Published in final edited form as:

Am J Obstet Gynecol. 2009 July ; 201(1): 58.e1–58.e8. doi:10.1016/j.ajog.2009.02.025.

Associations of diet and physical activity during pregnancy with risk for excessive gestational weight gain

Alison M. STUEBE, MD, MSc¹, Emily OKEN, MD, MPH², and Matthew W. GILLMAN, MD, SM^{2,3}

¹ Division of Maternal-Fetal Medicine, Brigham and Women's Hospital, Boston, MA

² Obesity Prevention Program, Department of Ambulatory Care and Prevention, Harvard Medical School/Harvard Pilgrim Health Care, Boston, MA

³ Department of Nutrition, Harvard School of Public Health, Boston, MA

Abstract

Objective—We sought to identify modifiable risk factors for excessive gestational weight gain (GWG).

Study Design—We assessed associations of diet and physical activity with excessive gain among 1388 women from the Project Viva cohort study.

Results—379 (27%) of women were overweight (BMI $\geq$ 26kg/m²) and 703 (51%) experienced excessive GWG, according to Institute of Medicine guidelines. In multivariable logistic regression models, we found that intake of total energy (OR 1.10, 95% CI 1.00–1.22, per 500 kcal/day), dairy (1.08, 95% CI 1.00–1.17, per serving/day), and fried foods (OR 3.47, 95% CI 0.91–13.24, per serving/day) were directly associated with excessive GWG. First trimester vegetarian diet (0.46, 95% CI 0.28–0.78) and mid-pregnancy walking (0.91, 95% CI 0.82–1.00, per half-hour/day) and vigorous physical activity (0.76, 95% CI 0.60–0.97, per half-hour/day) were inversely associated with excessive GWG.

Conclusion—Healthful diet and greater physical activity are associated with reduced risk for excessive gestational weight gain.

Keywords

diet; obesity; physical activity; pregnancy; weight gain

Introduction

In the current era of epidemic obesity, excessive gestational weight gain is emerging as an important predictor of maternal and offspring obesity, as well as obstetrical complications. Independent of their weight entering pregnancy, mothers who gain excessively during

Correspondence and reprint requests to: Alison Stuebe, MD, MSc, Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, School of Medicine, University of North Carolina at Chapel Hill, 3010 Old Clinic Building, CD# 7516, Chapel Hill, NC 27599-7516. Phone: 919-966-1601. Home: 919-883-4961. Fax: 919-966-6377. Email: E-mail: astuebe@med.unc.edu.

Location where study was conducted: Eastern Massachusetts

Prior Presentation: Preliminary results were presented at the Society for Maternal-Fetal Medicine, Dallas, Texas, Abstract #255, January 31, 2008.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

pregnancy are more likely to deliver by c-section^{1–4}, have an unsuccessful trial of labor after c-section⁵, develop pre-eclampsia³, retain excessive weight after delivery⁶, and become overweight or obese in later life^{7, 8}. Infants born to women who gain excessively during pregnancy are more likely to be born preterm⁹, be macrosomic at birth (> 9 lbs)^{2, 10, 11}, and become overweight or obese as toddlers,¹² adolescents¹³, and adults¹⁴.

Previously reported sociodemographic predictors of excessive gain include nulliparity, prepregnancy overweight body mass index, low income, and young maternal age^{15–17}. Limited data are available, however, regarding modifiable predictors of excessive gestational weight gain. We therefore explored associations of diet and physical activity with excessive gestational weight gain in Project Viva, a prospective cohort study of maternal and child health.

Methods

Women were recruited for Project Viva at their first prenatal visit at one of eight urban and suburban obstetrical offices of a multispecialty group practice in eastern Massachusetts. To be eligible for the study, potential participants were required to be fluent in English, <22 weeks gestation at study entry, and have a singleton pregnancy; 65% of women who met these criteria agreed to participate in the study. All participants provided written informed consent. A human studies committee approved all procedures in accordance with ethical standards for human experimentation.

Of 2128 women who delivered a live singleton infant, 2083 delivered after 34 weeks. We excluded from our study those missing information on pre-pregnancy BMI and gestational weight gain (N=31). Of the remaining 2052 women, we excluded those missing data on covariates associated with excessive gestational weight gain, including maternal age, race, first trimester nausea, household income, and smoking status (n=226). Among the remaining 1826 women, 1388 provided data on both first- and second-trimester diet and on mid-pregnancy physical activity, making them eligible for inclusion in our analysis.

Compared with the 2052 women potentially eligible for our study, those for whom diet, physical activity, or covariate data were not available were more likely to be black (30% vs. 10%) or Hispanic (11% vs. 5%), younger than 25 (18% vs. 5%) and multiparous (58% vs. 50%) than women who were included in the analysis. They were also more likely to be obese (24% vs. 15%). Rates of excessive gain were similar in the two groups (50 vs. 51%).

Measures of gestational weight gain

We determined gestational weight gain by calculating the difference between self-reported pre-pregnancy weight and the last weight recorded prior to delivery. Self-reported pre-pregnancy weight has been previously validated in our cohort¹⁸. We defined excessive weight gain as gain greater than the upper limit for each woman's pre-pregnancy BMI category by Institute of Medicine guidelines¹⁹. The guidelines recommend that women with a BMI < 19.8 kg/m² should gain 12.5–18 kg; those with a BMI of 19.8–26.0 kg/m² should gain 11.5–16 kg, and those with a BMI of 26.0–29.0 kg/m² should gain 7–11.5 kg, and those with a BMI > 29.0 kg/m² should gain at least 6.8 kg. We used an upper limit of 11.5 kg for women in this high BMI group.

Assessment of exposures

We assessed dietary exposures with semi-quantitative food frequency questionnaires administered in the first and second trimesters of pregnancy. The 166-item questionnaires were modified slightly from the extensively validated FFQ used in the Nurses' Health Studies and several other large cohort studies. At a mean of 11.7 weeks of gestation, participants completed

the first questionnaire, which covered diet since the last menstrual period, and at a mean of 29.2 weeks of gestation, they completed the second questionnaire, which covered the previous three months. The Project Viva FFQ has been biochemically calibrated in a pilot study of 72 African American and 132 Caucasian pregnant women²⁰. Because we have previously shown little change between intakes of most first and second-trimester foods and nutrients in our cohort²⁰, we used the mean of first and second trimester intake for our primary analysis. As a secondary analysis, we tested whether change in intake from first to second trimester was associated with excess weight gain.

We estimated servings per day of several foods, including sugar sweetened beverages, fried foods, dairy, fruits and vegetables, red and processed meats and whole grains. Whole milk dairy included servings per day of whole milk yogurt, cottage cheese, cream cheese, other cheese, whole milk, ice cream and milk shakes. We also estimated intake of total energy and several nutrients, including fiber, glycemic index and glycemic load. We used the nutrient residual method to energy-adjust fiber, glycemic index and glycemic load, and we modeled dietary fat, proteins and carbohydrates using energy density. During interviews in the first and second trimesters, participants were asked, “Since you learned you were pregnant, have you been eating a vegetarian diet? (A diet that excludes certain animal products).” We examined the association between vegetarian diet in each trimester and excessive gain separately because some women reported adhering to a vegetarian diet in one trimester but not the other (31 in the first but not the second trimester, 19 in the second but not the first trimester).

We assessed physical activity using a questionnaire modified from the Physical Activity Scale for the Elderly²¹. At 26–28 weeks’ gestation, participants reported hours per week of television watching, walking, light-to-moderate activities excluding walking, and vigorous activity during the previous 3 months. We calculated hours per week of total activity by summing walking, light-to-moderate and vigorous activity. We defined sedentary lifestyle as <2.5 h/wk, or less than 22 minutes per day, of total activity.

Covariates

We used participant interviews and questionnaires to collect data on parity (0,1,2 or 3+), age (14–<20, 20–<25, 25–<30, 30–<35, 35–<40, or ≥40 years), race (White, Black, Hispanic, Asian, or Other), employment status (student, employed less than 35 hours per week, employed greater than 35 hours per week, unemployed and not looking for work, unemployed and looking for work, or on maternity leave), work-related physical activity (low level of physical work vs. moderate or high level of physical work), household income (\$10,000 or less, \$10,001–20,000, \$20,001 to 40,000, \$40,001–70,000, more than \$70,000, or don’t know), maternal education (Less than high school, high school diploma, some college, BA or BS, or graduate degree), pregnancy-associated nausea and vomiting (yes or no), dietary cravings (yes or no), and depressive symptoms, measured by Edinburgh Postnatal Depression Scale in mid-pregnancy (≥15, 13–14, or < 13)²². Smoking status was coded as never, former, or current if the participant reported smoking at any time during pregnancy.

Analysis

We examined bivariate associations between outcome and exposures using t tests for normally distributed continuous exposures, Wilcoxon rank sum tests for non-normally distributed continuous exposures, and chi square tests for categorical exposures. We constructed our multivariable model in three steps: First, we identified demographic and psychosocial variables that were independently associated with excess weight gain, and included these variables in our model. Second, we examined associations between diet or physical activity and excessive

gain, adjusting for these independent predictors. Finally, for those behaviors that were associated with excessive gain, we tested for confounding by sociodemographic variables.

To identify independent predictors, we began with the variables that were associated with excessive gain in bivariate analyses, and we sequentially added these risk factors to our model. We retained those risk factors that were independently associated with excess weight gain (Type 3 analysis of effects $p < 0.05$). Because excessive gain varies considerably with body mass index, we explored several approaches to modeling baseline body mass index, including linear BMI, linear + quadratic BMI, BMI deciles, and BMI divided into five-percentile categories. We compared models associating pre-pregnancy BMI with excess gain using the likelihood ratio test, and we retained the more complex model if the p value was < 0.05 . Because our model with 5 percentile categories was superior to our model using BMI deciles (likelihood ratio $p = 0.01$), we used this more complex model to adjust for prepregnancy BMI.

We then related diet and lifestyle factors with excessive gestational weight gain, using multivariable logistic regression to model the continuous relation between each exposure and odds of excessive gestational weight gain vs adequate or inadequate gain, adjusting for independent predictors of excessive gain. We used a multivariable nutrient density model to examine macronutrient composition²³. In this model, we simultaneously entered total energy intake, as well as percent energy from protein, monounsaturated fat, polyunsaturated fat, saturated fat, and trans fat, into the model. The odds ratios in this model estimate the effect of intake of the macronutrient compared with an equivalent amount of energy from carbohydrates.

We then tested for confounding by additional demographic and psychosocial factors to our models, retaining those factors that changed the odds of excessive gain for a modifiable exposure by more than 10 percent. In a sensitivity analysis, we tested whether using only women with adequate gain, rather than women with inadequate or adequate gain, as our reference group, altered our results. In a secondary analysis, we used multivariable linear regression to examine the relation between modifiable behaviors and total weight gain, adjusted for gestational age at delivery.

Finally, we selected those dietary and physical activity exposures that were independently associated with excessive gain, total weight gain, or both, and we included them in a single multivariable model. For these models, we assessed both odds of excessive gain, using logistic regression, and total gain, using linear regression. We further adjusted these models for total energy intake, to test whether the caloric contribution of specific foods mediated the observed associations.

The purpose of our study was to investigate the strength and direction of potential associations, rather than test a specific null hypothesis. We therefore reported odds ratios or effect estimates and 95 percent confidence intervals, rather than p values, for multivariable analyses.

Results

A total of 1388 women met criteria for inclusion in our study, among whom 379 (27%) were overweight ($BMI \geq 26 \text{ kg/m}^2$) entering pregnancy and 703 (51%) experienced excessive gestational weight gain.

In bivariate analyses (Table 1), excessive weight gain was slightly more common among women who were 25–30 years of age, and less common among women who were ≥ 35 years of age. We also found somewhat higher rates of excessive gain among women who were nulliparous, did not experience first trimester nausea, were overweight ($BMI 26\text{--}29 \text{ kg/m}^2$) prior to pregnancy, or who were past or current smokers.

When we examined these risk factors for excessive weight gain using multivariable logistic regression, we found that pre-pregnancy body mass index, race, maternal age, smoking status, gestational age at delivery and nausea in the first trimester were independently related to excessive weight gain. Overweight women (BMI 26–29 kg/m²) had the highest risk of excessive gain, although obese women were also more likely than normal weight women to gain excessively. Women of Asian, black, or Hispanic race-ethnicity had lower risk of excessive gain than white women. Those ages 25–30 years were at higher risk of excess gain than younger or older women. We found several factors associated with lower risk of excessive gain, including first trimester nausea vs. no first trimester nausea, never-smoking status vs. current or past smoking status, and earlier gestational age at delivery vs. later gestational age at delivery. We included these factors as covariates in our multivariable-adjusted models. Other potential predictors, including parity, employment and work-related physical activity, Edinburgh depression score, maternal education, household income, and dietary cravings, were not independently associated with excessive weight gain, and we therefore did not include them in our model.

In unadjusted comparisons of diet and physical activity between women with and without excessive weight gain (Table 2), we found that total energy intake was higher among women with excessive gain, whereas walking, vigorous activity, and total activity, as well as prevalence of vegetarian diet, were lower among women with excessive gain. Sedentary lifestyle (< 2.5h/wk of total activity) was also somewhat more common among women with excessive gain. For intake of fried foods, we found that the median and interquartile range for servings per day did not differ, but the 90th percentile for intake among women with excessive gain was higher than for women without excessive gain. This difference in distribution of intake was statistically significant (Wilcoxon rank sum $p = 0.007$).

We found similar results for multivariable-adjusted logistic regression models (Table 2). Total energy intake (OR 1.11, 95% CI 1.00–1.23 per 500 kcal/d) and total dairy consumption (OR 1.08, 95% CI 1.00–1.17, per serving per day) were directly associated with excessive gestational weight gain. This association did not appear to be entirely related to whole-milk dairy intake, as both low-fat and whole milk dairy were associated with increased excessive gain. We also found a trend toward increased risk with fried food intake (OR 3.68, 95% CI 0.96–14.13, per serving per day). Vegetarian diet in the first trimester was inversely associated with excessive gain (OR 0.45, 95% CI 0.27–0.76). We did not find an association between second-trimester vegetarian diet and excessive gain. Sugar-sweetened beverage intake, trans fat intake, glycemic index and glycemic load were not associated with excessive gain (Table 2). When we assessed the relation of change in intake of foods and nutrients from the first to second trimester with excessive gain, we found no associations (data not shown).

In our analysis of percent energy from macronutrients and total weight gain, we compared the effects of substituting 5 percent energy from protein and various types of fat with 5 percent energy from carbohydrates (Table 2). We found that percent energy from monounsaturated fat was inversely related with risk for excess gestational weight gain (OR 0.63, 95% CI 0.40–0.99), whereas percent energy from protein, saturated fat, polyunsaturated fat and trans fat were directly associated with excess gain; however, confidence intervals for these macronutrients were wide.

Vigorous physical activity in the second trimester was inversely associated with excessive gain (OR 0.76, 95% CI 0.60–0.96, per half-hour per day) with a trend toward decreased risk for walking (OR 0.92, 95% CI 0.83–1.01, per half-hour per day) and total activity (0.95, 95% CI 0.89–1.01, OR per half-hour per day). Sedentary lifestyle (<2.5h/wk total activity) was associated with a non-significant increased risk of excessive gain (OR 1.26, 95% CI 0.95–1.69). We did not find an association between television-watching and excessive gain. Of note,

television-watching was not associated with sedentary lifestyle in our population, with similar patterns of television viewing among both active and sedentary women (median [IQR] 1.4 [0.9–2.1] vs. 1.4 [0.7–2.1] hours per day, Wilcoxon $p = 0.75$).

We tested several demographic and psychosocial risk factors as potential confounders of the observed associations, including employment, marital status, maternal education, household size, household income, Edinburgh depression score, perceived weight, and pregnancy-associated vomiting. None of these factors materially altered the multivariable-adjusted odds ratios for the observed associations (data not shown). When we examined significant predictors of excessive gain in a single model (Table 3), we found that fried food and dairy intake remained directly associated, whereas vegetarian diet, walking and vigorous activity remained inversely associated, with excessive gain. Adjustment for total energy intake slightly attenuated the associations with fried food intake and dairy intake, but did not change the associations with vegetarian diet, vigorous activity, and walking. These results suggest that excess calorie intake mediates part of the associations of fried foods and dairy products with excessive gain.

In a sensitivity analysis, we similarly modeled risk factors for excess gain compared with adequate gain. Using this approach, we found a stronger association between fried food intake and excess weight gain (OR 6.36, 95% CI 1.34–30.31 per serving per day). Otherwise, our results were not materially changed.

Predictors of total weight gain were similar to those of excessive gain. Using multivariable linear regression, we found that total dairy intake (0.21, 95% CI 0.02, 0.39, kg per serving per day) and low-fat dairy intake (0.23, 0.02, 0.44, kg per serving per day) were associated with increased gain, whereas 1st trimester vegetarian diet (−1.75, 95% CI −2.89, −0.61) and sugar-sweetened beverages (−0.39, 95% CI −0.79, 0.01, kg per serving per day) were associated with decreased gain. Whole milk dairy intake was not associated with total weight gain (0.08, 95% CI −0.20, 0.36, kg per serving per day). Walking was inversely associated with total gain (−0.25, 95% CI −0.48, −0.02, kg per half-hour per day), with a trend toward lower gain with total physical activity (−0.48, 95% CI −1.01, 0.04, kg per half-hour per day) and moderate activity (−0.12, 95% CI −0.27, 0.02, kg per half-hour per day).

Similar to results for excessive gain, total gain was directly associated with percent energy from protein, polyunsaturated fat and saturated fat, whereas percent energy from monounsaturated fat was associated with lower gain; however, confidence intervals were wide. We found no association between total weight gain and percent energy from trans fat ($p=0.94$).

When we assessed the effects of predictors of total weight gain in a single multivariable model (Table 3), we found that sugar-sweetened beverages, vegetarian diet and walking remained inversely associated with total gain, whereas dairy intake remained directly associated. Adding total energy intake to the model attenuated the association between dairy intake and total gain and strengthened the inverse association with sugar-sweetened beverages. Adjustment for total energy intake did not change the associations between vegetarian diet, walking and weight gain.

Comment

In this prospective cohort study, total energy intake and consumption of dairy and fried foods were directly associated with excessive weight gain, while early pregnancy vegetarian diet was inversely associated with excessive weight gain. Vigorous activity, walking and total activity during pregnancy were inversely associated with excessive gain. These findings suggest that moderating caloric intake, avoiding fried foods and engaging in physical activity during pregnancy may reduce risk for excessive gestational weight gain.

Strengths of our study include prospective assessment of diet, use of a validated food frequency questionnaire, and assessment of physical activity of different intensities. In addition, the extensive demographic and psychosocial data collected in Project Viva allowed us to adjust for multiple independent predictors of excessive weight gain. Nevertheless, our findings must be interpreted within the context of the study design. All observational studies are subject to confounding, and it is possible that unmeasured health behaviors confound observed associations between diet, physical activity and excessive gestational weight gain. However, adjusting for measured confounders did not materially alter our results. We examined multiple predictors of excessive gain in our model, and it is possible that some of our findings are due to chance, but most were in hypothesized directions. Randomized trials of dietary advice and encouragement of leisure-time physical activity during pregnancy will be needed to establish a causal association.

Our data confirm and extend earlier work on modifiable risk factors for excessive gestational weight gain. Several authors have reported that higher energy intake during pregnancy is correlated with greater absolute weight gain and/or increased risk of excessive gain^{24–27}. We also found that dairy consumption was associated with excessive gain, consistent with findings in two other studies. This association did not appear to be wholly related to whole-milk dairy intake. Olafsdottir et al²⁶ reported a higher risk of excessive weight gain among women who reported drinking more milk in later pregnancy, compared with intake prior to pregnancy. Olsen et al²⁸ similarly reported greater weight gain, and higher birth weights, with higher levels of milk consumption. The authors suggest that higher levels of IGF-I associated with milk intake may drive this association. IGF-I is present in both low-fat and whole-milk dairy products. We could not address whether current recommendations for three servings of dairy products per day²⁹ should be revised.

We found that intake of fried foods was directly related to risk of excessive gain. Some studies in non-pregnant populations have linked consumption of fried or fast food to weight gain^{30–32}. We did not observe any change in risk of excessive gain with consumption of fruits and vegetables, whole grains or fiber. These findings are consistent with a recent clinic-based trial designed to reduce excessive gestational weight gain through increased consumption of fruits, vegetables and high-fiber bread³³. In that trial, although women in the intervention group increased consumption of these foods, there was no reduction, and in fact a suggestion of an increase, in risk for excessive weight gain (overall OR for excessive gain in intervention vs. control clinics 1.94, 95% CI 0.97–4.34).

In linear regression analysis, we found that greater sugar-sweetened beverage intake was associated with lower total gestational weight gain (−0.39, 95% CI −0.79–0.01, kg per serving per day). This result conflicts with data from non-pregnant populations linking sugar-sweetened beverage consumption with increased obesity risk³⁴. It is possible that reverse causation explains our results. If individuals who are already overweight or struggling with weight gain decrease intake of sugar-sweetened beverages, it may give the appearance of an inverse association. Although we adjusted for pre-pregnancy BMI in our analysis, it is possible that residual confounding by body mass index or tendency to gain weight explains the observed association. Alternately, differences in macronutrient intake may underlie our finding. Two prior studies have reported lower gestational weight gain among women with higher carbohydrate intake. Lagiou²⁷ reported that energy-adjusted carbohydrate intake was inversely related with weight gain in the first 27 weeks of pregnancy, while energy-adjusted protein and animal fat was directly related with weight gain. Similarly, Olafsdottir²⁶ reported that overweight women with excessive gestational gain consumed a higher proportion of calories from fat and a lower proportion from carbohydrates. In our analysis, we found a trend toward greater excessive gain with greater percent energy intake from protein, saturated fat, polyunsaturated fat and trans fat, compared with equivalent percent energy intake from

carbohydrates. Further studies are needed to explore the effect of macronutrient composition intake on gestational weight gain.

We found a lower risk of excessive weight gain among women who reported adhering to a vegetarian diet in early pregnancy. This finding is consistent with results among non-pregnant women in the Oxford arm of the European Prospective Investigation into Cancer and Nutrition cohort, where vegetarian diet was associated with lower body mass index³⁵, and reduced weight gain over time³⁶, compared with meat-eating diets. Differences in macronutrient intake, or residual confounding by other health behaviors, may underlie these associations. In our cohort, however, this association persisted with adjustment for physical activity and intake of fried foods and dairy products. Our findings regarding physical activity and weight gain are consistent with earlier work. We found that vigorous activity during pregnancy, as well as walking and total activity, were associated with a lower risk of excessive gain. Olson et al¹⁶ found that decreased physical activity during pregnancy was associated with excessive weight gain. In a study of obese women with gestational diabetes, Artal et al³⁷ found that exercise combined with diet led to lower weight gain than diet alone. In our cohort, Oken et al³⁸ found that walking after delivery was also associated with a reduced risk of weight retention postpartum.

Most women can safely engage in physical activity during pregnancy, and current guidelines for uncomplicated pregnancies recommend 30 minutes per day of moderate physical activity on most days of the week. Nevertheless, most women reduce their physical activity during pregnancy²¹. Encouraging women to continue or increase their activity during pregnancy may reduce their risk of excessive weight gain. Oken and colleagues further found that postpartum television viewing was directly associated with postpartum weight retention. We found no association between television watching and excessive weight gain or total weight gain during pregnancy; however, duration of television viewing during pregnancy was not associated with sedentary lifestyle in our cohort.

In conclusion, we found that total energy intake, dairy consumption, and fried food consumption were directly related to excessive gestational weight gain. Vegetarian diet, physical activity and an active lifestyle were linked to lower risk. Future intervention studies should target these behaviors to see whether beneficial changes influence weight gains and, in turn, improve maternal and child health outcomes.

Acknowledgments

Funding sources: Supported by grants from the US National Institutes of Health (HD 34568, HL 68041), Harvard Medical School, and the Harvard Pilgrim Health Care Foundation.

We thank Sheyl Rifas-Shiman for technical support.

References

1. Stotland NE, Hopkins LM, Caughey AB. Gestational Weight Gain, Macrosomia, and Risk of Cesarean Birth in Nondiabetic Nulliparas. *Obstet Gynecol* 2004;104:671–677. [PubMed: 15458884]
2. Bianco AT, Smilen SW, Davis Y, Lopez S, Lapinski R, Lockwood CJ. Pregnancy outcome and weight gain recommendations for the morbidly obese woman. *Obstet Gynecol* 1998;91:97–102. [PubMed: 9464729]
3. Rosenberg TJ, Garbers S, Lipkind H, Chiasson MA. Maternal Obesity as Diabetes as Risk Factors for Adverse Pregnancy Outcomes: Differences Among 4 Racial/Ethnic Groups. *Am J Public Health* 2005;95:1544–1661.

4. Stuebe AM, Zera C, Ecker JL, McElrath TM. A prospective assessment of metabolic function, compliance with gestational weight gain guidelines, and associated pregnancy outcomes. *Am J Obstet Gynecol* 2006;195:S82.
5. Juhasz G, Gyamfi C, Gyamfi P, Tocce K, Stone JL. Effect of body mass index and excessive weight gain on success of vaginal birth after cesarean delivery. *Obstet Gynecol* 2005;106:741–6. [PubMed: 16199630]
6. Gunderson E, Abrams B, Selvin S. The relative importance of gestational gain and maternal characteristics associated with the risk of becoming overweight after pregnancy. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity* 2000;24:1660–8. [PubMed: 11126221]
7. Rooney B, Schauburger C. Excess pregnancy weight gain and long-term obesity: one decade later. *Obstet Gynecol* 2002;100:245–52. [PubMed: 12151145]
8. Rooney BL, Schauburger CW, Mathiason MA. Impact of Perinatal Weight Change on Long-Term Obesity and Obesity-Related Illnesses. *Obstet Gynecol* 2005;106:1349–1356. [PubMed: 16319262]
9. Schieve LA, Cogswell ME, Scanlon KS. Maternal weight gain and preterm delivery: differential effects by body mass index. *Epidemiology* 1999;10:141–7. [PubMed: 10069249]
10. Edwards LE, Hellerstedt WL, Alton IR, Story M, Himes JH. Pregnancy complications and birth outcomes in obese and normal-weight women: effects of gestational weight change. *Obstet Gynecol* 1996;87:389–94. [PubMed: 8598961]
11. Sewell MF, Huston-Presley L, Super DM, Catalano P. Increased neonatal fat mass, not lean body mass, is associated with maternal obesity. *Am J Obstet Gynecol* 2006;195:1100–3. [PubMed: 16875645]
12. Oken E, Tavares EM, Kleinman KP, Rich-Edwards J, Gillman M. Gestational weight gain and child adiposity at age 3 years. *Am J Obstet Gynecol*. 2007In Press
13. Oken EM, Rifas-Shiman SL, Field AE, Frazier AL, Gillman MW. Maternal Gestational Weight Gain and Offspring Weight in Adolescence. *Obstetrics & Gynecology* 2008;112:999–1006. [PubMed: 18978098]
14. Stuebe AM, Michels KB. Gestational weight gain and obesity at age 18 in the daughter. *Am J Obstet Gynecol* 2006;195:S228.
15. Stotland N, Haas J, Brawarsky P, Jackson R, Fuentes-Afflick E, Escobar G. Body mass index, provider advice, and target gestational weight gain. *Obstetrics & Gynecology* 2005;105:633–8. [PubMed: 15738036]
16. Olson C, Strawderman M. Modifiable behavioral factors in a biopsychosocial model predict inadequate and excessive gestational weight gain. *Journal of the American Dietetic Association* 2003;103:48–54. [PubMed: 12525793]
17. Brawarsky P, Stotland NE, Jackson RA, et al. Pre-pregnancy and pregnancy-related factors and the risk of excessive or inadequate gestational weight gain. *International Journal of Gynecology & Obstetrics* 2005;91:125–131. [PubMed: 16202415]
18. Oken E, Taveras EM, Kleinman KP, Rich-Edwards JW, Gillman MW. Gestational weight gain and child adiposity at age 3 years. *Am J Obstet Gynecol* 2007;196(322):e1–8. [PubMed: 17403405]
19. Institute of Medicine. Nutrition during pregnancy. Washington, DC: National Academies Press; 1990.
20. Rifas-Shiman SL, Rich-Edwards JW, Willett WC, Kleinman KP, Oken E, Gillman MW. Changes in dietary intake from the first to the second trimester of pregnancy. *Paediatr Perinat Epidemiol* 2006;20:35–42. [PubMed: 16420339]
21. Pereira MA, Rifas-Shiman SL, Kleinman KP, Rich-Edwards JW, Peterson KE, Gillman MW. Predictors of change in physical activity during and after pregnancy: Project Viva. *Am J Prev Med* 2007;32:312–9. [PubMed: 17383562]
22. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *Br J Psychiatry* 1987;150:782–6. [PubMed: 3651732]
23. Willett, WC.; Stampfer, MJ. Implications of Total Energy Intake for Epidemiologic Analyses. In: Willett, WC., editor. *Nutritional Epidemiology*. New York: Oxford University Press; 1998.
24. Olson C, Strawderman M, Reed R. Efficacy of an intervention to prevent excessive gestational weight gain. *American Journal of Obstetrics & Gynecology* 2004;191:530–6. [PubMed: 15343232]

25. Bergmann MM, Flagg EW, Miracle-McMahill HL, Boeing H. Energy intake and net weight gain in pregnant women according to body mass index (BMI) status. *Int J Obes Relat Metab Disord* 1997;21:1010–7. [PubMed: 9368824]
26. Olafsdottir AS, Skuladottir GV, Thorsdottir I, Hauksson A, Steingrimsdottir L. Maternal diet in early and late pregnancy in relation to weight gain. *Int J Obes* 2005;30:492–499.
27. Lagiou P, Tamimi RM, Mucci LA, Adami HO, Hsieh CC, Trichopoulos D. Diet during pregnancy in relation to maternal weight gain and birth size. *Eur J Clin Nutr* 2004;58:231–7. [PubMed: 14749741]
28. Olsen SF, Halldorsson TI, Willett WC, et al. Milk consumption during pregnancy is associated with increased infant size at birth: prospective cohort study. *Am J Clin Nutr* 2007;86:1104–10. [PubMed: 17921389]
29. U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans. Washington, DC: U.S. Government Printing Office; 2005.
30. Pereira MA, Kartashov AI, Ebbeling CB, et al. Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* 2005;365:36–42. [PubMed: 15639678]
31. Duffey KJ, Gordon-Larsen P, Jacobs DR Jr, Williams OD, Popkin BM. Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study. *Am J Clin Nutr* 2007;85:201–8. [PubMed: 17209197]
32. Taveras EM, Berkey CS, Rifas-Shiman SL, et al. Association of consumption of fried food away from home with body mass index and diet quality in older children and adolescents. *Pediatrics* 2005;116:e518–24. [PubMed: 16199680]
33. Kinnunen TI, Pasanen M, Aittasalo M, et al. Preventing excessive weight gain during pregnancy - a controlled trial in primary health care. *Eur J Clin Nutr* 2007;61:884–91. [PubMed: 17228348]
34. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr* 2006;84:274–88. [PubMed: 16895873]
35. Spencer EA, Appleby PN, Davey GK, Key TJ. Diet and body mass index in 38000 EPIC-Oxford meat-eaters, fish-eaters, vegetarians and vegans. *Int J Obes Relat Metab Disord* 2003;27:728–34. [PubMed: 12833118]
36. Rosell M, Appleby P, Spencer E, Key T. Weight gain over 5 years in 21,966 meat-eating, fish-eating, vegetarian, and vegan men and women in EPIC-Oxford. *Int J Obes (Lond)* 2006;30:1389–96. [PubMed: 16534521]
37. Artal R, Catanzaro RB, Gavard JA, Mostello DJ, Friganza JC. A lifestyle intervention of weight-gain restriction: diet and exercise in obese women with gestational diabetes mellitus. *Appl Physiol Nutr Metab* 2007;32:596–601. [PubMed: 17510701]
38. 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]

Table 1

Participant characteristics according to category of gestational weight gain, by Institute of Medicine guidelines. Data from 1388 participants from Project Viva.

	GWG inadequate or adequate		GWG Excessive		p
	N	%	N	%	
Age (years)					0.05
<25	39	(51.3)	37	(48.7)	
25-<30	127	(44.1)	161	(55.9)	
30-<35	299	(48.2)	321	(51.8)	
>=35	220	(54.5)	184	(45.5)	
Race					0.02
White	503	(47.7)	551	(52.3)	
Black	71	(51.4)	67	(48.6)	
Hispanic	42	(56.0)	33	(44.0)	
Asian	49	(66.2)	25	(33.8)	
Other	20	(42.6)	27	(57.4)	
Parity					0.16
0	328	(46.8)	373	(53.2)	
1	255	(51.8)	237	(48.2)	
2	80	(54.8)	66	(45.2)	
3+	22	(44.9)	27	(55.1)	
Smoking					0.002
Past	140	(44.6)	174	(55.4)	
Current	58	(39.2)	90	(60.8)	
Never	487	(52.6)	439	(47.4)	
First trimester nausea					0.002
Yes	611	(51.0)	587	(49.0)	
No	74	(38.9)	116	(61.1)	
Body Mass Index (kg/m²)					<0.001
less than 26	565	(56.0)	444	(44.0)	
26 to 29	35	(21.2)	130	(78.8)	
greater than 29	85	(39.7)	129	(60.3)	
Gestational age at delivery, median (IQR)	39.7	(38.7–40.6)	40.0	(39.0–40.9)	<0.001

p		%		%	
		GWG Excessive		GWG inadequate or adequate	
		N		N	

Table 2

Levels of dietary intake and physical activity among 1388 women enrolled in Project Viva, and those without and with excessive weight gain. We present mean values and standard deviation (sd) or median values and interquartile range [IQR].

N	GWG inadequate or adequate		Excessive GWG		Bivariate p value ^d	Multivariate adjusted odds of excessive GWG ^d	
	685	703	Mean or median	(sd) or [IQR]		OR	95% confidence interval
Food and food groups, servings/day							
Sugar-sweetened beverages, median [IQR] ^c	0.36	[0.11 – 0.75]	0.37	[0.12 – 0.75]	0.42 ^e	0.93	(0.78– 1.11)
Fried foods, median [IQR] ^c	0.11	[0.07 – 0.14]	0.11	[0.07 – 0.14]	0.007 ^e	3.68	(0.96–14.13)
Dairy	2.90	(1.52)	3.04	(1.49)	0.08	1.08	(1.00– 1.17)
Low fat dairy	1.49	(1.31)	1.59	(1.34)	0.17	1.08	(0.98– 1.18)
Whole milk dairy	1.41	(1.01)	1.46	(0.97)	0.42	1.06	(0.94– 1.20)
Fruits & vegetables	5.84	(2.60)	5.90	(2.71)	0.68	1.03	(0.98– 1.07)
Red & processed meats	0.53	(0.40)	0.56	(0.39)	0.19	1.00	(0.74– 1.34)
Whole grains	1.25	(1.03)	1.27	(1.04)	0.63	1.06	(0.95– 1.19)
Nutrients and dietary patterns							
Kcal/day	2060.01	(593.76)	2131.40	(570.36)	0.02	1.11	(1.00– 1.23)
Fiber (g/day)	19.97	(5.75)	19.50	(5.04)	0.10	0.98	(0.87– 1.09)
Glycemic Index	754.24	(120.92)	746.08	(115.09)	0.20	0.98	(0.88– 1.08)
Glycemic Load	14597.52	(1940.93)	14516.26	(1930.13)	0.43	1.00	(0.88– 1.13)
Vegetarian diet							
First trimester, n (%)	55	(8.0)	27	(3.9)	0.001 ^f	0.45	(0.27– 0.76)
Second trimester, n (%)	42	(6.2)	28	(4.0)	0.06 ^f	0.70	(0.40– 1.20)
Macronutrient composition (% energy)							
Carbohydrates	54.95	(6.41)	54.67	(6.30)	0.41	1.0	(ref)
Protein	17.53	(2.56)	17.62	(2.46)	0.53	1.10	(0.86 – 1.42)
Total fat	28.94	(5.12)	29.16	(4.93)	0.41		
Monounsaturated fat	10.96	(2.33)	10.98	(2.22)	0.87	0.63	(0.40 – 0.99)
Polysaturated fat	6.18	(1.40)	6.25	(1.41)	0.40	1.32	(0.80 – 2.18)
Saturated fat	10.78	(2.32)	10.94	(2.21)	0.20	1.33	(0.87 – 2.02)

N	GWG inadequate or adequate		Excessive GWG		Bivariate p value ^d	Multivariate adjusted odds of excessive GWG ^a	
	685	703	Mean or median	(sd) or [IQR]		OR	95% confidence interval
Trans fat	0.97	0.99		(0.29)	0.13	1.27	(0.39 – 4.13)
Physical activity minutes/day ^c ,						OR per hh/day	95% CI
Walking	34	34		[17 – 60]		0.92	(0.83 – 1.01)
Moderate activity	0	0		[0 – 17]	0.03 ^e	1.00	(0.85 – 1.17)
Vigorous activity	0	0		[0 – 9]	0.005 ^e	0.76	(0.60 – 0.96)
Total activity	34	34		[17 – 60]	0.03 ^e	0.95	(0.89 – 1.01)
TV watching	86	86		[43 – 129]	0.11 ^e	0.98	(0.93 – 1.02)
Sedentary lifestyle(<2.5 h/wk total activity) n (%)	132	165		(19.3)	0.06 ^d	1.26	(0.95 – 1.69)

^a Adjusted for pre-pregnancy body-mass index (in 5 percentile categories), maternal age (14-<20, 20-<25, 25-<30, 30-<35, 35-<40, 40+) race/ethnicity, smoking status, gestational age at delivery (wks), and nausea in the first trimester of pregnancy.

^b Multivariate nutrient density model. Total energy intake, as well as percent energy from protein, monounsaturated fat, polyunsaturated fat, saturated fat, and trans fat were entered simultaneously into the model, so odds ratios estimate the effect of intake of the macronutrient compared with an equivalent amount of energy from carbohydrates.

^c Median and interquartile range presented for exposures that were not normally distributed

^d t-test with equal variance, not excessive vs. excessive gain.

^e Wilcoxon rank-sum test, not excessive vs. excessive gain

^f Chi square test

Table 3Multivariate regression models^a incorporating significant predictors of excessive weight gain or total weight gain.

Exposure	Odds Ratio ^b for excessive GWG (95% CI)	Effect estimate for total weight gain (kg) ^c (95% CI)
Sugar sweetened beverages, per serving per day	0.87 (0.72 – 1.05)	−0.46 (−0.87, −0.05)
Fried foods, per serving per day	4.24 (1.04 – 17.18)	1.21 (−1.93, 4.34)
Dairy, per serving per day	1.09 (1.01 – 1.19)	0.23 (0.05, 0.41)
Vegetarian diet, first trimester	0.48 (0.28 – 0.81)	−1.65 (−2.79, −0.51)
Walking (hh/day) ^d	0.94 (0.85 – 1.05)	−0.20 (−0.43, 0.04)
Vigorous activity (hh/day) ^d	0.78 (0.61 – 1.00)	−0.37 (−0.90, 0.17)

^a Adjusted for pre-pregnancy body-mass index (in 5 percentile categories), maternal age (14-<20, 20-<25, 25-<30, 30-<35, 35-<40, 40+) race/ethnicity, smoking status, gestational age at delivery (wks), and nausea in the first trimester of pregnancy.

^b Multivariate logistic regression model

^c Multivariate linear regression model

^d Per half hour per day