Published in final edited form as:
Matern Child Health J. 2012 January ; 16(1): 119–124. doi:10.1007/s10995-010-0713-5.

The Association between Inadequate Gestational Weight Gain and Infant Mortality among U.S. Infants born in 2002

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Abstract

OBJECTIVES—The purpose of this study was to determine the relative importance of inadequate maternal weight gain as a cause of infant mortality.

METHODS—Birth and infant death certificate data were obtained from a random sample of 100,000 records from the National Center for Health Statistics 2002 Linked Birth/Infant Death Data Set. Descriptive and proportional hazards regression analyses were used to assess the risk of infant mortality associated with inadequate gestational weight gain compared to normal weight gain.

RESULTS—Inadequate gestational weight gain was associated with increased odds of infant death. The increased risk remained after adjustment for gestational age, low birth weight, maternal age, maternal education, and maternal race. Among racial or ethnic subgroups, African American women with inadequate maternal weight gain were 1.3 times more likely than white women to have infant death.

CONCLUSION—There is a substantial and significant association between inadequate gestational weight gain and infant death.

Keywords

Infant Mortality; Weight Gain; Pregnancy; Prenatal care; Institute of Medicine

Introduction

The United States (U.S.) has experienced an impressive reduction in infant mortality over the past several decades. According to the Centers for Disease Control and Prevention (CDC), the infant mortality rate - the rate at which babies less than one year of age die - has steadily declined from 26 per 1,000 live births in 1960 to 6.75 per 1,000 live births in 2007 (1). Low birth weight (less than 2500g) is an important determinant of infant mortality. In 2007, low birth weight was one of the second leading causes of U.S. infant deaths (1).

Researchers have consistently demonstrated a strong relationship between gestational weight gain and birth weight. Low maternal weight gain is considered an important risk factor for low birth weight (2). Recognition of this risk led the Institute of Medicine (IOM) of the National Academy of Sciences to issue weight gain recommendations in 1990 (3). Recently reexamined in 2009, these guidelines provide target weight gain ranges specific to a woman's pre-pregnancy body mass index (BMI; in kg/m^2) and are associated with the best

infant and maternal outcomes (4). Recommendations are based on a woman's pre-gravid weight status and include weight gains of (a) 28 to 40 pounds for women who are underweight (< 18.5 BMI); (b) 25 to 35 pounds for women of normal weight (18.5–24.9 BMI); and (c) 15 to 25 pounds for women who are overweight (25 – 29.9 BMI). The recommendations also include a relatively narrow range of recommended gain of 11 to 20 pounds for women who are obese (≥ 30.0 BMI). A divergence from the 1990 IOM report, the recommended weight gain ranges for short women and for racial or ethnic groups are the same as those for the entire population (4).

Insufficient maternal weight gain can negatively influence pregnancy outcomes. Inadequate weight gain has been associated with an increased risk of intrauterine growth restriction, preterm birth, and perinatal mortality (5, 6). Studies have also found that when maternal weight gain is within the IOM recommended range, incidences of low birth weight births are reduced (7). However, published studies suggest most pregnant women do not achieve the ideal weight gain. In a review of observational studies examining maternal and fetal outcomes, Abrams et al. reported only 30–40% of American women actually have weight gains within the IOM recommended ranges (6). Further, during the recent re-examination of the gestational weight gain guidelines using birth certificate, Pregnancy Risk Assessment Monitoring System (PRAMS), and Pregnancy Nutrition Surveillance System (PNSS) data, the IOM found less than half of the women represented in these populations met the previously released recommendations (4)

Along with gaining weight within the IOM recommended range, the data on pregnancy outcomes suggests carrying a baby to term is also an important factor in achieving and maintaining optimal maternal weight. Women who deliver preterm have less time to gain weight and are at significant risk of neonatal, infant and perinatal mortality (8). The rate of weight gain varies throughout pregnancy. The slowest gains occur in the first trimester (0.4 lbs/wk), fastest gains in the second trimester (1.2 lbs/wk), and slightly slower rates in the third trimester (1.1 lbs/wk) (9).

Preterm birth is defined as delivery before the last quarter of the third trimester (37 weeks gestation). Uncertainty continues about the causes and best management of premature labor (10). The American College of Obstetricians and Gynecologists (ACOG) Committee of Obstetric Practice, however, strongly recommends preconception counseling and/or education about ideal weight gain during the first prenatal visit. Routine monitoring of maternal weight status and referral to nutrition counseling is also encouraged (11).

Despite a large body of perinatal literature, there is not universal acceptance that pregnancy weight gain within the ideal ranges improves short- and long-term infant outcomes (6). Those who question the recommendations believe weight gain within the IOM ranges could cause substantive postpartum weight retention and will produce overgrown newborns at increased risk of cesarean delivery. Data on maternal postpartum weights are not widely available, particularly for times later in the year after birth. Further research is also needed to more clearly understand relationships between maternal pre-pregnancy BMI, gestational weight gain, and cesarean deliveries in the United States.

Since the release of the IOM (1990) weight gain recommendations, low (< 16 pound) gestational weight gain has become more common (6). Currently there is very limited literature assessing gestational weight gain and infant morality. In the IOM (1990) report, only one National Center for Health Statistics (NCHS) study on perinatal mortality was examined using 1980 vital health statistics data and there has been only one additional study since then (3, 6, 12). As part of the National Maternal and Infant Health Survey (NMIHS), Chen et al. examined maternal pre-pregnancy BMI and gestational weight gain among 4,265

infant deaths and 7,293 controls (13). Among underweight and normal weight women, low gestational weight gain was associated with an increase in infant mortality, with relative risks of three to four compared to those with the highest gestational weight gain. The effects were more modest among overweight and obese women, with both lower and higher gestational weight gain associated with approximately two-fold increases in the risk of infant mortality. In all cases, the patterns were stronger for neonatal deaths (in the first 30 days of life) than for post neonatal deaths (those occurring after 1 month but before the completion of 1 year) (4). The importance of this adverse birth outcome warrants further research. The purpose of this analysis was to assess the relationship between low pregnancy weight gain and risk of infant death for the 2002 U.S. birth cohort.

Methods

Infants were identified through U.S. birth records for 2002 linked to their death records within the following year. A sample of 100,000 records was selected at random from the linked file of 4.02 million births. The methodology used to create the linked file is described in the NCHS Public Use Data documentation. The full data set contains information from birth and death certificates for all individuals born in the United States in 2002. Available information includes maternal race, education, marital status, obstetric history, antenatal high-risk conditions, maternal life-style factors, prenatal care history, labor and delivery complications, gestational age, birth weight, and infant diseases and death (14).

Currently available data sources are inadequate for studying national trends in gestational weight gain. Although the 1990 IOM report called for collection of national data on maternal weight gain and pre-pregnancy height and weight for proper surveillance, today there are still no nationally representative data with which to study trends in the United States (4). In the present study, pre-pregnancy maternal weight was not available in the data set and could, therefore not be used to precisely replicate the IOM guidelines. The stated number of total pounds of weight gained during pregnancy was used to classify maternal weight gain.

To be conservative, the lower limit of the IOM recommended range was used to define low weight gain. Gestational weight gain was classified into three outcome categories: inadequate (less than or equal to 24 lbs.), normal (between 25 and 40 lbs), or excessive (more than or equal 41 lbs). Low birth weight was defined as less than 2500 grams, infant deaths were those within 365 days of birth, and a full-term birth was defined as greater than 36 weeks of gestation at the time of delivery. Advanced maternal age, associated with infant mortality, was treated as a dummy variable indicating if the mother was age 35 and older at time of delivery versus under 35. Maternal education was classified into three groups: high school graduate (12 years of school), some college (13 to 15 years of school), and college graduate (more than or equal to 16 years of school). The risk of infant mortality was used as the dependent variable and gestational weight gain as the main independent variable. The infant's gestational age and mother's age at delivery were included as controls. Low birth weight was used as a mediator and maternal race/ethnicity was used as a potential moderator. An interaction between inadequate maternal weight gain and maternal race was also included. Because white women and women of normal weight gain had the lowest risk of adverse outcomes, they served as the reference group in the analysis. Records were also weighted to compensate for differential rates of non-linkage of birth/infant death records. Cox proportional hazards regression was used to compute the hazard of infant death by day after birth up to 365 days. Those who survived were censored after 12 months. Statistical analyses were performed using SAS version 9.1software (SAS Institute Inc., Cary, NC) (15). Evidence for mediation is a decline in the coefficient for weight gain after the addition of a low birth weight dummy variable. Evidence for moderation is provided by a significant

interaction between race/ethnicity and the weight gain dummy variables (16,17). Fit was assessed by the difference in −2 log likelihood across models. Figure 1 depicts directed acyclic graphs linking inadequate maternal weight gain, low birth weight, and infant mortality.

The hypotheses examined in the present study were (1) women with inadequate gestational weight gain are at increased risk of infant mortality, (2) infants born of low birth weight are at increased risk of infant mortality, and 3) low birth weight partially explains the effect of inadequate weight gain on infant mortality. It was also hypothesized 4) that minority women are at higher risk of infant mortality than their white counterparts when they do not achieve the recommended weight gain.

Results

A total of 80,224 infants had complete information on the variables in the model. Some 21,684 records were excluded as a result of missing variables for birthweight, gestational age, maternal education, total weight gain, and Hispanic race (Table 1). Mothers in the sample had a mean age of 27.21 years and the age at delivery ranged from 12 to 54 years. The majority of the study sample was white (62.4%), followed by 17.2 % Hispanic, 15.5% Black, 4% Asian or Pacific Islander, and 1% American Indian. Nearly 30% of mothers experienced inadequate weight gain and only 49.8% gained the recommended amount of weight. In 2002, 0.64% of infants died. Of the infants whose mothers gained an inadequate amount of weight during pregnancy, 1.17% died, compared with 0.42% of those whose mothers gained a normal or excessive amount of weight (not shown). Of the infants born low birth weight (7.75%), 5.48% died compared with 0.23% of those of normal birth weight. Table 1 shows the characteristics of mothers and infants.

Table 2 shows the results from a series of nested proportional hazards regression models. Model 1 displays the odds ratios for infant death associated with the two weight gain categories - inadequate and excessive - with controls for gestational and maternal age. The reference group for the two categories included infants whose mothers had a total pregnancy weight gain within the normal range. Inadequate maternal weight gain was associated with increased odds of infant mortality, whereas excessive weight gain was not (AOR [adjusted odds ratio] =2.23, $p<0.0001$, 95% CI [confidence interval]: 1.84, 2.70). Infants born to women with inadequate gestational weight gain had odds of infant death that were 123% higher than the odds for the reference group of infants. Gaining more than the recommended weight was associated with an insignificant 0.6% increase in the chance of infant mortality compared with weight gain within the normal range.

Model 1 also shows an association between gestational age and infant mortality. Babies of women who delivered after 36 weeks gestation were 92% less likely to experience death than those who delivered preterm.

Low birth weight was added to Model 2 to determine whether it had a mediating effect. The fit of the model improved (Chi square =403, df=1, $p<.001$) The coefficient for inadequate weight gain declined 20%, from 0.818 to 0.654 (not shown), but remained significant and positive. After controlling for birth weight, infants of women with low pregnancy weight gain were 92% more likely to die than infants of women achieving the recommended range (AOR=1.92, $p<0.0001$, 95% CI: 1.59, 2.33). Thus, low birth weight was a partial mediator for infant mortality. Newborns weighing less than 2500g had odds of infant death that were 905% higher than those of normal birth weight.

Model 3 shows the association between weight gain and infant mortality including controls for maternal race. Again, the fit of Model 3 was an improvement over Model 2 (Chi Square

= 14, df=4, p<.01). The effect of inadequate weight gain remained significant (AOR= (1.89, p<0.0001, 95% CI: 1.56, 2.30) and of the same magnitude after race/ethnicity was introduced. Black mothers had an increased chance of infant death when compared to White mothers (AOR=1.33, p<0.01, 95% CI: 1.08, 1.63). Asian mothers had a reduced chance of infant dealth when compared to White mothers, though the association did not reach significance at conventional levels (AOR=0.56, p<.07, 95% CI: 0.30, 1.05) in this sample.

Model 4 adds maternal education, and the model is a significant improvement over Model 3 (Chi square=20, df=3, p<.001). After controlling for birth weight and maternal education and race, infants born to women with inadequate gestational weight gain had odds of infant death that were 1.84 times the odds for infants born to women with normal weight gain (p<0.0001, 95% CI: 1.51, 2.23). Newborns weighing less than 2500g had odds of infant death that were 867% higher than those of normal birth weight. Consistent with previous research, mortality was strongly linked to schooling, with increased years of education predicting lower levels of infant mortality.

In a fifth model, the interactions between inappropriate pregnancy weight gain and maternal race in their effects on infant mortality were added. The main effect of inadequate weight gain was not substantially altered by the addition of the interaction terms and none of the interaction terms was statistically significant. The findings indicated that maternal race does not moderate the influence of maternal weight gain on infant mortality; data are not presented.

Discussion

The analysis supports Hypothesis 1, that inadequate maternal weight gain was associated with increased odds of infant death. Supporting Hypothesis 2, low birth weight was associated with a greater odds of infant death. Hypothesis 3 was partially supported in that the association between inadequate maternal weight gain and the odds of infant death declined after the inclusion of low birth weight. However, although low birth weight explained some of this effect (18%) and was itself strongly associated with infant death, inadequate maternal weight gain was a significant predictor of infant death even after adjusting for gestational age and low birth weight.

Hypothesis 4 was not supported. The study failed to find any difference in the association of inadequate maternal weight gain with increased risk of infant death by race/ethnicity. The risks of inadequate weight gain apply to the four minority groups that could be examined in the present study and to the majority white population of mothers. The results, however, support previous research that has shown that infants born to Black women are at especially high mortality risk (18). In contrast, infants born to Asian or Pacific Islander mothers may be at low mortality risk. Little was previously known about the link between weight gain and perinatal outcomes among this population, so this research fills an important gap. Studies have found that Asian women have lower pre-pregnancy weight, on average (18). Future research should explore the role of weight gain and infant mortality among Asian Americans and whether the current weight gain recommendations are appropriate for this population.

Strengths and Limitations

Despite concerted efforts to examine the relationship between gestational weight gain and infant mortality, the study was not without limitations. Although the sample included thousands of U.S. women, the standard birth certificate lacks data on maternal pre-pregnancy weight and height. Thus, overweight or obese women who achieved the recommended weight gain could have been incorrectly classified as inadequate in this

research. This potential misclassification of exposure status prompted a sensitivity analysis to determine if similar results would be obtained if inadequate weight gain was categorized as less than or equal to 14 pounds (below the lower limit of the IOM target weight gain range for overweight women). After taking into account gestational age, maternal age, and low birth weight, infants born to women with inadequate gestational weight gain continued to have odds of infant death (AOR= 2.37) that were higher than the odds for the reference group of infants. Inappropriate gestational weight gain also continued to be harmful for black mothers, increasing the chance of infant death by 28%. The methodological limitations are not unique to the present study, but rather reflect the reality of analyzing secondary data sources. At present only PRAMS and PNSS collect data on gestational weight gain and pre-pregnancy BMI in U.S. women. While the data sources could facilitate the identification of trends in recommended weight gains, neither of these two U.S. surveillance systems is nationally representative. In 2001, the NCHS Panel to Evaluate the U.S. Standard Certificates recommended maternal height and pre-pregnancy weight be added to U.S. birth certificates to allow BMI calculation (19). These data were added to the 2003 revised U.S. Certificate of Live Birth and by 2006, 19 states had already implemented the revised certificate. Birth certificate data may yield more useful statistics for maternal weight gain surveillance in the very near future (4).

Overall, the study data support the conclusion that inadequate pregnancy weight gain is associated with negative outcomes for infants. The magnitude of this association is consistent with the results of other studies that have linked inadequate weight gain with infant mortality and low birth weight. Because the amount of total weight gain is widely variable among women of the same age, weights, heights, and ethnic backgrounds, and because infant mortality and LBW are multifactorial in origin, weight gain alone should not be used as a screening and diagnostic tool (6). Nonetheless, inadequate weight gain is associated with poorer pregnancy outcomes than weight gain within the normal range, even controlling for several other factors.

Public Health implications

Given the study results, health care professionals should be particularly concerned by the fact that most U.S. women do not seem to gain weight within the IOM-recommended ranges. Clinical and public health interventions should help pregnant women achieve their ideal weight gain with the goal of ensuring the best possible outcome for their infants.

The findings of this study suggest the need for pre-conception counseling about diet and physical activity as well as continued monitoring and counseling throughout pregnancy. This critical area of public health intervention could not only improve individual maternal and infant health, it may also have a positive impact on the current public health concern about obesity and overweight among women of childbearing ages as well as on the developmental Healthy People 2010 objective to increase the proportion of mothers who achieve the recommended weight gain during their pregnancies (20).

Additionally, there are only a small number of published studies examining inadequate gestational weight gain. More research investigating low gestational weight gain and infant mortality as well as other outcomes for underweight women who are at high risk is warranted.

Finally, there is evidence that the pattern of gestational weight gain may be as or more important than the total amount gained (20). Current studies indicate that gestational weight gain, particularly during the second and third trimesters, is an important determinant of fetal growth, birth weight, and preterm delivery (6,21). The new recommended gestational weight

gain values suggest normal weight women gain 1 lb per week (~0.4 kg) in the second and third trimesters of pregnancy; underweight women gain slightly more at 1.3 lbs (~0.5 kg) per week; and overweight women slightly less at 0.6 lbs (~0.3 kg) per week. Obese women should gain approximately .05 lbs (~0.2 kg) per week (4). Maternal weight gain is susceptible to intervention and monitoring patterns of weight gain may represent an avenue for prevention of poor birth outcomes. The rate of maternal weight gain should continue to be examined in future research.

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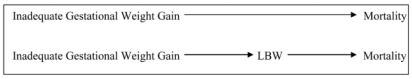

Figure 1.
Directed Acyclic Graphs linking inadequate maternal weight gain, low birth weight, and infant mortality.

Table 1

Select Descriptive Statistics of Sample (80,224) of Mother and Infants Born in 2002: U.S. Linked Birth and Infant Death Data Set, 2002

Variable	%	No.
Mortality		
Surviving	99.4	80,376
Died	0.6	517
Birthweight, g		
≥ 2500	92.3	74,626
<2500	7.7	6,267
Gestational Age		
Term Birth (>36 weeks)	88.0	71,215
Preterm Birth	22.0	9,678
Gestational Weight Gain, lbs		
≤24	29.3	23,738
25–40 (Ref)	49.8	40,324
≥41	19.2	15,568
Maternal Age, y		
≤34	86.7	70,167
≥35	13.3	10,726
Maternal Education, y		
Less than High School (<12) (Ref)	20.0	16,063
Completed High School (=12)	31.8	25,469
Some College (13–15)	21.8	17,525
Completed College (≥16)	26.4	21,168
Race/Ethnicity		
White (Ref)	62.4	50,493
African American	15.5	12,500
Hispanic	17.2	13,917
Asian or Pacific Islander	4.0	3,201
American Indian	1.0	781

Table 2

Association between Inadequate Gestational Weight Gain and Infant Mortality by Analytic Model: U.S. Linked Birth and Infant Death Data Set, 2002

	Model I		Model 2		Model 3		Model 4	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Gestational Weight Gain								
Inadequate	2.23 ***	1.84, 2.70	1.92 ***	1.59, 2.33	1.89 ***	1.56, 2.23	1.84 ***	1.59, 2.34
Normal (Ref)	-		-		-		-	
Excessive	0.99	0.75, 1.33	1.04	0.78, 1.39	1.04	0.78, 1.39	1.03	0.78, 1.38
Maternal and Infant Characteristics								
Term Birth (>36 weeks)	0.08 ***	0.06, 0.09	0.29 ***	0.23, 0.37	0.29 ***	0.23, 0.37	0.29 ***	0.23, 0.37
Maternal Age ≤34 y	0.78	0.59, 1.02	0.77	0.59, 1.02	0.80	0.61,1 .05	0.89	0.67, 1.17
Birth Weight ≤2500			10.05***	7.89, 12.80	9.83 ***	7.71, 12.52	9.67 ***	7.60, 12.30
Race/Ethnicity								
White (Ref)	-		-		-		-	
Hispanic					1.07	0.83, 1.37	0.91	0.70, 1.18
African American					1.33 **	1.08, 1.63	1.22	0.99, 1.51
Asian or Pacific Islander					0.56	0.30, 1.05	0.59	0.31, 1.08
American Indian					1.63	0.77, 3.44	1.46	0.70, 3.10
Maternal Education								
Less than High School (<12y) (Ref)	-		-		-		-	
Completed High School (=12y)							0.75 **	0.60, 0.94
Some College (13–15y)							0.66 **	0.51, 0.86
Completed College (≥16y)							0.54 ***	0.41, 0.72
−2 Log Likelihood	10,514		10,111		10,077		10,097	

Note. OR=odds ratio. CI=confidence interval. Mothers of White race and who gained within the recommended range served as reference groups. Sampling weights were applied to produce population-level estimates.

** p < .01

*** p < .001