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Optimizing weight gain in pregnancy to prevent obesity in women and children

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Abstract

Pregnancy is now considered to be an important risk factor for new or persistent obesity among women during the childbearing years. High gestational weight gain is the strongest predictor of maternal overweight or obesity following pregnancy. A growing body of evidence also suggests that both high and low gestational weight gains are independently associated with an increased risk of childhood obesity, suggesting that influences occurring very early in life are contributing to obesity onset. In response to these data, the United States Institute of Medicine (IOM) revised gestational weight gain guidelines in 2009 for the first time in nearly two decades. However, less than one-third of pregnant women achieve guideline-recommended gains, with the majority gaining above IOM recommended levels. To date, interventions to optimize pregnancy weight gains have had mixed success. In this paper, we summarize the evidence from human and animal studies linking over-nutrition and under-nutrition in pregnancy to maternal and child obesity. Additionally, we discuss published trials and ongoing interventions to achieve appropriate gestational weight gain as a strategy for obesity prevention in women and their children.

Keywords

Gestational weight gain; Obesity; Pregnancy; Maternal health; Child health; Postpartum; Fetal growth

Introduction

Obesity remains a global health crisis. Currently half of European adults meet criteria for overweight (body mass index [BMI] 25–29.9 kg/m^2) or obesity (BMI ≥ 30 kg/m^2) [1]. In the United States (US), the prevalence of obesity among adults exceeds 33%, with an additional 34% categorized as overweight [2]. Children are also affected; almost 32% of 2- through 19-

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year-old US children and adolescents along with 20% of European children are overweight or obese (BMI for age and sex at or above the 85th percentile) [3, 4]. High rates of obesity beget high rates of diabetes mellitus and cardiovascular disease [5], even among children [6].

Pregnancy is now considered to be a strong risk factor for new or persistent obesity. Recently published data from the US National Longitudinal Survey of Youth revealed that parous women (those who have had 1 or more live births) were 3 to 4 times more likely to develop obesity in the 5 years after childbirth compared to nonparous women followed over the same time period [7]. High gestational weight gain is the strongest predictor of maternal overweight or obesity following pregnancy [8]. Other identified risk factors, including sociodemographic characteristics and modifiable postpartum behaviors [9–14], account for very little of the variability in postpartum weight change. Additionally, a growing body of evidence suggests that both high and low gestational weight gains are independently associated with an increased risk of childhood obesity [15, 16], suggesting that influences occurring very early in life are also contributing to obesity onset.

In response to these data, the US Institute of Medicine (IOM) revised gestational weight gain guidelines in 2009 for the first time in nearly two decades (Table 1), recommending the most restrictive gains since the early part of the 20th century, particularly for women who are already overweight or obese entering pregnancy [17]. While achieving an infant birth weight of between 3000 and 4000 grams remains the primary goal of these guidelines to ensure the lowest risk of short-term infant morbidity and mortality, the 2009 recommendations have also taken into account the long-term maternal and child complications from both high and low weight gains [17]. However, currently less than one-third of pregnant women achieve guideline recommended gains, with the majority gaining above IOM recommended levels [18, 19]. Attempts to optimize pregnancy weight gains are therefore critical for obesity prevention efforts in both women and their children.

In this article, we outline the physiology of gestational weight gain and its association with fetal growth. We summarize the evidence from human and animal studies linking over-nutrition and under-nutrition in pregnancy to maternal and child obesity. We present the known sociodemographic and behavioral predictors of high and low gestational weight gains followed by a review of published randomized controlled trials designed to achieve appropriate gestational weight gain. Finally, we discuss ongoing and future intervention strategies to optimize pregnancy weight gains.

Why do women gain weight in pregnancy?

The weight gained in a normal pregnancy is the result of biologic processes that promote fetal growth. Although the composition of weight gained during pregnancy varies across women, a general picture can be described. Approximately 27% resides in the fetus, 20% includes the placenta, amniotic fluid and uterus, 3% comprises breast weight, 23% is made up of blood volume and extravascular fluid, and the remaining 27% consists of maternal fat stores [17]. In early to mid-pregnancy, underweight and normal weight women (pre-pregnancy BMI < 25 kg/m^2) deposit fat in their hips, back, and upper thighs, which is thought to be important as a caloric reserve for late pregnancy and lactation [20]. Insulin secretion and sensitivity rise, favoring increased lipogenesis and fat accumulation, in preparation for the increased energy needs of the growing fetus [21]. However, women entering pregnancy overweight or obese (who may already have some baseline insulin resistance), do not have this same rise in peripheral insulin sensitivity in early pregnancy and little or no additional fat is accrued, perhaps due to a reduced need for extra caloric reserves [22]. By late pregnancy, insulin resistance increases among all mothers (although it is more

pronounced in obese women) and weight gain slows, a normal physiologic adaptation that shifts maternal energy metabolism from carbohydrate to lipid oxidation and thus spares glucose for the fetus [23]. This complex series of adjustments in carbohydrate and fat metabolism ensure that the fetus receives a continuous supply of fuel when its needs are maximal.

The pattern of gestational weight gain is most commonly described as sigmoidal, with the majority of weight gained in the 2nd and early 3rd trimesters of pregnancy [17]. A higher rate of maternal weight gain in the second trimester is most strongly correlated with higher infant weight at birth [24]. This association is particularly strong among women with a low or normal pregravid BMI [25]. Across studies published in the US since 1985, total pregnancy weight gains of normal weight adult women giving birth to healthy term infants ranged from a low of 10.0 kg to a high of 16.7 kg [17]. Among women who are overweight or obese, however, gestational weight gain is a less strong predictor of fetal growth [26]. Healthy term infants have been born to these women despite lower total gestational weight gains (mean gain 9 kg, standard deviation 7.4 kg)[27]. Recent data have suggested that the lowest prevalence of adverse birth outcomes for very obese (BMI ≥ 40 kg/m^2) women (including preterm delivery and low birth weight) occurs with weight loss [28–31].

Gestational weight gain and obesity risk in mother and child

Lower gains may have additional benefits for the short- and long-term weight status of women and children. A number of epidemiologic studies suggest that lower gains may be protective against postpartum maternal weight retention and obesity [11, 32–38]. In contrast, women with higher gains remain heavier; for example, in one observational study, women with average gains of 17.7 kg vs. 13.1 kg had higher BMI and more central adiposity that persisted 16 years after the index pregnancy, even after adjusting for parity, total caloric intake, physical activity, smoking, breastfeeding, and pre-pregnancy BMI [38]. Higher gestational weight gains are also associated with higher offspring weight at birth [24, 39–42], in childhood [43–45], during adolescence [46–48], and as adults [49, 50]. Similar results have been found among the offspring of rodent dams fed obesogenic diets during pregnancy [51–53]. While shared genes and behaviors explain part of the risk, maternal over-nutrition appears to have a direct influence on several aspects of offspring physiology, including appetite, metabolism, and activity levels [54]. Offspring of overfed rat dams have reduced energy expenditure [51, 52], and a greater taste for junk food [53], as do human children of obese mothers [55, 56]. Maternal prenatal over-nutrition may also result in increased fetal adipose tissue deposition [57]. Since adipocyte number appears to be set in the first years of life [58], excess fat formed in early life may result in lifelong excess adiposity. Lower gestational weight gains seem to improve birth outcomes and reduce risk of childhood obesity, especially among obese mothers [59, 60].

Worth noting, however, are several studies that have reported a U- or J-shaped association between gestational weight gain and child adiposity, with greater overweight risks also with the lowest maternal gains, especially in women with lower pre-pregnancy BMI [61, 62]. Although lower gains are associated with lower fetal growth, a body of literature suggests that prenatal under-nutrition is associated with later obesity, cardiovascular disease, and diabetes [16, 63]. Under-nutrition sets in motion a “survival phenotype” that aids in early life survival but has adverse consequences from adolescence through adulthood [64]. Once born and exposed to a world of plenty, neonates with poor in-utero nutrition may undergo catch-up growth or rapid weight gain. This early accelerated growth has been shown to adversely affect glucose metabolism, lipids, and blood pressure in adolescents who were born small, perhaps in part because most of the catch-up body weight distributes centrally and results in insulin resistance [65, 66]. Neonates with in-utero exposure to the Dutch

Hunger Winter of 1944–45 experienced catch-up growth after food rations were lifted and were more likely to experience adult disease (insulin resistance, dyslipidemia, central adiposity, and hypertension) than neonates exposed to prolonged under-nutrition both during and after pregnancy [66, 67]. Similarly, rats randomized to chronic maternal undernutrition in-utero were significantly smaller than control well-fed rats until 12 weeks of age [68]. However, after starting a normal diet, these previously restricted rats were larger and more likely to be hypertensive at 30, 48 and 56 weeks of age than the unrestricted controls. Thus, both maternal prenatal under-nutrition and over-nutrition may alter weight regulation and cardiovascular risk in offspring.

In the context of our current obesity epidemic, how much weight gain in pregnancy is ideal?

Determining if and how much weight gain is necessary in pregnancy is clearly complicated, and depends on the relative adversity of its various sequelae. If small size at birth is considered substantially worse than other outcomes because of its links with later cardiovascular disease and adverse neurologic development [63, 69], higher gains might be preferable, particularly for women who begin pregnancy underweight or normal weight. On the other hand, minimizing gains might be ideal if maternal postpartum weight retention or child obesity is rated worse, especially for women with pregravid obesity. In 2009, the IOM used available data to determine the most favorable amount of weight gain considering 5 short- and longer-term outcomes: extremes of birth weight (expressed as small- or large-for-gestational age), cesearean delivery, preterm birth, postpartum weight retention, and child obesity [70]. Previously, they did not take into account the long-term maternal and child complications from both high and low weight gains. The committee found that the lowest-risk gestational weight gains were within prior recommended ranges for women who were normal weight or overweight entering pregnancy but were lower for obese women. Modifications were then made to the guidelines for weight gain in pregnancy and published in 2009, recommending smaller weight gains for obese mothers, based on data primarily from women with BMI values of 30–34.9 kg/m^2 (Table 1) [17]. However, the IOM committee did not stratify their recommendations for obese women further; no additional guidance was given for women with class II (BMI ≥ 35–39.9 kg/m^2) or class III (BMI ≥ 40 kg/m^2) obesity. The committee continued to discourage weight loss during pregnancy, even among the very obese, citing insufficient evidence that low weight gains or weight loss wouldn't lead to small size at birth and poor neurologic outcomes in the offspring [71]. Given rising numbers of class II and III obese gravid women [2], more research is needed to determine if greater weight restriction in pregnancy, or no weight gain at all, will achieve the best short and long-term maternal and child outcomes for these heaviest mothers.

Why is it so hard to achieve guideline recommended weight gain in pregnancy?

Despite continued debate over the optimal range of gestational weight gain for obese mothers, too few mothers of all pregravid BMI categories gain within recommended ranges, and excessive gain is more common than inadequate gain [10]. For example, among 427 low-income, ethnically diverse mothers, Gould Rothberg *et al.* found only 22% of women gained weight within 2009 IOM guidelines according to pre-pregnancy BMI, with the majority of women (62%) exceeding IOM weight gain recommendations [19].

A complex interplay among biological, psychosocial, and behavioral factors influences the amount of weight a woman gains in pregnancy. Despite the consistent inverse relationship observed between total gestational weight gain and pregravid BMI category, overweight and

obese women are nearly 2 times more likely to exceed IOM recommended gains compared to normal weight women [18, 72, 73]. Underweight women, on the other hand, are more likely to gain below IOM guidelines [72]. Additionally, mutiparity, smoking during pregnancy, older age and being of low income, black or Hispanic race/ethnicity, un-married status, and limited education are associated with inadequate gain [17, 74, 75]. A number of these same sociodemographic characteristics have also emerged as risk factors for gaining above IOM recommendations. For example, among a sample of 622 predominately white women living in New York State, Olson *et al.* found that those with household incomes below 185% of the US federal poverty line were 2.5 times more likely to gain excessively in pregnancy than those women with higher incomes [76].

Not surprisingly, modifiable behaviors, including dietary intake and physical activity, influence the amount of weight a woman gains in pregnancy. While current recommendations encourage the gravid woman to increase caloric consumption by approximately 300 kcal per day [77], particularly in the second and third trimesters, higher energy intake during pregnancy is correlated with greater absolute weight gain and increased risk of exceeding guideline recommended gain [76, 78, 79]. Many mothers still believe they need to “eat for two” to have a healthy baby, promoting overeating and higher gains [80]. On the other hand, consuming “a lot less food in pregnancy” is associated with inadequate gestational weight gain [76]. This latter finding may be modified by BMI, as limiting caloric intake among obese women has been shown to appropriately reduce absolute and guideline recommended gains [81]. Less is known about the relationship of specific dietary components with weight gain in pregnancy. Extrapolating from studies among non-pregnant women, increased consumption of starches (particularly potatoes and potato chips), sugar-sweetened beverages, and processed meats may independently and aggregately promote weight gain while fruits, vegetables, nuts, and yogurt may be protective against higher gains [82]. Data examining physical activity, ranging from walking to more vigorous activity, have revealed an inverse relationship between greater activity and excessive gestational weight gain [76, 78, 83]. Exercise alone may even be enough to lower total weight gain in pregnancy [84]; however, most pregnant women reduce their time spent in physical activity [85], increasing their risk for higher gains.

How can we help more mothers achieve recommended gestational weight gains?

Could the obstetric provider be the answer? Because pregnant women have frequent interactions with the health care system, obstetric clinicians are uniquely positioned to address weight gain with their pregnant patients. In fact, data suggest that women’s actual weight gain in pregnancy is strongly correlated with health care provider advice [86, 87]. Cogwell *et al.* found that women who received advice from their health care provider to gain within IOM recommended ranges were 2 times more likely to gain within those ranges than women who did not receive any advice [86]. However, in a recent study of 401 pregnant women from Providence, Rhode Island, fewer than half (41.7%) reported receiving weight gain advice from a practitioner [88]. Further, the small number of obstetric providers who do advise their patients may not be recommending gestational weight gain ranges concordant with IOM guidelines, particularly for overweight or obese women [88, 89]. Several interventions to promote recommended gestational weight gain have included clinician advice as one component of the intervention [90–93]. However, these interventions have generally not been successful in improving the proportion of women gaining within recommended limits [90, 91, 93], or were successful only in a subset of women [92].

Intervention studies to promote recommended gestational weight gain at the individual level have also used other providers, including dietitians, health coaches, and public health nurses,

to deliver nutrition and healthy weight gain messages to pregnant mothers with somewhat more success. For example, in 2008, Wolff *et al.* randomized 50 obese pregnant women in Denmark to either 10, 1-hour dietary consultations with a trained dietitian or to usual care [81]. The women in the intervention group successfully limited their energy intake and restricted their total gestational weight gain to an average of 6.6 kg compared to 13.3 kg in the control group (p=0.002). Phelan *et al.* conducted the largest randomized controlled trial (n=401) to date designed to decrease the proportion of pregnant women exceeding IOM recommendations for weight gain [94]. The women in the intervention group were provided a multi-component program that included: 1) 1 in-person visit with a dietitian at treatment onset providing education about appropriate gestational weight gain, exercise, and healthy diet; 2) automated postcards mailed weekly with additional educational information; 3) personalized graphs for weight gain mailed after each clinic visit; 4) 3, 15-minute dietitian support telephone calls; and 4) supplementary supportive telephone calls for mothers over or under weight gain guidelines. Intent-to-treat analyses showed that the intervention decreased the percentage of normal weight women who exceeded IOM recommendations compared to standard care (40.2% vs. 52.1%, p=0.003), but did not successfully reduce excessive gestational weight gain among overweight or obese women (66.7% vs. 61.1%, p=0.33). However, normal and overweight/obese women assigned to the intervention were both more likely to return to their pregravid weights or below by 6 months postpartum compared to standard care (30.7% vs. 18.7%, p=0.005). Because the intervention in Phelan's study stopped after delivery, their findings suggest that interventions during pregnancy may exert an ongoing influence over the health and well-being of women, even if they fail to show significant changes in pregnancy weight or weight-related behaviors. A summary of the 7 randomized clinical trials specifically designed to prevent excessive gestational weight gain can be found in Table 2 [81, 90, 93–97].

Seven systematic or meta-analytic reviews have been published since 2010 of behavior-based dietary and/or physical activity interventions designed to limit gestational weight gains and reduce the proportion of mothers exceeding guideline recommended gains [84, 98–103]. The results of these reviews are mixed: two concluded that mean gestational weight gain was not statistically lower among intervention groups than control groups [99, 103]; two concluded that gestational weight gain was reduced only in some populations, and often not to the levels recommended by the IOM [98, 101]; and three concluded that mean gestational weight gain was reduced among dietary and/or physical activity intervention groups compared with controls, but did not comment on whether these interventions affected the proportion of mothers achieving guideline recommended weight gains [84, 100, 102]. Significant heterogeneity in the trials chosen for inclusion and in the trials themselves (e.g., intervention content and dose, self-reported vs. measured weight variables used in the calculation of gestational weight gain, attrition, randomized vs. non-randomized study designs) explains much of the inconsistencies among these reviews. No specific intervention strategy, such as individual nutrition counseling or weight monitoring, appeared particularly effective or ineffective. Thus, evidence-based recommendations to guide clinical practice around weight control in pregnancy remain elusive.

Within the next five years, however, fewer questions may remain unanswered. In 2011, the US National Institutes of Health issued a call for proposals "to conduct studies testing behavioral/lifestyle interventions in overweight and obese pregnant women designed to improve weight and metabolic outcomes in both the pregnant women and their offspring. Studies are expected to continue follow-up of mothers and their offspring for a minimum of 12 months postpartum." Five to six projects are projected to be funded in late 2011. Additionally, two large studies among pregnant women are currently ongoing. Investigators in upstate New York are recruiting and randomizing nearly 5,000 pregnant women to receive either 1) an electronically-mediated behavioral weight control intervention program

only during pregnancy, 2) the same intervention program both during and after pregnancy, or 3) non-weight related content at the project web site. The goals of the interventions are to decrease the prevalence of excessive weight gain during pregnancy and excessive weight retention (> 5 pounds) in the first 18 months postpartum in a racially/ethnically diverse sample of both higher and lower income women who enter pregnancy with normal, overweight, and obese BMI [104]. At the same time, researchers at the University of Adelaide, Australia, are working to limit gestational weight gain among a diverse population of 2500 overweight and obese pregnant women. Data on body composition and cardio-metabolic outcomes for mother and child will also be collected [105].

In summary, efforts to help mothers gain within IOM recommended ranges in pregnancy offer a strategy for prevention of new or persistent obesity in young women and children. These efforts are also likely to be economical, as a single intervention could benefit the health of mother, her child, future pregnancies, and subsequent generations. Ongoing and planned research will provide greater guidance in the coming years regarding the best way to support women in how to achieve optimal gains, with the potential to reduce the exceedingly high prevalence of obesity worldwide.

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Table 1

Total weight gains and rates of weight gain recommended for women with singleton pregnancies, 2009 Institute of Medicine guidelines [17]

	Recommended total weight gain ranges		Recommended rates of weight gain in the 2nd and 3rd trimester*	
Pre-pregnancy weight status (body mass index category)	**Pounds**	**Kilograms**	**Pounds/week**	**Kilograms/week**
Underweight (<18.5 kg/m^2)	28–40	12.5–18	1.0 (1.0–1.3)	0.51 (0.44–0.58)
Normal (18.5–24.9 kg/m^2)	25–35	11.5–16	1.0 (0.8–1.0)	0.42 (0.35–0.50)
Overweight (25–29.9 kg/m^2)	15–25	7–11.5	0.6 (0.5–0.7)	0.28 (0.23–0.33)
Obese (≥ 30 kg/m^2)	11–20	5–9	0.5 (0.4–0.6)	0.22 (0.17–0.27)

*Calculations assume a 0.5–2 kg (1.1–4.4 lbs) weight gain in the first trimester

Table 2

Randomized controlled trials specifically designed to prevent excessive gestational weight gain *

Study	Sample & Setting	Intervention	Main findings
Asbee *et al.* 2009 [90]	Primarily Hispanic or African- American women recruited from resident obstetric clinic in Charlotte, North Carolina before 16 weeks' gestation 60 underweight and normal BMI (35 I) 18 overweight BMI (10 I) 22 obese BMI (12 I)	1 intensive counseling session by a dietitian on diet, lifestyle, and appropriate gestational weight gain at 1st obstetric visit Health care provider monitoring of weight at follow-up visits; advice given about diet or exercise if weight gain not within IOM guidelines	No significant effect on % adhering to IOM recommendations by BMI (no p values provided) Underweight and normal BMI: 80% I vs. 68.8% C Overweight BMI: 30% I vs. 25% C Obese BMI: 33.3% I vs. 20% C Significant differences on total weight gain (28.7 lbs I vs. 35.6 lbs C, p=0.01) No significant differences in mode of delivery
Guelinckx *et al.* 2010 [95]	Obese (BMI ≥ 30) women recruited from University Hospital of Leuven in Belgium before 15 weeks' gestation 37 passive I group 42 active I group 43 C group	Passive intervention group given brochure with advice on nutrition, activity, and tips to limit pregnancy- related weight gain at 1st prenatal visit Active intervention group received brochure and were counselled by nutritionist in 3,1-hour group sessions on healthy diet and activity using behavior modification techniques	No significant effect on % adhering to IOM recommendations (27% passive I vs. 26.2% active I vs. 23.3% C, p=0.981) No significant differences on total weight gain (10.9 kg passive I vs. 9.8 kg active I vs. 10.6 kg C, p=0.749) The passive and active groups had significantly lower energy intake, but no differences in activity No significant differences in obstetrical or neonatal outcomes
Haakstad *et al.* 2011 [96]	Nulliparous women recruited via advertisements and health care provider referrals in Norway before 24 weeks gestation 52 I 53 C	Twice weekly, 60-minute supervised aerobic dance classes for a minimum of 12 weeks plus encouragement to do an additional 30 minutes of self- imposed moderate activity on the remaining weekdays	No significant effect on % adhering to IOM recommendations (67% I vs. 62% C, p=0.59) No significant differences on total weight gain (13.0 kg I vs. 13.8 kg C, p=0.31) No miscarriages in either group No significant differences in weight retention at 6–12 weeks postpartum (3.3 kg I vs. 3.3 kg C, p=0.93)
Jeffries *et al.* 2009 [93]	Australian women recruited from public hospital in Melbourne before 14 weeks' gestation 125 I 111 C Approximately 64% underweight or normal BMI, 16% overweight BMI, 20% obese BMI (relatively equal between groups)	Education from midwives about IOM weight gain guidelines by BMI Weight gain graph	No significant effect on % adhering to IOM recommendations (82% I vs. 77% C, p=0.42) Significant effect on rate of weight gain in overweight group only (mean difference between I and C in overweight group, 0.12 kg/wk, p=0.01) No significant differences in obstetrical or neonatal outcomes
Phelan *et al.* 2011 [94]	Primarily nulliparous women recruited from obstetric offices in Providence, Rhode Island between 10 to 16 weeks' gestation 186 normal BMI (92 I) 177 overweight/obese BMI (87 I)	1 in-person visit with a dietitian at treatment onset about appropriate weight gain, exercise, and diet Educational automated postcards mailed weekly Personalized graphs for weight gain mailed after each clinic visit 3, 15-minute dietitian support calls Additional supportive calls for mothers over or under weight gain guidelines	Significant effect in normal BMI women only (%gaining above IOM recommendations, 40.2% I vs. 52.1% C, p=0.003) No significant differences on total weight gain by BMI Significant effect on proportion of normal BMI and overweight/obese BMI women who returned to their pre-pregnancy weights by 6 months postpartum (30.7% I vs. 18.7% C, p=0.005) Normal BMI women in I group had fewer obstetrical and neonatal complications
Polley *et al.* 2002 [97]	Black and white low-income women recruited from hospital-based clinic in Pittsburgh, Pennsylvania before 20 weeks' gestation 61 normal BMI (30 I) 49 overweight BMI (27 I)	In-person (by nutritionist or clinical psychologist), telephone, and mailed education about appropriate weight gain, exercise, and healthy diet with increasingly structured goals if weight exceeded IOM guidelines Personalized graphs for weight gain mailed after each clinic visit	Significant effect in normal BMI women only (%gaining above IOM recommendations, 33.3% I vs. 58.1% C, p<0.05) Non-significant trend in opposite direction for overweight women (% gaining above IOM recommendations, 59.3% I vs. 31.8%, p=0.09) No significant differences in diet, activity, or obstetrical or neonatal outcomes

Study	Sample & Setting	Intervention	Main findings
Wolff *et al.* 2008 [81]	Obese (BMI ≥ 30) women recruited from Herlev Hospital in Sweden before 15 weeks' gestation 23 I 27 C	10, 1-hour counseling sessions with a dietitian instructing women to eat a healthy diet according to Danish dietary recommendations, with restricted energy intake	Significant effect on total weight gain (6.6 kg I vs. 13.3 kg C, p=0.002) Significant lower energy intake in I women Serum-insulin and leptin were reduced by 20% in I No significant differences in obstetrical or neonatal outcomes Significant effect on weight retention at 4 weeks postpartum (−4.5 kg I versus −2.4kg, p=0.003)

*I=Intervention group; C=Control Group; BMI=body mass index; IOM=Institute of Medicine