HHS Public Access

Author manuscript

*Matern Child Health J*. Author manuscript; available in PMC 2024 March 25.

Published in final edited form as:

*Matern Child Health J*. 2014 July ; 18(5): 1123–1131. doi:10.1007/s10995-013-1342-6.

# Relationship Between Gestational Weight Gain and Birthweight Among Clients Enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Hawaii, 2003–2005

**Izumi Chihara**,

Community Health Sciences Division, School of Public Health, University of Illinois at Chicago, 1603 W. Taylor St., Chicago, IL 60612-4394, USA

**Donald K. Hayes**,

Hawaii Department of Health, Honolulu, HI, USA

Division of Reproductive Health, Centers for Disease Control and Prevention, Druid Hills, GA, USA

**Linda R. Chock**,

Hawaii Department of Health, Honolulu, HI, USA

**Loretta J. Fuddy**,

Hawaii Department of Health, Honolulu, HI, USA

**Deborah L. Rosenberg**,

Epidemiology and Biostatistics Division, School of Public Health, University of Illinois at Chicago, Chicago, IL, USA

**Arden S. Handler**

Community Health Sciences Division, School of Public Health, University of Illinois at Chicago, 1603 W. Taylor St., Chicago, IL 60612-4394, USA

## Abstract

To investigate the relationship between gestational weight gain (GWG) and birthweight outcomes among a low-income population in Hawaii using GWG recommendations from the 2009 Institute of Medicine (IOM) guidelines. Data were analyzed for 19,130 mother-infant pairs who participated in Hawaii's Special Supplemental Nutrition Program for Women, Infants, and Children from 2003 through 2005. GWG was categorized as inadequate, adequate, or excessive on the basis of GWG charts in the guidelines. Generalized logit models assessed the relationship between mothers' GWG and their child's birthweight category (low birthweight [LBW:<2,500 g], normal birthweight [2,500 g ≤ BW < 4,000 g], or high birthweight [HBW: ≥4,000 g]). Final models were stratified by prepregnancy body mass index (underweight, normal weight, overweight, or obese) and adjusted for maternal age, education, race/ethnicity, smoking status,

✉I. Chihara, ichiha2@uic.edu.

*Disclaimer*: The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

parity, and marital status. Overall, 62 % of the sample had excessive weight gain and 15 % had inadequate weight gain. Women with excessive weight gain were more likely to deliver a HBW infant; this relationship was observed for women in all prepregnancy weight categories. Among women with underweight or normal weight prior to pregnancy, those with inadequate weight gain during pregnancy were more likely to deliver a LBW infant. Among the low-income population of Hawaii, women with GWG within the range recommended in the 2009 IOM guidelines had better birthweight outcomes than those with GWG outside the recommended range. Further study is needed to identify optimal GWG goals for women with an obese BMI prior to pregnancy.

**Keywords**

WIC; Gestational weight gain; LBW; HBW; IOM guideline

## Introduction

Low birthweight (LBW, <2,500 g) is associated with infant mortality [1–3] and infant and childhood morbidity, including neurodevelopmental sequelae, mental retardation, and lower respiratory conditions [1–6]. LBW is also associated with long-term outcomes such as diabetes mellitus, hypertension, and cardiovascular disease in adults [7–14]. Likewise, high birthweight (HBW), which has been inconsistently defined as birthweight of at least 4,000, 4,500, or 5,000 g, is also associated with perinatal morbidity and mortality, maternal complications [15–23], and obesity in adolescence and adulthood [24–26].

Gestational weight gain (GWG) is a potentially modifiable risk factor that may help achieve optimal birthweight and prevent adverse consequences for the woman and her infant. Inadequate GWG or weight gain below the 1990 Institute of Medicine (IOM) recommendations [27] has been associated with an increased likelihood of delivering LBW [28, 29] or small for gestational age infants [30, 31], and with preterm delivery [32–34]. Excessive GWG or weight gain above the 1990 IOM recommendations is associated with an increased likelihood of delivering HBW [28, 29, 35–37] or large for gestational age infants [30, 31, 38], and with low infant Apgar scores [38], cesarean delivery [29–31, 35], and maternal weight retention [39–41].

In 2009, the IOM issued new GWG guidelines [42] updating the old guidelines in response to an increase in prepregnancy body mass index (BMI; calculated as weight in kilograms over square of height in meters) and GWG among all population subgroups, and changing demographics of the maternal population including age and race/ethnicity. The new guidelines use the World Health Organization BMI categories instead of the Metropolitan Life Insurance Company's BMI categories, as the previous IOM guidelines did. The 2009 guidelines also include recommended GWG ranges for obese women. The guidelines specify GWG ranges for the entire pregnancy and rates of weight gain for the second and third trimester for women in each prepregnancy BMI category (underweight, normal weight, overweight, and obese) (Appendix 1). In addition, the IOM recommended that women's GWG be monitored using charts showing recommended weight gain ranges for each gestational week for women in each prepregnancy BMI category (Appendix 2).

The IOM considered special populations who may benefit from separate recommendations such as racial and ethnic minorities, and found limited data to indicate a need to have a separate recommendation. As such, the IOM concluded that their recommendations should be generally applicable to various racial/ethnic subgroups [42]. The current study was conducted to examine whether the weight gain recommendations in the revised IOM guidelines are associated with improved birthweight outcomes among the diverse population of Hawaii, using data from Hawaii's Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Specifically, the study examined whether gaining weight within the recommended ranges delineated in the weight gain charts from the 2009 IOM guidelines is associated with improved birthweight outcomes.

## Methods

### Data

Program and administrative data collected for births between January 1, 2003 to December 31, 2005 were analyzed. Maternal records and infant records were first linked, which gave us 26,101 infant-mother pairs (83 % match rate). Infant birth date and family ID from the infant record, and family ID and actual delivery date from the maternal record were used for matching. From this group, 6,233 pairs (24 %) were excluded because the mother did not have a prenatal WIC record, leaving us with 19,868 fully matched records. Most of the women excluded at this stage likely entered WIC after the birth of their infant, but might also include those who did not have an EDC or delivery date in their WIC chart. After excluding matched record pairs that included infants whose estimated gestational age at birth was less than 20 weeks (n = 2) or more than 44 weeks (n = 55), those that involved multiple births (n = 644), and those with missing information on infants' birthweight (n = 34) or mothers' GWG (n = 3), 19,130 mother-infant pairs remained for the analysis.

### Variables

The outcome variable in this study, infant birthweight, was based on the reports of mothers at the time of their infant's first WIC visit. The validity and reliability of such reports have been well documented [43–47]. Birthweight was trichotomized as low birthweight (LBW, less than 2,500 g), normal birthweight (2,500–3,999 g), and high birthweight (HBW, 4,000 g or greater). A cutoff of 4,000 g was used since prior studies have shown birthweight greater than 4,000 g to be positively associated with perinatal morbidity and mortality and with maternal complications [16, 22].

The exposure variable of interest was GWG, and we classified women as having inadequate, appropriate, or excessive GWG on the basis of the 2009 IOM prenatal weight gain charts. In order to use the IOM charts, a measure of weight gain during pregnancy and a measure of prepregnancy BMI are required because the recommendations vary according to BMI category (underweight, BMI < 18.5; normal weight, BMI 18.5–24.9; overweight, BMI 25.0–29.9; and obese, BMI C 30.0). Mothers' GWG was estimated by subtracting their estimate of their prepregnancy weight (which they reported when they entered the WIC program during the prenatal period [mean 20 weeks gestation]) from their estimate of their weight at delivery (which they reported at their first postpartum visit [mean 5 weeks postpartum]).

Women's prepregnancy BMI was estimated on the basis of their self-reported prepregnancy weight and their measured height at prenatal WIC entry. For example, for normal weight women, inadequate or excessive GWG per 2009 IOM recommendations was defined as below or above the recommended weight gain range for a particular gestational age as shown in Appendix 2. For underweight, overweight, and obese women, corresponding prenatal weight gain charts from the 2009 IOM recommendations were used to define inadequate or excessive GWG. Because the IOM charts did not include recommended weight gain ranges for women in weeks 41–44 of their pregnancy, weight gain ranges for women in week 40 were used to be consistent with prior studies. A sensitivity analysis was conducted, which excluded women who delivered between 41 and 44 weeks gestation.

Other potential confounders and effect modifiers that we considered in the analysis were maternal age at delivery (<20, 20–29, or ≥30 years); self-identified race-ethnicity (Hawaiian/part Hawaiian, Asian, white, Pacific Islander, or other); self-reported years of education (<12 years, 12 years or high school diploma, or more than 12 years); marital status (married or unmarried); parity (no previous live birth or at least one previous live births); self-reported current smoking status at last WIC visit during pregnancy (smoker or non-smoker); receipt of Medicaid, Temporary Assistance for Needy Families (TANF), or Food Stamps (yes or no); and trimester of WIC entry (1st, 2nd, or 3rd). For the maternal age variable, the cutoff point of 30 years instead of 35 years was used because the prevalence of inadequate weight gain was greater among those 30 years or older, and a prior study used this cutoff point [41]. Race-ethnicity classification was based on two questions. At the time of WIC entry, each client self-identified her race as "American Indian or Alaska Native," "Asian," "Black or African American," "Hawaiian or Pacific Islander," or "Caucasian or White." Each client could choose as many categories as needed. Furthermore, if applicable, they were asked about their ancestry from a list. In Hawaii, individuals who identify themselves as being part-Hawaiian are considered Hawaiian [48]. Therefore, any person who chose multiple categories as her race was categorized as Hawaiian/Part Hawaiian if she chose "Hawaiian or part Hawaiian" as her ancestry. All other combinations of multiple race and those who identified themselves as "Black" and "Native Indian/Alaska Native" were categorized as "Other" because the sample sizes for each of these categories were small.

## Statistical Analysis

Because previous studies have shown that women's prepregnancy BMI modifies the relationship between GWG and LBW [28, 49, 50] or HBW [50], we decided a priori that final models be stratified by prepregnancy BMI categories (underweight, normal weight, overweight, and obese). This effect modification was later confirmed in our sample.

A contingency table approach was first used to describe the crude relationship between all potential covariates and the three-category GWG variable (inadequate, adequate, or excessive) and also to describe the relationship between each potential covariate, the exposure variable (GWG), and the outcome variable (infant birth weight classification). In addition, this approach was used to inform categorization decisions, aimed at ensuring sufficient sample size in all categories.

Bivariate logistic regression analyses were conducted using a generalized logit model to determine the crude odds ratios for the relationship between birthweight and GWG and between birthweight and potential covariates. The generalized logit model instead of the cumulative logit model was used because its results are easier to interpret and because of the public health importance of generating odds ratios for both LBW and HBW. The 95 % confidence intervals (CIs) were computed around each odds ratio.

Finally, multivariable logistic regression analyses were conducted using a generalized logit model to examine the relationship between GWG categories based on 2009 IOM weight gain charts and birthweight outcomes, stratified by prepregnancy BMI categories (underweight, normal weight, overweight, and obese). Each covariate was included in the model one at a time to determine if confounding was present. Confounding was deemed to be present when the adjusted odds ratios for LBW and/or HBW were at least 10 percent different from the crude odds ratios. We included two-way interaction terms in the models to determine whether they modified the relationship between GWG and infants' birthweight classification. Maternal race-ethnicity, age, education level, parity, and smoking status during pregnancy were included in the final models as covariates because they are conceptually important variables that have been included in previous studies [33]. All analyses were conducted using SAS Version 9.1 (SAS Institute, Cary, NC). The study protocol was approved by the University of Illinois at Chicago Institutional Review Board prior to the initiation.

## Results

Table 1 presents the characteristics of women and infants in the study sample. The majority of women were in their twenties and had a high school diploma. Hawaiians comprised 35.4 % of the sample followed by Asians, Whites, Others, and Pacific Islanders. In this sample, 6.0 % of women were underweight, 48.6 % were normal weight, 23.0 % were overweight, and 22.5 % were obese. Excessive GWG (61.6 %) was far more prevalent than inadequate GWG (14.8 %). The prevalence of low and high birthweight were 6.4 and 7.7 %, respectively. Bivariate analysis (Table 2) indicated that excessive GWG was positively associated with being<30 years of age; having a racial-ethnic classification of Pacific Islander, Hawaiian, white, or "other"; being unmarried; being a smoker; and being overweight or obese. Women who were Asian, married, and with at least one previous live birth were more likely to report inadequate GWG.

In multivariable analyses, none of the covariates were found to be true confounders while prepregnancy BMI was an effect modifier for the relationship between GWG and LBW/HBW. Therefore, final models were stratified by prepregnancy BMI and adjusted for the conceptually important variables mentioned earlier. Results of our final models (Table 3) showed that excessive GWG was associated with higher odds of delivering an HBW infant among all women, regardless of their prepregnancy BMI status. Inadequate GWG was associated with lower odds of delivering a HBW infant among normal weight women (OR 0.47, 95 %CI 0.29–0.75), but not among overweight (OR 1.02, 95 %CI 0.57–1.83) or obese women (OR 0.92, 95 %CI 0.62–1.36). On the other hand, inadequate GWG was associated with higher odds of delivering a LBW infant among underweight (OR 2.01, 95

%CI 1.27–3.21) and normal weight women (OR 1.81, 95 %CI 1.44–2.27), but not among obese women (OR 0.99, 95 %CI 0.61–1.59). For overweight women, this association did not reach significance ($p = 0.0611$). Gaining excessive weight was associated with lower odds of delivering a LBW infant for underweight women (OR 0.54, 95 %CI 0.34–0.87), but this relationship was not observed for normal weight, overweight, or obese women. The odds of delivering a HBW infant differed little between obese women with inadequate GWG (OR 0.99, 95 %CI 0.61–1.59) and obese women with appropriate GWG (reference population, OR 1). A sensitivity analysis excluding women who delivered between 41 and 44 weeks gestation showed similar results (data not shown).

## Discussion

To our knowledge, this study is the first to examine the effect of GWG on low and high birthweight using GWG classification based on weight gain charts from the 2009 IOM recommendations. The results of the current study showed that GWG within IOM-recommended ranges was associated with a decreased likelihood of delivering a HBW infant among women in the study sample regardless of BMI classifications, and with a decreased likelihood of delivering a LBW infant among those who were underweight, normal weight, or overweight. Based on these results, we conclude that the GWG ranges of the weight gain charts from 2009 IOM recommendations are appropriate for minimizing the odds of both LBW and HBW for underweight, normal weight, and overweight women in this low-income population of Hawaii. The results of the current study are consistent with those from a previous study in this population, which showed that GWG within ranges recommended by the IOM in 1990 was associated with lower incidence of LBW or HBW [39].

On the contrary, the results also showed that the odds of delivering a LBW infant and HBW infant among obese women with inadequate GWG were almost identical to corresponding odds among obese women with appropriate GWG. These results suggest that the recommended weight gain range for obese women could be decreased without increasing the risk for harm to the children of obese women.

One possible explanation for the lack of association between GWG and LBW among obese women is that the likelihood of LBW among children of obese women may be independent of their mothers' GWG [51]. Critics of the 2009 IOM recommendations have argued that evidence for an association between increased calorie intake during pregnancy (especially among obese women) and an increase in infant birth weight is lacking in developed countries [51]. Another possible explanation is that, because obese women are a heterogeneous group, separate weight gain recommendations may be needed for subgroups of obese women, such as those who comprise obesity classes II (BMI 35.0–39.9 $kg/m^2$) and III (BMI ≥ 40.0 $kg/m^2$) [51]. In addition, data on pregnancy complications such as gestational diabetes and preeclampsia were not available from our data source; these morbidities, known to be more common in obese women [52], may have modified the relationship between GWG and infant birth weight among obese women. Further investigation is needed to determine the optimal GWG ranges for obese women in general, for those who are morbidly obese, and for those with pregnancy complications.

### Study Strengths and Weaknesses

One strength of the study was the use of GWG ranges by gestational age that prevent preterm delivery bias. Studies investigating the effect of GWG on fetal growth need to take into consideration potential preterm delivery bias because women who deliver preterm have less time in which to gain weight than women who deliver at term. Dietz et al. [53] proposed a method to account for this bias by using estimated weight gain during the second and third trimesters based on information on total GWG, gestational age at delivery, and an assumed average GWG during the first trimester from the IOM report [27]. The use of total GWG information, infants' gestational age at birth, and IOM-recommended GWG ranges in the current study to define inadequate, appropriate, and excessive GWG resembles the method proposed by Dietz et al. because the GWG charts we used were based on the assumption that the rate of GWG is not uniform across trimesters. In addition, the method in the current study has the added advantage of being relevant to how clinicians and women are advised to monitor GWG [42].

Several limitations must be considered. First, self-reported weight gain during pregnancy has not been validated among the WIC population. Results of a validation study among women in the general population showed that a woman's reported delivery weight was 2.82 pounds less than her measured delivery weight [41]. The same study also showed that the level of underreporting increased with increases in prepregnancy BMI, current BMI, pregnancy weight gain, and weight change from delivery to recall and that the reporting error was greater among women who were non-White, less educated, unmarried, whose pregnancy was unintended, and who initiated prenatal care late or had no prenatal care [41]. Data from other studies suggest that non-pregnant women also tend to underreport their weight [54, 55]. If the underreporting of weight in the current study occurred only when women reported their prepregnancy weight at the first prenatal visit but not when reporting their weight at delivery at the first postpartum visit (average 5 weeks postpartum), this may have incorrectly lead to an overestimate of the prevalence of excessive weight gain. In addition, if this differential underreporting occurred only among a specific socio-demographic group, the results may have identified a false association between weight gain and birthweight among this sub-population. The magnitude of differential underreporting for both prepregnancy weight and weight at delivery needs to be studied among the WIC population in Hawaii. On the other hand, maternal reported infant birth weight has been validated among the WIC population. A study by Gayle et al. [43] showed that when children were classified into low and normal weight categories according to maternal reported birth weight, only 1.1 % of births were misclassified. Nonetheless, it would be useful to replicate these results using standardized measures of prepragnancy and gestational weight gain, such as prenatal chart abstraction.

The results of the current study were also affected by limitations inherent in the Hawaii WIC data. Educational level, marital status, and enrollment status for Food Stamps, TANF, or Medicaid do not reflect the women's status during pregnancy, but rather the status as of July 2007, when the data for this study were extracted for analysis. If the mother continued to be enrolled in WIC for a subsequent pregnancy, her status with respect to these programs would have been updated. In addition, Hawaii WIC data lacked information on additional potential confounders or effect modifiers, such as history of LBW and maternal complications (e.g., gestational diabetes and preeclampsia). Furthermore, the prevalence of LBW was low in this population, thus the results may not be generalizable to other low-income population in the United States.

The WIC program offers a unique opportunity to provide nutrition education to low-income women during pregnancy. Because a high percentage of women had a GWG outside IOM-recommended ranges, additional interventions that encourage women to gain weight appropriately during pregnancy are likely needed. Although the 2009 IOM committee recommended that women enter pregnancy with a BMI in the normal range [42], implementation of weight reduction interventions during the preconception or interconception period for obese or overweight low-income women is challenging because of the high prevalence of unintended pregnancies among such women and the lack of a system through which to reach them, particularly during the preconception period. However, increasing attention focused on the well woman preventive health visit [56, 57] may help alleviate some of these obstacles. In addition, women who enter pregnancy overweight or obese may benefit from interventions focused on preventing excess weight gain during the prenatal period or on reducing weight during the postpartum or interconception periods [58–60]. Given the unique population of Hawaii, the development of culturally appropriate weight-reduction interventions for the various ethnic groups that live in Hawaii will require further research.

## Conclusion

Among non-obese low-income women in Hawaii, gaining weight within 2009 IOM-recommended ranges was associated with lower likelihood of delivering a LBW and HBW infant. Further investigations are needed to determine the appropriate GWG ranges for obese women.

## Acknowledgments

The authors would like to thank Ms. Melanie Murakami, Mr. Gordon Chinen, Mr. Lloyd Miyashiro, and other staff of the Hawaii State Department of Health, Family Health Services Division for their help in extracting and interpreting the WIC data. The authors also appreciate the assistance from Dr. Cheryl Prince, Dr. Dave Goodman, and Dr. Charlan Kroelinger from the Maternal and Child Health Epidemiology Program, Applied Sciences Branch, Division of Reproductive Health, National Center for Chronic Disease Prevention and Public Health Promotion, Centers for Disease Control and Prevention, for scientific guidance on this analysis and manuscript.

## Appendix 1

See Table 4

**Table 4**

2009 Institute of Medicine recommendation for total and rate of gestational weight gain by prepregnancy body mass index (BMI) categories

| Prepregnancy BMI | Recommended total weight gain, range in lbs | Rates of weight gain† in 2nd and 3rd Trimester, Mean (range) in lbs/week |
|---|---|---|
| Underweight (<18.5 kg/m$^2$) | 28–40 | 1 (1–1.3) |
| Normal (18.5–24.9 kg/m$^2$) | 25–35 | 1 (0.8–1) |
| Overweight (25.0–29.9 kg/m$^2$) | 15–25 | 0.6 (0.5–0.7) |
| Obese (≥30.0 kg/m$^2$) | 11–20 | 0.5 (0.4–0.6) |

Calculations assume a 1.1–4.4 lbs weight gain in the first trimester (IOM 2009)

Institute of Medicine, 2009. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington, DC. National Academies Press; Committee to Reexamine IOM Pregnancy Guidelines

## Appendix 2

See Fig 1

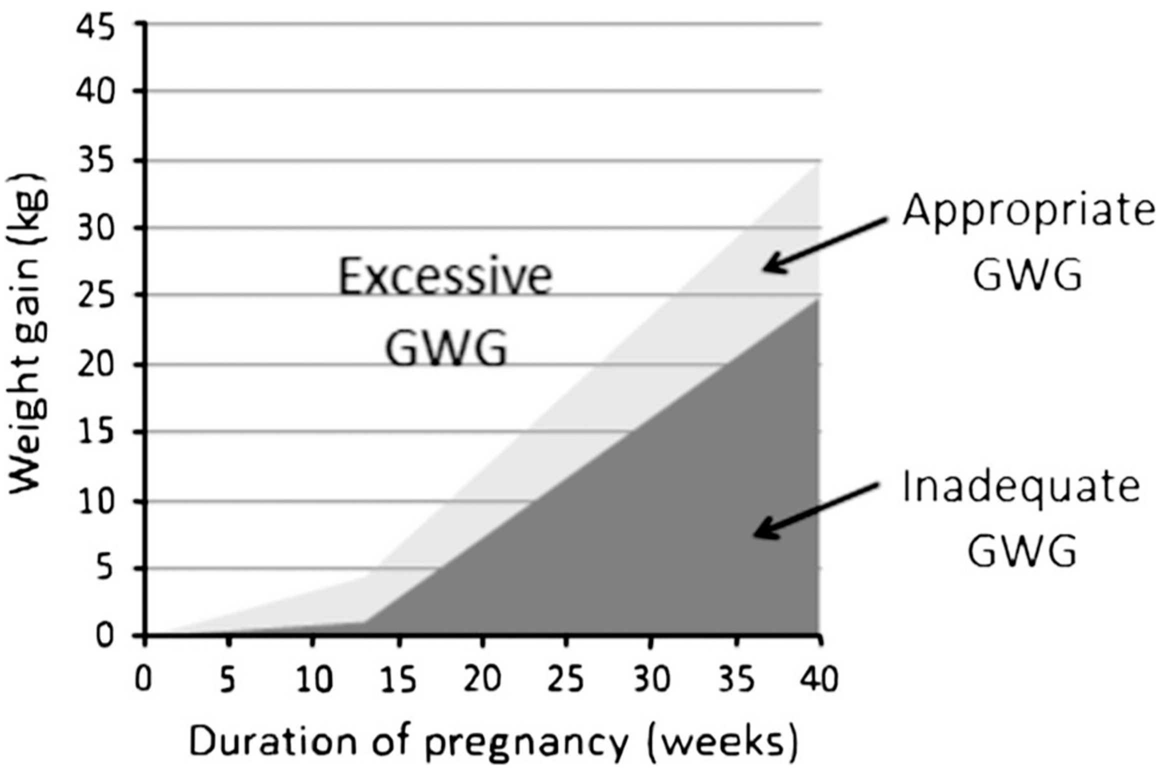


**Fig. 1.**
Gestational weight gain chart for normal weight women based on 2009 Institute of Medicine Recommendations. *Source* Institute of Medicine, 2009. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington, DC. National Academies Press; Committee to Reexamine IOM Pregnancy Guidelines

## References


1. Kiely JL, Brett KM, Yu S, et al. (1994). Low birth weight and intrauterine growth retardation. From Data to Action: CDC's public health surveillance for women, infants, and children. CDC's maternal and child monograph. Atlanta, GA: Centers for Disease Control and Prevention.
2. Kramer MS (1987). Determinants of low birth weight: Methodological assessment and meta-analysis. Bulletin of the World Health Organization, 65, 663–737. [PubMed: 3322602]
3. McCormick MC (1985). The contribution of low birth weight to infant mortality and childhood morbidity. New England Journal of Medicine, 312, 82–90. [PubMed: 3880598]
4. Croen LA, Grether JK, & Selvin S (2001). The epidemiology of mental retardation of unknown cause. Pediatrics, 107, E86. [PubMed: 11389284]
5. Dezateux C, & Stocks J (1997). Lung development and early origins of childhood respiratory illness. British Medical Bulletin, 53, 40–57. [PubMed: 9158283]
6. McCormick MC, Brooks-Gunn J, Workman-Daniels K, et al. (1992). The health and developmental status of very low-birth-weight children at school age. JAMA, 267, 2204–2208. [PubMed: 1556798]
7. Barker DJ, Eriksson JG, Forsen T, et al. (2002). Fetal origins of adult disease: Strength of effects and biological basis. International Journal of Epidemiology, 31, 1235–1239. [PubMed: 12540728]
8. Barker DJ, Hales CN, Fall CH, et al. (1993). Type 2 (non-insulin-dependent) diabetes mellitus, hypertension and hyperlipidaemia (syndrome X): Relation to reduced fetal growth. Diabetologia, 36, 62–67. [PubMed: 8436255]
9. Barker DJ, & Martyn CN (1992). The maternal and fetal origins of cardiovascular disease. Journal of Epidemiology and Community Health, 46, 8–11. [PubMed: 1573367]
10. Byberg L, McKeigue PM, Zethelius B, et al. (2000). Birth weight and the insulin resistance syndrome: Association of low birth weight with truncal obesity and raised plasminogen activator inhibitor-1 but not with abdominal obesity or plasma lipid disturbances. Diabetologia, 43, 54–60. [PubMed: 10663216]
11. Eriksson JG, Osmond C, Kajantie E, et al. (2006). Patterns of growth among children who later develop type 2 diabetes or its risk factors. Diabetologia, 49, 2853–2858. [PubMed: 17096117]
12. Rich-Edwards JW, Stampfer MJ, Manson JE, et al. (1997). Birth weight and risk of cardiovascular disease in a cohort of women followed up since 1976. BMJ, 315, 396–400. [PubMed: 9277603]
13. Savona-Ventura C, & Chircop M (2003). Birth weight influence on the subsequent development of gestational diabetes mellitus. Acta Diabetologica, 40, 101–104. [PubMed: 12861409]
14. Williams S, St George IM, & Silva PA (1992). Intrauterine growth retardation and blood pressure at age seven and eighteen. Journal of Clinical Epidemiology, 45, 1257–1263. [PubMed: 1432007]
15. Boulet SL, Alexander GR, Salihu HM, et al. (2003). Macrosomic births in the United States: Determinants, outcomes, and proposed grades of risk. American Journal of Obstetrics and Gynecology, 188, 1372–1378. [PubMed: 12748514]
16. Boyd ME, Usher RH, & McLean FH (1983). Fetal macrosomia: Prediction, risks, proposed management. Obstetrics and Gynecology, 61, 715–722. [PubMed: 6843930]
17. Ferber A (2000). Maternal complications of fetal macrosomia. Clinical Obstetrics and Gynecology, 43, 335–339. [PubMed: 10863631]
18. Grassi AE, & Giuliano MA (2000). The neonate with macrosomia. Clinical Obstetrics and Gynecology, 43, 340–348. [PubMed: 10863632]
19. Lipscomb KR, Gregory K, & Shaw K (1995). The outcome of macrosomic infants weighing at least 4500 grams: Los Angeles County + University of Southern California experience. Obstetrics and Gynecology, 85, 558–564. [PubMed: 7898833]
20. Meshari AA, De Silva S, & Rahman I (1990). Fetal macrosomia–maternal risks and fetal outcome. International Journal of Gynaecology and Obstetrics, 32, 215–222. [PubMed: 1972112]
21. Raio L, Ghezzi F, Di Naro E, et al. (2003). Perinatal outcome of fetuses with a birth weight greater than 4500 g: An analysis of 3356 cases. European Journal of Obstetrics, Gynecology, and Reproductive Biology, 109, 160–165. [PubMed: 12860334]
22. Spellacy WN, Miller S, Winegar A, et al. (1985). Macro-somia–maternal characteristics and infant complications. Obstetrics and Gynecology, 66, 158–161. [PubMed: 4022478]

23. Wollschlaeger K, Nieder J, Koppe I, et al. (1999). A study of fetal macrosomia. Archives of Gynecology and Obstetrics, 263, 51–55. [PubMed: 10728630]
24. Dietz WH (1994). Critical periods in childhood for the development of obesity. American Journal of Clinical Nutrition, 59, 955–959. [PubMed: 8172099]
25. Gillman MW, Rifas-Shiman S, Berkey CS, et al. (2003). Maternal gestational diabetes, birth weight, and adolescent obesity. Pediatrics, 111, e221–e226. [PubMed: 12612275]
26. Parsons TJ, Power C, Logan S, et al. (1999). Childhood predictors of adult obesity: A systematic review. International Journal of Obesity and Related Metabolic Disorders, 23(Suppl8), S1–S107.
27. Institute of Medicine. (1990). Nutrition during pregnancy. Washington, DC: National Academy Press.
28. Cogswell ME, Serdula MK, Hungerford DW, et al. (1995). Gestational weight gain among average-weight and overweight women–what is excessive? American Journal of Obstetrics and Gynecology, 172, 705–712. [PubMed: 7856711]
29. Johnson JW, Longmate JA, & Frentzen B (1992). Excessive maternal weight and pregnancy outcome. American Journal of Obstetrics and Gynecology, 167, 353–370. [PubMed: 1497038]
30. DeVader SR, Neeley HL, Myles TD, et al. (2007). Evaluation of gestational weight gain guidelines for women with normal prepregnancy body mass index. Obstetrics and Gynecology, 110, 745–751. [PubMed: 17906004]
31. Parker JD, & Abrams B (1992). Prenatal weight gain advice: An examination of the recent prenatal weight gain recommendations of the Institute of Medicine. Obstetrics and Gynecology, 79, 664–669. [PubMed: 1565346]
32. Schieve LA, Cogswell ME, & Scanlon KS (1999). Maternal weight gain and preterm delivery: Differential effects by body mass index. Epidemiology, 10, 141–147. [PubMed: 10069249]
33. Schieve LA, Cogswell ME, Scanlon KS, et al. (2000). Prepregnancy body mass index and pregnancy weight gain: Associations with preterm delivery. The NMIHS Collaborative Study Group. Obstetrics and Gynecology, 96, 194–200. [PubMed: 10908762]
34. Siega-Riz AM, Adair LS, & Hobel CJ (1994). Institute of Medicine maternal weight gain recommendations and pregnancy outcome in a predominantly Hispanic population. Obstetrics and Gynecology, 84, 565–573. [PubMed: 8090394]
35. Jain NJ, Denk CE, Kruse LK, et al. (2007). Maternal obesity: Can pregnancy weight gain modify risk of selected adverse pregnancy outcomes? American Journal of Perinatology, 24, 291–298. [PubMed: 17514601]
36. Rode L, Hegaard HK, Kjaergaard H, et al. (2007). Association between maternal weight gain and birth weight. Obstetrics and Gynecology, 109, 1309–1315. [PubMed: 17540802]
37. Shapiro C, Sutija VG, & Bush J (2000). Effect of maternal weight gain on infant birth weight. Journal of Perinatal Medicine, 28, 428–431. [PubMed: 11155426]
38. Stotland NE, Cheng YW, Hopkins LM, et al. (2006). Gestational weight gain and adverse neonatal outcome among term infants. Obstetrics and Gynecology, 108, 635–643. [PubMed: 16946225]
39. Baruffi G, Hardy C, Waslien C, et al. (2005). The association of pregnancy weight gain with infant birth weight and postpartum weight retention: Ethnic differences in Hawaii, 1997 & 1998. California Journal of Health Promotion, 3, 144–156.
40. Luke B, Hediger ML, & Scholl TO (1996). Point of diminishing returns: When does gestational weight gain cease benefiting birthweight and begin adding to maternal obesity? J Matern Fetal Med, 5, 168–173. [PubMed: 8796789]
41. Schieve LA, Perry GS, Cogswell ME, et al. (1999). Validity of self-reported pregnancy delivery weight: An analysis of the 1988 National Maternal and Infant Health Survey. NMIHS Collaborative Working Group. American Journal of Epidemiology, 150, 947–956. [PubMed: 10547140]
42. Institute of Medicine. (2009). Weight gain during pregnancy: Reexamining the guidelines. Washington, DC: The National Academies Press.
43. Gayle HD, Yip R, Frank MJ, et al. (1988). Validation of maternally reported birth weights among 46,637 Tennessee WIC program participants. Public Health Reports, 103, 143–147. [PubMed: 3128829]

44. Lederman SA, & Paxton A (1998). Maternal reporting of prepregnancy weight and birth outcome: Consistency and completeness compared with the clinical record. Maternal and Child Health J, 2, 123–126.
45. Olson JE, Shu XO, Ross JA, et al. (1997). Medical record validation of maternally reported birth characteristics and pregnancy-related events: A report from the Children's Cancer Group. American Journal of Epidemiology, 145, 58–67. [PubMed: 8982023]
46. Seidman DS, Slater PE, Ever-Hadani P, et al. (1987). British Journal of Obstetrics and Gynaecology, 94, 731–735. [PubMed: 3663531]
47. Tomeo CA, Rich-Edwards JW, Michels KB, et al. (1999). Reproducibility and validity of maternal recall of pregnancy-related events. Epidemiology, 10, 774–777. [PubMed: 10535796]
48. Sorensen CA, Wood B, & Prince EW (2003). Developing a common language for public health surveillance in Hawaii. California Journal of Health Promotion, 1, 91–104.
49. Hickey CA, Uauy R, Rodriguez LM, et al. (1990). Maternal weight gain in low-income black and Hispanic women: Evaluation by use of weight-for-height near term. American Journal of Clinical Nutrition, 52(5), 938–943. [PubMed: 2239772]
50. Crane JM, White J, Murphy P, et al. (2009). The effect of gestational weight gain by body mass index on maternal and neonatal outcomes. Journal of Obstetrics and Gynaecology Canada, 31(1), 28–35. [PubMed: 19208280]
51. Artal R, Lockwood CJ, & Brown HL (2010). Weight gain recommendations in pregnancy and the obesity epidemic. Obstetrics and Gynecology, 115, 52–55.
52. Siega-Riz AM, Siega-Riz AM, & Laraia B (2006). The implications of maternal overweight and obesity on the course of pregnancy and birth outcomes. Maternal and Child Health Journal, 10, S153–S156. [PubMed: 16927160]
53. Dietz PM, Callaghan WM, Cogswell ME, et al. (2006). Combined effects of prepregnancy body mass index and weight gain during pregnancy on the risk of preterm delivery. Epidemiology, 17, 170–177. [PubMed: 16477257]
54. Rowland ML (1989). Reporting bias in height and weight data. Statistical Bulletin/Metropolitan Insurance Companies, 70, 2–11.
55. Stewart AW, Jackson RT, Ford MA, et al. (1987). Underestimation of relative weight by use of self-reported height and weight. American Journal of Epidemiology, 125, 122–126. [PubMed: 3788941]
56. Institute of Medicine. (2011). Clinical preventive services for women: Closing the gaps. Consensus Report. Washington, DC: The National Academies Press.
57. Gee RE, Brindis CD, Diaz A, et al. (2011). Recommendations of the IOM clinical preventive services for women committee: Implications for obstetricians and gynecologists. Current Opinion in Obstetrics and Gynecology, 23(6), 471–480. [PubMed: 22011955]
58. Asbee SM, Jenkins TR, Butler JR, et al. (2009). Preventing excessive weight gain during pregnancy through dietary and lifestyle counseling. Obstetrics and Gynecology, 113, 305–312. [PubMed: 19155899]
59. Kinnunen TI, Pasanen M, Aittasalo M, et al. (2007). Preventing excessive weight gain during pregnancy: A controlled trial in primary health care. European Journal of Clinical Nutrition, 61, 884–891. [PubMed: 17228348]
60. Olson CM, Strawderman MS, & Reed RG (2004). Efficacy of an intervention to prevent excessive gestational weight gain. American Journal of Obstetrics and Gynecology, 191, 530–536. [PubMed: 15343232]

## Table 1

Characteristics of Women and Infants Enrolled in the in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Hawaii, 2003–2005 (N = 19,130 mother/infant pairs)

| Characteristic | n (%) |
|---|---|
| Maternal age (years) | |
| <20 | 2,767 (14.5) |
| 20–29 | 11,827 (61.9) |
| ≥30 | 4,536 (23.7) |
| Maternal education | |
| <12 years | 2,370 (12.4) |
| 12 years or high school diploma | 11,849 (61.9) |
| >12 years | 4,910 (25.7) |
| Maternal race/ethnicity | |
| Hawaiian/part Hawaiian | 6,780 (35.4) |
| Asian | 4,521 (23.6) |
| White | 3,121 (16.3) |
| Pacific Islander | 1,686 (8.8) |
| Other | 3,022 (15.8) |
| Marital status | |
| Married | 9,204 (48.4) |
| Unmarried | 9,832 (51.6) |
| Smoking status | |
| Smoker | 2,015 (10.6) |
| Non-smoker | 17,029 (89.4) |
| Parity | |
| No previous live birth | 8,064 (42.2) |
| One or more previous live births | 11,051 (57.8) |
| Prepregnancy BMI status | |
| Underweight (BMI < 18.5) | 1,153 (6.0) |
| Normal weight (BMI 18.5–24.9) | 9,291 (48.6) |
| Overweight (BMI 25.0–29.9) | 4,391 (23.0) |
| Obese (BMI ≥ 30.0) | 4,295 (22.5) |
| Weight gain during pregnancy | |
| Inadequate | 2,831 (14.8) |
| Appropriate | 4,515 (23.6) |
| Excessive | 11,784 (61.6) |
| Received Medicaid, TANF, or food stamps | |
| Yes | 10,080 (52.7) |
| No | 9,050 (47.3) |
| Trimester of WIC Entry | |
| 1st | 5,868 (30.7) |
| 2nd | 8,580 (44.9) |

| Characteristic | n (%) |
|---|---|
| 3rd | 4,682 (24.5) |
| Infant's sex | |
| Male | 9,824 (51.4) |
| Female | 9,306 (48.6) |
| Infant's birth weight | |
| Low birth weight (<2,500 g) | 1,219 (6.4) |
| Normal birth weight (2,500–3,999 g) | 16,441 (85.9) |
| High birth weight (≥4,000 g) | 1,470 (7.7) |
| Gestational duration | |
| <37 weeks (preterm delivery) | 1,387 (7.3) |
| ≥37 weeks (term delivery | 17,743 (92.8) |

*BMI* body mass index, *TANF* temporary assistance for needy families

## Table 2

Characteristics of women and infants enrolled in the Hawaii WIC Program, by mothers' gestational weight gain classification, 2003–2005 (N = 19,130)

| Characteristic | Subjects (n) | Gestational weight gain (%) | | | *p* value* |
|---|---|---|---|---|---|
| | | Inadequate | Appropriate | Excessive | |
| Maternal age (years) | | | | | <.0001 |
| <20 | 2,767 | 12.0 | 21.6 | 66.4 | |
| 20–29 | 11,827 | 13.8 | 23.0 | 63.2 | |
| 30 and older | 4,536 | 19.2 | 26.3 | 54.5 | |
| Maternal education | | | | | 0.0002 |
| Less than 12 years | 2,370 | 14.6 | 23.0 | 62.4 | |
| 12 years or high school diploma | 11,849 | 14.8 | 22.7 | 62.4 | |
| More than 12 years | 4,910 | 14.8 | 26.0 | 59.2 | |
| Maternal race/ethnicity | | | | | <.0001 |
| Hawaiian/part Hawaiian | 6,780 | 12.5 | 19.7 | 67.8 | |
| Asian | 4,521 | 20.1 | 31.3 | 48.6 | |
| White | 3,121 | 12.9 | 25.8 | 61.3 | |
| Pacific Islander | 1,686 | 14.3 | 16.4 | 69.3 | |
| Other | 3,022 | 14.2 | 22.7 | 63.2 | |
| Marital status | | | | | <.0001 |
| Married | 9,204 | 16.5 | 25.5 | 58.0 | |
| Unmarried | 9,832 | 13.2 | 21.8 | 65.0 | |
| Smoking status | | | | | <.0001 |
| Smoker | 2,015 | 13.1 | 20.5 | 66.5 | |
| Non-smoker | 17,029 | 15.0 | 24.0 | 61.0 | |
| Parity | | | | | <.0001 |
| No previous live birth | 8,064 | 11.7 | 21.7 | 66.6 | |
| One or more previous live births | 11,051 | 17.1 | 25.0 | 57.9 | |
| Prepregnancy BMI status | | | | | <.0001 |
| Underweight (<18.5 kg/m$^2$) | 1,153 | 18.9 | 41.8 | 39.3 | |
| Normal (18.5–24.9 kg/m$^2$) | 9,291 | 16.3 | 28.6 | 55.1 | |
| Overweight (25.0–29.9 kg/m$^2$) | 4,391 | 9.5 | 16.5 | 74.0 | |
| Obese (≥ 30.0 kg/m$^2$) | 4,295 | 15.9 | 15.1 | 69.0 | |
| Enrolled in Medicaid, TANF, or Food Stamps | | | | | <.0001 |
| Yes | 10,080 | 14.4 | 22.1 | 63.5 | |
| No | 9,050 | 15.2 | 25.3 | 59.5 | |
| Trimester of WIC entry | | | | | 0.0483 |
| 1st trimester | 5,827 | 15.6 | 22.6 | 61.8 | |
| 2nd trimester | 8,539 | 14.3 | 23.8 | 61.9 | |
| 3rd trimester | 4,662 | 14.6 | 24.6 | 60.8 | |
| Birth weight | | | | | <.0001 |
| Low birth weight (<2,500 g) | 1,219 | 23.7 | 24.9 | 51.4 | |

| Characteristic | Subjects (n) | Gestational weight gain (%) | | | *p* value* |
|---|---|---|---|---|---|
| | | Inadequate | Appropriate | Excessive | |
| Normal birth weight (2,500–3,999 g) | 16,441 | 14.9 | 24.4 | 60.7 | |
| High birth weight (≥4,000 g) | 1,470 | 6.7 | 13.1 | 80.3 | |

*Chi square tests were used to calculate P values

**Table 3**

Adjusted odds ratios for the relationship between women's gestational weight gain classification and the birthweight classification of their child, stratified by women's prepregnancy bmi classification (N = 19,130)

| Prepregnancy BMI classification | GWG | LBW Adjusted OR (95 % CI) | HBW Adjusted OR (95 % CI) |
|---|---|---|---|
| Underweight (BMI < 18.5) | Inadequate | 2.01 (1.27–3.21) | 0.22 (0.03–1.72) |
| | Appropriate | Reference | Reference |
| | Excessive | 0.54 (0.34–0.87) | 2.47 (1.15–5.28) |
| Normal weight (BMI 18.5–24.9) | Inadequate | 1.81 (1.44–2.27) | 0.47 (0.29–0.75) |
| | Appropriate | Reference | Reference |
| | Excessive | 0.86 (0.70–1.05) | 2.22 (1.74–2.82) |
| Overweight (BMI 25.0–29.9) | Inadequate | 1.53 (0.98–2.39) | 1.02 (0.57–1.83) |
| | Appropriate | Reference | Reference |
| | Excessive | 0.73 (0.51–1.03) | 2.66 (1.83–3.85) |
| Obese (BMI ≥ 30.0) | Inadequate | 0.99 (0.61–1.59) | 0.92 (0.62–1.36) |
| | Appropriate | Reference | Reference |
| | Excessive | 0.87 (0.59–1.28) | 1.95 (1.45–2.63) |

Results were adjusted for maternal age, education, race/ethnicity, marital status, smoking status, and parity *OR* odds ratio, *CI* confidence interval