP, Rifas-Shiman SL, Oken E, et al. Association of fewer hours of sleep at 6 months postpartum with substantial weight retention at 1 year postpartum. *Am J Epidemiol* 2008;167:178–87. [PubMed: 17971337]
14. Schmitt NM, Nicholson WK, Schmitt J. The association of pregnancy and the development of obesity: results of a systematic review and meta-analysis on the natural history of postpartum weight retention. *Int J Obes* 2007;31:1642–51.
15. Gunderson EP, Quesenberry CP Jr, Lewis CE, et al. Development of overweight associated with childbearing depends on smoking habit: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Obes Res* 2004;12:2041–53. [PubMed: 15687406]
16. Gunderson EP, Abrams B, Selvin S. The relative importance of gestational gain and maternal characteristics associated with the risk of becoming overweight after pregnancy. *Int J Obes Relat Metab Disord* 2000;24:1660–8. [PubMed: 11126221]
17. Oken E, Taveras EM, Popoola FA, et al. Television, walking, and diet: associations with postpartum weight retention. *Am J Prev Med* 2007;32:305–11. [PubMed: 17383561]
18. Parker JD, Abrams B. Differences in postpartum weight retention between black and white mothers. *Obstet Gynecol* 1993;81:768–74. [PubMed: 8469470]
19. Olson CM, Strawderman MS, Hinton PS, et al. Gestational weight gain and postpartum behaviors associated with weight change from early pregnancy to 1 y postpartum. *Int J Obes Relat Metab Disord* 2003;27:117–27. [PubMed: 12532163]
20. McKeown T, Record RG. The influence of weight and height on weight changes associated with pregnancy in women. *J Endocrinol* 1957;15:423–9. [PubMed: 13475601]
21. Brawarsky P, Stotland NE, Jackson RA, et al. Pre-pregnancy and pregnancy-related factors and the risk of excessive or inadequate gestational weight gain. *Int J Gynaecol Obstet* 2005;91:125–31. [PubMed: 16202415]
22. Chasan-Taber L, Schmidt MD, Pekow P, et al. Predictors of excessive and inadequate gestational weight gain in Hispanic women. *Obesity* 2008;16(7):1657–66. [PubMed: 18451771]
23. Wells CS, Schwalberg R, Noonan G, et al. Factors influencing inadequate and excessive weight gain in pregnancy: Colorado, 2000–2002. *Matern Child Health J* 2006;10(1):55–62. [PubMed: 16496222]
24. Cogswell ME, Serdula MK, Hungerford DW, et al. Gestational weight gain among average-weight and overweight women: what is excessive? *Am J Obstet Gynecol* 1995;172:705–12. [PubMed: 7856711]
25. Gunderson EP, Abrams B, Selvin S. Does the pattern of postpartum weight change differ according to pregravid body size? *Int J Obes Relat Metab Disord* 2001;25:853–62. [PubMed: 11439300]
26. Jensen DM, Damm P, Sorensen B, et al. Pregnancy outcome and prepregnancy body mass index in 2459 glucose-tolerant Danish women. *Am J Obstet Gynecol* 2003;189:239–44. [PubMed: 12861169]

27. Kiel DW, Dodson EA, Artal R, et al. Gestational weight gain and pregnancy outcomes in obese women: how much is enough? *Obstet Gynecol* 2007;110:752–8. [PubMed: 17906005]
28. Boardley DJ, Sargent RG, Coker AL, et al. The relationship between diet, activity, and other factors, and postpartum weight change by race. *Obstet Gynecol* 1995;86:834–8. [PubMed: 7566859]
29. Greene GW, Smiciklas-Wright H, Scholl TO, et al. Postpartum weight change: how much of the weight gained in pregnancy will be lost after delivery? *Obstet Gynecol* 1988;71:701–7. [PubMed: 3357658]
30. Schauburger CW, Rooney BL, Brimer LM. Factors that influence weight loss in the puerperium. *Obstet Gynecol* 1992;79:424–9. [PubMed: 1738527]
31. Kac G, Benicio MH, Velasquez-Melendez G, et al. Gestational weight gain and prepregnancy weight influence postpartum weight retention in a cohort of Brazilian women. *J Nutr* 2004;134:661–6. [PubMed: 14988464]
32. Keppel KG, Taffel SM. Pregnancy-related weight gain and retention: implications of the 1990 Institute of Medicine guidelines. *Am J Public Health* 1993;83:1100–3. [PubMed: 8342716]
33. Kac G, Benicio MH, D'Aquino, Valente JG, et al. Postpartum weight retention among women in Rio de Janeiro: a follow-up study. *Cad Saude Publica* 2003;19(Suppl 1):S149–61. [PubMed: 12886445]
34. Harris HE, Ellison GT, Holliday M, et al. The impact of pregnancy on the long-term weight gain of primiparous women in England. *Int J Obes Relat Metab Disord* 1997;21:747–55. [PubMed: 9376886]
35. Maddah M, Nikooyeh B. Weight retention from early pregnancy to three years postpartum: a study in Iranian women. *Midwifery*. Mar 27;2008 [Epub ahead of print].
36. Linne Y, Dye L, Barkeling B, et al. Long-term weight development in women: a 15-year follow-up of the effects of pregnancy. *Obes Res* 2004;12:1166–78. [PubMed: 15292482]
37. Butte NF, Ellis KJ, Wong WW, et al. Composition of gestational weight gain impacts maternal fat retention and infant birth weight. *Am J Obstet Gynecol* 2003;189:1423–32. [PubMed: 14634581]
38. Muscati SK, Gray-Donald K, Koski KG. Timing of weight gain during pregnancy: promoting fetal growth and minimizing maternal weight retention. *Int J Obes Relat Metab Disord* 1996;20:526–32. [PubMed: 8782728]
39. Stevens-Simon C, Roghmann KJ, McAnarney ER. Relationship of self-reported prepregnant weight and weight gain during pregnancy to maternal body habitus and age. *J Am Diet Assoc* 1992;92:85–7. [PubMed: 1728630]
40. Rowland ML. Self-reported weight and height. *Am J Clin Nutr* 1990;52:1125–33. [PubMed: 2239790]
41. Clapp JF III, Seaward BL, Sleamaker RH, et al. Maternal physiologic adaptations to early human pregnancy. *Am J Obstet Gynecol* 1988;159:1456–60. [PubMed: 3207124]
42. Lederman SA, Paxton A, Heymsfield SB, et al. Body fat and water changes during pregnancy in women with different body weight and weight gain. *Obstet Gynecol* 1997;90:483–8. [PubMed: 9380301]
43. Williamson DF, Kahn HS, Byers T. The 10-y incidence of obesity and major weight gain in black and white US women aged 30–55 y. *Am J Clin Nutr* 1991;53:1515S–8S. [PubMed: 2031480]
44. Rookus MA, Rokebrand P, Burema J, et al. The effect of pregnancy on the body mass index 9 months postpartum in 49 women. *Int J Obes* 1987;11:609–18. [PubMed: 3440682]
45. Smith DE, Lewis CE, Caveny JL, et al. Longitudinal changes in adiposity associated with pregnancy: the CARDIA Study. Coronary Artery Risk Development in Young Adults Study. *JAMA* 1994;271:1747–51. [PubMed: 8196117]
46. Williamson DF, Madans J, Pamuk E, et al. A prospective study of childbearing and 10-year weight gain in US white women 25 to 45 years of age. *Int J Obes Relat Metab Disord* 1994;18:561–9. [PubMed: 7951478]
47. Sidebottom AC, Brown JE, Jacobs DR Jr. Pregnancy-related changes in body fat. *Eur J Obstet Gynecol Reprod Biol* 2001;94:216–23. [PubMed: 11165728]
48. Sohlstrom A, Forsum E. Changes in adipose tissue volume and distribution during reproduction in Swedish women as assessed by magnetic resonance imaging. *Am J Clin Nutr* 1995;61:287–95. [PubMed: 7840065]

49. Soltani H, Fraser RB. A longitudinal study of maternal anthropometric changes in normal weight, overweight, and obese women during pregnancy and postpartum. *Br J Nutr* 2000;84:95–101. [PubMed: 10961165]
50. Troisi RJ, Wolf AM, Mason JE, et al. Relation of body fat distribution to reproductive factors in pre- and postmenopausal women. *Obes Rev* 1995;3:143–51.
51. denTonkelaar I, Seidell JC, van Noord PA, et al. Fat distribution in relation to age, degree of obesity, smoking habits, parity and estrogen use: a cross-sectional study in 11,825 Dutch women participating in the DOM-project. *Int J Obes* 1990;14:753–61. [PubMed: 2228408]
52. Kaye SA, Folsom AR, Prineas RJ, et al. The association of body fat distribution with lifestyle and reproductive factors in a population study of postmenopausal women. *Int J Obes* 1990;14:583–91. [PubMed: 2228393]
53. Gunderson EP, Murtaugh MA, Lewis CE, et al. 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]
54. Hubert HB, Feinleib M, McNamara PM, et al. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. *Circulation* 1983;67:968–77. [PubMed: 6219830]
55. Willett WC, Manson JE, Stampfer MJ, et al. Weight, weight change, and coronary heart disease in women: risk within the 'normal' weight range. *JAMA* 1995;273:461–5. [PubMed: 7654270]
56. Ford ES, Williamson DF, Liu S. Weight change and diabetes incidence: findings from a national cohort of US adults. *Am J Epidemiol* 1997;146:214–22. [PubMed: 9247005]
57. Colditz GA, Willett WC, Rotnitzky A, et al. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med* 1995;122:481–6. [PubMed: 7872581]

Fig. 1.

Percentage of women within categories of late (6 weeks to 2 years) postpartum weight change (gain >2 kg, loss >2 kg, and stable $\pm$ 2 kg) according to pregravid BMI group. (From Gunderson EP, Abrams B, Selvin S. Does the pattern of postpartum weight change differ according to pregravid body size? *Int J Obes Relat Metab Disord* 2001;25:860; with permission.)

Fig. 2.

Adjusted differences in weight gain (kg) before and after pregnancy (mean [95% CI]) among parous versus nulliparous (1 birth, 2+ births versus 0 births) CARDIA women adjusted for time, center, age, height, baseline and education, smoking status, physical activity score, and oral contraceptive use with race groups and pre-pregnancy BMI groups. Pairwise comparisons, * $P < .05$, ** $P < .01$, *** $P < .001$. (Data from Gunderson EP, Murtaugh MA, Lewis CE, et al. 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;28:525–35.)

Fig. 3. Unadjusted and adjusted mean (95%CI) 5-year changes in visceral adipose tissue (cm^2) from before to after pregnancy for women with one birth and women with no births during the 5-year interval. (From Gunderson EP, Sternfeld B, Wellons MF, et al. Childbearing may increase visceral adipose tissue independent of overall increase in body fat. *Obesity (Silver Spring)* 2008;16(5):1078–84; with permission.)

Table 1

Correlates of excessive gestational weight gain (GWG): pregravid BMI and race/ethnicity

Author, Year, Location, Study Period	Number of Subjects	Race (%)	Data Source	Excess GWG (%)	Adjusted OR (95% CI) of High GWG
Parker, 1993, USA, NMIHS, 1988	2119	Black, 47 White, 53	Survey	36 34	—
Keppel, 1993, USA, NMIHS, 1988	1592	Black, 17 White, 83	Survey	33 37	Mean GWG, 14.3 kg
Brawarsky, 2005, USA, Project WISH, San Francisco, 1980–1990	1100	Black, 16 White, 33 Latina, 36 Asian, 15	Telephone, chart review	61 57 51 47	NS for race Pregravid BMI (vs NW) OW: 2.3 (1.4–3.6)
Wells, 2006, USA, PRAMS, Denver, CO, 2000–2002	9115	Black, 4 White, 64 Hispanic, 28 Other, 3	Birth certificate	46 43 36 35	NS for race Pregravid BMI (vs NW) OW: 2.7 (2.0–3.4) OB: 6.6 (4.0–10.8)
Chasan-Taber, 2008, USA, West, MA	770	Hispanic (Puerto Rican), 100	—	45	Pregravid BMI (vs NW) OW: 2.2 (1.3–3.8)

Abbreviations: OR, odds ratio; NMIHS, National Maternal and Infant Health Survey; NW, normal weight; OB, obese; OW, overweight; WISH, Women and Infants Starting Healthy; PRAMS, pregnancy risk assessment and monitoring system.

Table 2

Percentage of women classified with substantial postpartum weight retention (weighing ≥ 5 kg above pre-pregnancy weight at postpartum measurement) in pregnancy cohort studies (n >500)

Author, Year, Country, Years Data Collected	Sample Size	Age Range (years)	Time of Postpartum Measurement	Overweight Before Pregnancy (%)	Substantial Weight Retention ≥ 5 kg (%)
Schauberger, 1995, USA, 1989–1990	790	Not stated	6 wks 6 mos	Not reported	>16
Ohlin, 1990, Sweden, 1971–1984	463	17–49	12 mos	7 ^b	14
Keppel, 1993, ^a USA, 1988	1423	>15	10–18 mos	10 ^b	>20
Greene, 1988, ^a USA, 1959–1965	2944	23 $\pm$ 11	Variable (between 2 pregnancies)	24 ^d	~20
Gunderson, 2001, USA, 1980–1990	7116	18–41 (mean, 27)	Variable (between 2 pregnancies)	13 ^b	18
Olson, 2003, USA, not stated	1300	18 to >40	12 mos	41 ^b	~20
Huang, 2008, Taiwan, 2004	540	30 $\pm$ 4	6 mos	19 ^c	25
Gunderson, 2008, USA, 1999–2003	602	33 $\pm$ 5	12 mos	25 ^b	13

^aSample includes teenagers.

^bDefined as BMI ≥ 26 .

^cDefined as BMI ≥ 24 .

^dDefined as >120% of ideal body weight for height.

Table 3

Longitudinal studies of women of reproductive age: weight gain associated with childbearing (nulliparous referent group and preconception and postpartum weight measurements, except self-reported weights by Rosenberg and colleagues)

Author, Year, Study	Number of Parous Subjects (primiparas)	Race, Age Range (yr) at Baseline	Study Period	Childbearing Weight Gain (kg) (Net Difference in Mean Gain for Paras versus Nulliparas)
Williamson, 1994, NHEFS, USA	308 (82)	White, 25–45	10 yrs (1971–1984)	Primiparas: 0 Multiparas: +1.7 kg per birth
Wolfe, 1997, NHEFS, USA	413 (not stated)	86% White, 25–45	10 yrs (1971–1984)	White race: Primiparas +0.5 kg Multiparas +3.2 kg Black race: Primi & Multiparas +2.3 kg
Smith, 1994, CARDIA study, USA	203 (89)	50% Black/white, 18–30	5 yrs (1985–1991)	Primiparas +2 – 3 kg
Gunderson, 2004, CARDIA study, USA	845 (557)	50% Black/white, 18–30	10 yrs (1985–1996)	Primiparas by Pregravid BMI: BMI < 25: +1 kg BMI ≥ 25: +3 –6 kg (3-way interaction: $p < .001$) ^a
Rosenberg, 2003, BWHS, USA	1230 (598)	Black, 21–39	4 yrs (1995–1999)	Primiparas by Pregravid BMI BMI < 25: +0.6 kg BMI ≥ 25: +3.0 kg or more

^aSignificant three-way interaction by parity, baseline BMI group (overweight and not overweight), and childbearing groups during follow-up. No significant interaction for race. Gunderson and colleagues (2004) and Rosenberg and colleagues (2003) had sufficient sample size to examine parity and pregravid BMI effect modification. NHEFS, NHANES I epidemiologic follow-up study; CARDIA, coronary artery risk development in young adults study; BWHS, black women's health study.