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MATERNAL RISK FACTORS ASSOCIATED WITH
INAPPROPRIATE PREGNANCY WEIGHT GAIN IN
LOW-INCOME WOMEN IN DEVELOPED COUNTRIES

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By

Marcia Renee Gebben

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ABSTRACT

MATERNAL RISK FACTORS ASSOCIATED WITH INAPPROPRIATE PREGNANCY WEIGHT GAIN IN LOW-INCOME WOMEN IN DEVELOPED COUNTRIES

By

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The prevention of pregnancy weight gain outside the IOM recommendations could prevent poor infant outcomes as well as excess maternal weight retention. The purpose of this study was to identify maternal characteristics associated with either inadequate pregnancy weight gain or with excessive pregnancy weight gain compared to adequate pregnancy weight gain. A cohort of low-income women who delivered a liveborn, singleton, term infant were used from a randomized clinical trial that examined two home visiting models. Women with fewer than 12 years of education or those who sometimes to never had the necessary food in pregnancy were almost three times more likely to have inadequate weight gain. Women with 12 years of education or less, those with less than two previous live births, those who reported feeling happy about the pregnancy, those who had a history of sexually abuse or those with low self-esteem were two to three times more likely to have excess weight gain. Uncovering risk factors for inappropriate pregnancy weight gain, i.e. too little or too much, may help to guide clinical and public health intervention strategies.

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INTRODUCTION

As the pendulum swung from advising pregnant women to gain very little pregnancy weight in the 1960s to gaining as much weight as desired in the 1980's (1,2), the optimal amount of pregnancy weight gain to maximize fetal and maternal well-being was questioned. In 1990, after extensive literature review, the Institute of Medicine (IOM) established the current recommendations for total weight gain during pregnancy, which were individualized to pre-pregnancy body mass index (BMI) categories (3). Subsequently, pregnancy weight gain within the IOM recommendations has been found to be associated with improved pregnancy outcomes as compared to gains outside the IOM recommendations (4,5,6,7). However, only 29-38% of women have prenatal weight gains within these recommendations in the United States (8,9,10).

Pregnancy weight gain outside the IOM recommendations has significant public health implications. Gains of less than the IOM recommendations have been associated with low birth weight (LBW), or infant birthweight of less than 2500 grams (11,12,13,14). Low birth weight infants have higher infant mortality rates, particularly in infants with birthweights below 2500 grams (15).

Gains of more than the IOM recommended amount of pregnancy weight has been associated with increasing maternal weight retention after pregnancy. In two studies, women who gained more than the recommended amount of weight retained almost twice the amount of weight 6-18 months after delivery than did women who gained the recommended amount (16,17). Weight gain has been found to increase as women age and as parity increases (18,19). As weight increased in women aged 40 and above, the risk for chronic diseases increased. Several studies have reported that as BMI increased in overweight and obese women when compared to normal and underweight women, the risk for diabetes, hypertension, coronary heart disease and colon cancer was found to be two to four time greater (20,21,22).

Low-income women, in particular, may not be well-informed about the range of optimal weight gain in pregnancy, or may lack the resources to achieve this goal. Identifying low-income women likely to gain outside the IOM recommendations early in pregnancy will allow health care providers adequate time to provide intensive nutritional and behavioral interventions in an attempt to optimize pregnancy weight gain.

CHAPTER 1

BACKGROUND

Components of Pregnancy Weight Gain

A woman's weight gain during pregnancy is primarily attributable to the uterus and its contents, mammary tissue, blood volume, and extravascular fluid. A smaller fraction is attributable to cellular water and a deposition of fat and protein. The 19th Edition of Williams Obstetrics estimates that in a 40 week pregnancy with an average 27.5 pounds weight gain, 7.5 pounds is fetal weight; 6.1 pounds is an enlarged uterus, amniotic fluid, placenta and increased mammary tissue; 3.2 pounds is increased maternal blood volume; 3.3 pounds is extravascular fluid; and 7.4 pounds is maternal fat (1). Extravascular fluid increases almost 20-fold in the last 10 weeks of pregnancy, while the other components gradually increase over the duration of the pregnancy. The purpose of accumulated fat has been speculated to be as a maternal energy reserve for use during pregnancy or lactation. It is uncertain how variations in maternal weight gain during pregnancy affect each of these components.

Pregnancy Weight, Height and Weight Gains

In the late 1980s, the Institute of Medicine's Food and Nutrition Board felt that there were many gaps and weaknesses in knowledge about maternal nutrition and about how recent findings should be applied in prenatal care (3). To address these deficiencies the Committee on Nutritional Status During Pregnancy and

Lactation was established in 1987 to conduct a detailed assessment of the published data. The goals of one subcommittee, the Nutritional Status and Weight Gain During Pregnancy subcommittee, were to analyze the scientific evidence pertaining to weight gain during pregnancy and to formulate recommendations for healthy weight gain. The subcommittee concluded that pre-pregnancy body mass index (weight for height ratio) and serial weight measurements were the only anthropometric measurements with documented clinical value for assessment of weight gain during pregnancy. Total pregnancy weight gain is commonly based upon the self-reported pre-pregnancy weight that is subtracted from the measured weight at the last obstetric visit prior to delivery.

Pre-pregnancy weight for height ratio and total pregnancy weight gain often rely on accurate self-reporting of pre-pregnancy weight and height. The validity of self-reported weight and height must be considered. Several studies examined self-reported weight in the general population. These studies found that women underreported their weight by 1.0 to 1.6 pounds, and as a woman's weight increased, the amount she underreported her weight also increased (23,24). The amount of underreporting in underweight women was less than 0.5 pounds whereas the range in obese women was between 4.1 to 6.7 pounds. Both studies also found that a woman whose reported weight ended in a 0 or a 5 underreported their weight more than if their weight ended in any other digit, with underreporting ranging from 2.3 to 4.1 pounds. Both studies also found that height was underreported in women by 0.29 to 0.72 inches. However, shorter women tend to over report their height the most. The level of a woman's education and her age were also found to affect self-reported weight and height. Stewart found that women with higher education were less likely to under report weight and less likely to over report height (24). He also found that as age increased, weight was more likely to be over reported. No studies examining the effect of ethnicity or income on self-reported weight or height were found.

The validity of self-reported pre-pregnancy weight in pregnant women also must be examined. Underweight pregnant women underreported their pre-pregnancy weight more than overweight pregnant women (10 pounds versus 4.5 pounds. respectively), with no reporting differences seen in average weight women of all ages (25). In an earlier study by Stevens-Simon, just the opposite was observed in adolescents, with overweight pregnant teens underreporting pre-pregnancy weight, and no reporting differences in underweight or average weight pregnant teens (26). Yu compared a calculated estimate of pre-pregnancy weight to self-reported pre-pregnancy weight observing an underreporting of 4.3 pounds (27). Yu also observed that women taller than 5 feet 6 inches underreported their weight by almost 7 pounds. No studies examining the effect of education, ethnicity or income on a pregnant women's self-reported pre-pregnancy weight or height were found.

In sum, reporting bias for weight and height occur to varying degrees and these reporting errors do not happen randomly. Thus caution with interpretation in studies of weight gain is needed when dealing with obesity, short stature, lower educational status and/or higher age in women when only self-reported weight and height is available.

Anthropometric Methods

Body mass index (BMI), also known as the Quetelet Index, was formulated and named after Lambert Quetelet in the 19^{th} century to describe the relation between body weight and height (28). BMI is defined as weight in kilograms divided by height in meters squared. BMI is not a true measure of fat, though studies frequently treat it as such. Misclassification of fatness may occur since BMI is strongly correlated with fat, muscle and skeletal masses. High BMI values can be observed in athletes with large muscle mass, in obese people and in people who are extremely tall or have large-boned body builds, but in general population BMI provides a reliable indicator of over/under weight for height.

Other anthropometric methods have been developed for measuring the components of body mass. Bioelectrical impedance analysis (BIA) measures electrical characteristics of the human body that allow for the calculation of fat and lean masses. Dual-energy X-ray absorptionmetry (DXA) gives direct measurements of lean and bone mass. Fat mass can then be derived from these two measurements by using total body X-ray. Underwater weighing, or hydrodensitometry, gives measurements of body density and volume by submerging subjects in a tank of water. Body volume is adjusted for measured residual lung volume. All of these anthropometric methods, BIA, DXA and underwater weighing, also allow for the calculation of fat mass, body fat percentage and fat free body mass, using a multitude of equations.

Studies have examined BMI measurements in comparison to measurements obtained from BIA, DXA and underwater weighing. Snijder, et al examined the differences between body fat percentage measured by underwater weighing versus body fat percentage predicted from BMI and BIA (29). Body fat percentage measured by underwater weighing was 29.3 $\pm$ 5%, which was significantly different from body fat percentage predicted from BIA (27.1$\pm$ 6.7%) and BMI (25.9 $\pm$ 2.2%). They determined that skeletal widths and limb lengths were related to the prediction error of body fat percentages from BMI and BIA, respectively.

In healthy adults aged 18 to 72 years of varying body compositions, Gray and Fujioka compared fat mass and body fat percentage calculated by BMI and BIA to fat mass and body fat percentage determined by under water weighing (30). They found a significant correlation between BMI and body fat percentage in women (R_2 = 0.74, p <0.001). Furthermore, fat mass calculated from BMI (R_2 = 0.95) correlated highly with fat mass determined from BIA and underwater weighing (R_2 = 0.97). Morabia et al, compared the validity of BMI as a measure of fatness to DXA measurements in 1999 using healthy Caucasians aged 15 to 86 years (31). They found that BMI and fat mass determined from DXA were highly correlated (r 0.85, p <0.05) but BMI and lean mass determined from DXA were weakly correlated (r 0.44, p <0.05).

BIA, DXA and underwater weighing are not practical for use in population studies due to issues such as expense and labor, complexity of use, reliability of administrators, and time constraints. BMI is more practical given that body weight and height are simple, inexpensive and safe measurements that can easily be acquired in physician offices or from patient recall. It is important to remember when using BMI that it is inaccurate in defining the degree of fatness.

The IOM subcommittee on pregnancy and weight gain chose not to use BIA, DXA or underwater weighing to assess body size because they concluded that they were based on assumptions that had not been validated for pregnant women and that they may not distinguish between the added maternal and fetal tissues (3). The subcommittee determined that pre-pregnancy BMI was a better indicator of maternal nutritional status than pre-pregnancy weight alone, and pregnancy weight gain should be specific to pre-pregnancy BMI category. BMI categories were determined in which the cutoff points corresponded to 90, 120, and 135% of the 1959 Metropolitan Life Insurance Company's weight for height standards. The selected BMI categories were:

- Underweight: BMI <19.8
- Normal weight: BMI 19.8 to 26.0
- Overweight: BMI >26.0 to 29.0
- Obese: BMI >29.0

Historical Trends in Pregnancy Weight Gain

Weight gain during pregnancy is necessary for appropriate growth and development of the fetus. The recommended amount of weight a woman should gain during pregnancy has steadily increased since the 1960s. A total weight gain of 20 pounds, 25 pounds at the most, was recommended in the 12th Edition of Williams Obstetrics (2). The National Academy of recommended 20 - 25 pounds total weight gain (32). This increased in 1983 when the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists jointly recommended a total weight gain of 22 - 27 pounds (33). Similarly a total weight gain of at least 20 pounds with no upper limit for gain was recommended in the 17th Edition of Williams Obstetrics (1). In 1990 the IOM established the current recommendations for total weight gain during pregnancy (3). They were: 28 to 40 pounds for underweight women (BMI <19.8), 25 to 35 pounds for normal weight (BMI 19.8 to 26.0), 15 to 25 pounds for overweight (BMI >26.0 to 29.0), and at least 15 pounds for obese women (BMI >29.0). An upper limit for obese women was not defined. They assumed a low weight for height ratio reflected marginal fat reserves, whereas a high value was indicative of excessive fat reserves; hence the differing amounts of recommended weight gain. In addition, the subcommittee recommended that young adolescents and black women should gain more towards the upper end of the recommended range, and short women (<62 inches) should strive for gains more at the lower end of the recommended range.

The response of actual pregnancy weight gain to these changing recommendations for pregnancy weight gain needs to be examined. As the recommendations for pregnancy weight gain increased, the amount of weight gained during pregnancy also increased steadily from the 1960's. In studies that included pregnancy weight gain and fullterm, livebirths from the 1940's and the 1950's, the mean weight gain was 20 to 21 pounds (34,35). In a study of deliveries that occurred at 22 U. S. naval hospitals from 1964 to 1966, Nyirjesy found a mean weight gain of 22 pounds (36). In a study of clinic patients in St. Paul, MN from 1969 to 1976, Brown found a mean weight gain of 27.5 pounds (14). Haworth found a similar mean weight gain of 27.9 pounds in a 1975 to 1976 study of 536 private and public patients in Manitoba, Canada (37). By the 1980's, pregnancy weight gain increased greatly as an upper limit on weight gain was no longer recommended. Taffel utilized 1980 data and found a mean weight gain of 28.7 pounds (38). Data from birth certificates of 46 states and the District of Columbia showed a further increase of the mean to 30.3 pounds in 1989 (39).

While an increase in pregnancy weight gain has been observed overtime; other lifestyle trends, such as shifts in maternal age distribution or parity, may affect comparisons of weight gain across decades. According to birth certificate data from the National Center for Health Statistics (Table 1), in 1971 56% of mothers were 24 years of age or less, 43% were aged 25 to 39 years and 1% were 40 years of age or older (40,41,42,43,44). By 1984 the maternal age distribution had shifted such that 44% were 24 years of age or less and 55% were aged 25 to 39 years. This shift in age distribution continued into 1992 with 38% 24 years of age or less and 61% aged 25 to 39 years. This observed shift in age distribution toward older mothers may account for some of the observed mean weight gain increases since younger women, especially teenagers, tend to gain less weight during pregnancy. To better understand these trends, one would need to do a maternal age-adjusted comparison.

Table 1. Maternal Age Trends Over Time (%)

Maternal Age	1971	1975	1984	1987	1992
$\leq$24	56	54	44	40	38
25-39	43	45	55	59	61
$\geq$40	1	1	1	1	1

Using birth certificate data from the National Center for Health Statistics, parity has changed slightly since 1971, with the majority of change observed in 1975 (Table 2) (40,41,42,43,44). In 1971, 39% of women reported one live birth, 28 % two live births, 15% with three live births and 17% with 4 or more live births. By 1975, this distribution changed and then remained consistent into 1992. In 1984, 42% were women with their first live birth, 33% with their 2nd live birth, 15% with their 3rd live birth and only 10% with 4 or more live births. Traditionally women experience greater pregnancy weight gain as parity increases. Since parity was observed to decreased over time, adjusting for this change would result in a wider weight gain gap from earlier years to the present.

Table 2. Maternal Parity Trends Over Time (%)

Number of Livebirths	1971	1975	1984	1987	1992
1	39	42	42	41	40
2	28	31	33	33	32
3	15	14	15	16	16
≥ 4	17	12	10	10	10

Pregnancy Weight Gain and Infant Outcome

Maternal weight gain during pregnancy is important because of its potential effects on infant outcome. When looking at studies on the association of maternal weight gain and infant outcome, the length of gestation greatly effects maternal weight gain and fetal growth. The shorter the gestation of pregnancy, the less weight a woman will have the opportunity to gain. In addition, a preterm infant will almost always be LBW since the fetus has less time to gain weight. The more preterm an infant, the lower the birthweight of the infant. In preterm delivery, infant birth weight as an outcome variable should be used with individual gestational ages, or strictly in full term infants. Iatrogenic preterm deliveries should also be excluded from any analyses involving preterm delivery, since they are typically due to maternal or fetal complications.

Accurate determination of gestational age is difficult. Methods that have been utilized include relying on maternal recall of the first day of her last menstrual period (LMP), early ultrasound (done in the 16^{th} to 18^{th} week of pregnancy), and Dubowitz scoring of the infant shortly after birth. Each of these methods has weaknesses. LMP places a heavy reliance on maternal recall and also may be confused by postconceptual bleeding often interpreted as normal menses. In addition, the follicius phase can exceed two weeks, so conception may occur later in the cycle. Ultrasound is subjective to adequate fetal growth; therefore a poorly growing fetus may potentially cause underestimation of gestational age. Poor infant tone, abnormal neurologic behavior or extreme prematurity may lead to an underestimate of gestational age, thus affecting Dubowitz scoring.

Pregnancy Weight Gain and Prematurity

Many studies involving maternal weight gain during pregnancy use total weight gain or net weight gain (total weight gain minus infant's birth weight) for analyses. In studies of preterm delivery, these are not appropriate techniques. Since the longer a woman is pregnant, the more time she has to gain weight. To avoid this difficulty, many studies use a rate or pattern of gain, which refers to the amount of gain per week or month over the entire pregnancy. However, rate of gain should not be based on the calculation of overall gain divided by the week's gestation of the pregnancy since gain is not linear. Women with extremely preterm deliveries will have a lower overall rate of gain than those women who deliver at term. Furthermore, the amount of weight gained in the first trimester is not equivalent to the amount gained in the 2nd and 3rd trimesters. However, this type of calculation is commonly used in the literature, with rates and patterns of gain frequently categorized into adequate or inadequate, or low, average or high weight gain.

The influence that the rate and pattern of weight gain have on preterm deliveries, in which iatrogenic preterm deliveries are excluded, have been examined in many studies, with positive associations being found. Several studies utilized adequate *vs* inadequate gains. In a study of primarily white, middle class women, Berkowitz found that women with inadequate rate of gain had a positive association with preterm delivery (OR = 4.28, 95% CI 2.3-8.0) (45). To define adequate and inadequate rates of gain in this study, he used and undescribed schedule that corrected for gestational age. Berkowitz relied exclusively on the Dubowitz score to determine gestational age. Scholl et al also found a positive association between preterm delivery and inadequate rate of weight gain in low-income adolescents who had a reported LMP and an early ultrasound (46). They found an association between preterm delivery and inadequate rate of weight gain (OR = 1.75, 95% CI 1.22, 2.58) through the use of LMP data to determine gestational age. When they repeated their analysis using ultrasound data, this association decreased slightly (OR = 1.49, 95% CI 1.10, 2.02). In low-income adolescents, Hediger et al categorized the rate of gain before 24 weeks gestation (early gain) and the rate of gain after 24 weeks gestation (late gain) as either inadequate or adequate during each period of gain (13). Inadequate late gain was strongly associated with preterm delivery when compared to both late adequate gain and early adequate gain.

Other studies examined the rate of gain throughout the pregnancy. In women at high risk for nutritional problems, Abrams et al found a low rate of weight gain (less than 0.27 kg/week) was highly associated with preterm delivery when compared with an average weight gain of 0.27 to 0.52 kg/week (OR = 2.54, 95% CI 1.49, 4.88) and a high rate of weight gain of more than 0.52 kg/wk (OR = 1.59, $P < 0.05$) (47).

While adjusting for age, smoking, pre-pregnancy BMI and education, no significant associations between a low net rate of gain and an average net rate of gain were found by Kramer et al (48). In an attempt to obtain more accurate estimates of gestation duration, Kramer excluded women if the LMP and ultrasound at 16-18 weeks did not agree within $\pm$ 7 days. This exclusion left only 35% of all potential deliveries for analyses and a potential for selection bias, which may have eliminated the poorly growing fetuses along with those who had a less accurate LMP.

Pregnancy Weight Gain and Infant Birth Weight

In looking for associations between pregnancy weight gain and fetal growth, there is inherent difficulty in interpreting the findings. Is low maternal weight gain the cause of the poor fetal growth, or is the poor fetal growth the cause of the low maternal weight gain? In most instances not enough is known about biologic mechanisms to determine the ordering of these related factors.

LBW in preterm and term infants can be due to different etiologies and should not be examined together. LBW in preterm infants is frequently due to a shortened gestation with less time to gain weight; whereas, in a full term infant, LBW is due to fetal growth retardation. In order to account for the fact that preterm infants have less time to gain weight, preterm births should be excluded or controlled for in any analysis of weight gain involving fetal growth or gestational age.

Several studies have examined the effect of maternal weight gain during pregnancy and infant birth weight. In a study of underweight and average weight women who delivered singletons between 1969 and 1976, Brown et al examined maternal weight gain of 9 kg or less compared to a gain of more than 9 kg (14). Term infants born to mothers who gained 9 kg or less were significantly lighter at each week of gestation from 37 to 41 weeks when compared to term infants of mothers who gained 9 kg or more (Table 3).

Table 3. Mean Birth Weight with Total Weight Gain during Pregnancy by Gestational Age

Weeks' Gestation	Infant weight (grams)		P-value
	Total Pregnancy Weight gain ≤19.8 lbs	Total Pregnancy Weight gain >19.8 lbs	
37	2571 ± 114	2993 ± 72	<0.005
38	2985 ± 81	3179 ± 68	<0.021
39	2883 ± 89	3126 ± 47	<0.01
40	3076 ± 55	3254 ± 28	<0.005
41	3142 ± 104	3463 ± 60	<0.016

Using 1980 National Natality Survey data, Taffel reported on both preterm and term infants in relation to maternal weight gain (49). He did not control for weeks of gestation in the premature deliveries so only information on term deliveries will be presented. In pregnancies of 37 to 39 weeks' gestation, Taffel found that the mean infant birth weight increased linearly as maternal weight gain increased from less than 16 pounds to 36 pounds or more, with a difference in mean birth weight of 300 grams (Table 4). The same linear increase was seen in gestations 40 weeks and beyond, with a mean birth weight increase of 290 grams.

Table 4. Mean Birth Weight (grams) with Total Weight Gain during Pregnancy by Gestational Age

Weeks' Gestation	Weight gain during pregnancy					Difference lowest to highest gain
	<16 lbs	16-20 lbs	21-25 lbs	26-35 lbs	≥36 lbs	
37-39	3,120	3,187	3,251	3,301	3,420	300 gms
≥40	3,340	3,363	3,472	3,521	3,628	290 gms

In Sydney, Australia, a low rate of maternal weight gain (<0.27 kg per week) was found to be related to the incidence of small for gestational age (SGA) in term infants (12). SGA was defined as birth weight less than the 10^{th} percentile for gestational age. Using multiple linear regression while controlling for gestational length, smoking, height, pre-pregnant weight, age, parity and education, they found that for each kg increase in total maternal weight gain, birthweight increased by 29.7 grams (95% CI 15.6, 43.9).

Abrams and Parker examined maternal weight gain in women who did not experience diabetes or hypertension and who delivered a live, singleton term infant without congenital anomalies (50). Each infant was initially classified as SGA, average for gestational age (AGA) or large for gestational age (LGA). AGA was defined as birth weight in the 10^{th} to 90^{th} percentile for gestational age, and LGA was birth weight greater than the 90^{th} percentile for gestational age. Mothers of SGA infants gained significantly less weight (13.4 kg) than mothers of AGA (15.3 kg) and LGA (17.7 kg) infants (P<0.001).

In an attempt to account for the shortened time to gain weight, some studies used rates of weight gain in their analyses. In 1991, Abrams and Newman looked at the effect of a low rate of weight gain (<0.27 kg per week) on the incidence of SGA (11). A significant difference existed between SGA (44.2%) and AGA (21.6%) infants born to women with a low rate of gain (P = 0.0001). In multiple logistic regression, there was a strong association between a low rate of gain and delivering a SGA infant when compared to average rate of gain (OR 2.96, 95% CI 2.17-4.04), adjusted for smoking, Black and Asian ethnicity, maternal hypertensive disorder, maternal pregravid underweight, primiparity, and low maternal height.

Rates of weight gain were calculated in a study of low-income teenagers, who delivered a liveborn, singleton infant after 24 weeks gestation (13). Adequate weight gain was defined as at least 4.3 kg (9.5 lbs.) by 24 weeks gestation (early gain) and at least 400 grams per week from 24 weeks' gestation until delivery (late gain). After adjusting for maternal age, ethnicity, pre-pregnancy BMI and smoking, delivering a LBW infant was found to be associated with inadequate early weight gain (OR 2.85, 95% CI 2.82-4.47), inadequate late weight gain (OR 2.17, 95% CI 1.41-3.34), or inadequate early and late weight gains (OR 4.33, 95% CI 2.58-7.26).

There appear to be associations between maternal weight gain and poor fetal growth, but it must be stressed again that one cannot determine in all pregnancies if inadequate maternal weight gain leads to poor fetal growth or visa versa. Until the biologic mechanisms and components of pregnancy are fully understood, this will continue to be a weakness of these studies.

Infant Birthweight and Prematurity – Effect on Mortality and Morbidity

In conjunction with the associations found between inappropriate maternal weight gain during pregnancy and infant outcome, the public health impact of these adverse infant outcomes is great. Increased infant mortality and morbidity is related to LBW and to premature birth (less than 37 weeks' gestation). Using 1999 linked birth and death certificate data from the United States, the infant mortality rate (IMR) per 1000 live births for infants weighting 2500 grams or more at birth was 2.5 (Table 5) (51). The IMR increased dramatically as birth weight decreased, with an IMR of 247.0 observed in infants born weighing less than 1500 grams. Similar trends were observed for premature births, with the IMR rising dramatically as gestational age decreased, from 2.7 in 37 to 41 weeks gestation infants to 408.0 for less than 28 week gestation infants.

Table 5. Infant Mortality Rate (IMR) for Specified Birth Weight and Gestational Age Groups, 1999 (per 1000 live births)

	Birth Weight (grams)			Gestational Age (weeks)				
	<1500	1500-2499	≥2500	<28	28-31	32-36	37-41	≥42
IMR	247.0	16.0	2.5	408.0	47.7	9.1	2.7	2.9

If a LBW or premature infant survives, the incidence of morbidity is great, especially in infants with very low birth weight (VLBW), a birth weight of less than 1,000 grams, or in extremely premature infants (gestational age of less than 28 weeks). In studies of VLBW or extremely premature infants admitted to NICUs in the U.S, Canada and Finland, the incidence of RDS was reported to be between

50% and 76%, with a resulting incidence of chronic lung disease (CLD) between 15% and 39% (52,53,54,55). The incidence of at least stage three retinopathy of prematurity (ROP), which may lead to blindness or decreased visual acuity, was between 9% and 13%. The incidence of NEC, which may lead to long term gastrointestinal and nutritional difficulties, was between 7% and 22%. The incidence of at least grade three intraventricular hemorrhage (IVH) was between 10% and 11%. An IVH of at least grade 3 is suspected to play a role in developmental delay and mental retardation.

These chronic medical conditions or developmental disabilities can affect the infant's quality of life and continue to do so as the infant progresses into childhood and adulthood. In United States and Canadian follow-up studies of LBW or premature infants at 18 to 20 months corrected age (age corrected for prematurity), the incidence of CLD has been reported to be between 16% and 17% (56,57). The incidence of cerebral palsy was between 14% and 17%. The incidence of borderline cognitive development was between 13% and 26%, and deficient cognitive development was between 16% and 76%. Sensory deficits were also studied, with an incidence of blindness between 0.5% and 1%, and the incidence of deafness between 0.5% and 9%. As can be seen, the prevention of prematurity and/or LBW is important because these adverse infant outcomes affect the infant and family throughout the infant's lifetime,

Pregnancy Weight Gain and Maternal Health

Weight retention after pregnancy and it's influence on the development of obesity and chronic diseases related to increases in BMI are important public health issues. A study by Brown looked at long-term weight retention in women at ages 30, 40 and 50 (19). The cohort, ages 55 to 69 years of age and identified from Iowa driver's license data, was surveyed for recalled lifelong parity and weight at 18, 30, 40, and 50 years of age, in addition to current weight and height. They found that as women became older and as parity increased, the prevalence of overweight increased, and a weight gain of 0.02 kg per year for each additional livebirth was observed.

A follow-up cohort of 2,547 women contacted in 1982 to 1984, who were from the initial National Health and Nutrition Examination Survey (NHANES I) conducted in 1971 to 1975, were re-interviewed to look at estimated weight gain for the elapsed time period (18). They also found that weight gain increased as a woman's parity after age 25 increased. Parous women with no livebirths between interview periods had an average gain of 3.7 kg. This increased to 5.4 and 5.6 kg for women with 1 or 2 livebirths respectively, and it significantly increased to 6.2 kg for those with 3 livebirths between the interview periods. Nulliparous women during the same time frame had an estimated weight gain of 5.3 kg, similar to those with 1 or 2 livebirths.

From the 1988 National Maternal Health Survey, Keppel and Taffel interviewed a random sample of non-obese women 10 to 18 months post partum who had a term, livebirth, and were not pregnant again (58). The women were categorized retrospectively for IOM weight gain recommendations. At 18 months post partum, women who gained the recommended amount of weight retained 2.2 pounds, whereas women who gained less than the recommended amount retained only 1.2 pounds. Women who gained more than the recommended amount of weight retained 5.6 pounds. When they examined Caucasian and African American women separately, African American women had a median weight gain three times that of Caucasian women in all three categories. These associations were not affected when lactation was controlled for.

In Stockholm, Sweden, Ohlin and Rossner found a mean weight gain of 1.5 kg at 12 months post partum in 1,423 women who delivered a liveborn, singleton (59). They found that 56% retained 0 to 5 kg and 14% retained 5 kg or more at 12 months post partum. They found that lactation had the largest effect on weight loss between 2.5 and 6 months postpartum, but by 6-7 months, no significant differences were found between lactating and nonlactating women.

Several studies have included participants from hospital-based or hospital sponsored OB clinics, many of which are traditionally low-income women. Schauberger et al examined weight retention at 6 months postpartum in white women who delivered a liveborn, singleton at 36 weeks' gestation or greater (60).

They found an average weight retention of 1.4 kg, with significant linear increases in retained weight as pregnancy weight gain increased. For those who gained less than 11.3 kg, a weight loss of 1.2 kg was observed, those who gained 11.4 to 15.9 kg, 1.6 kg was retained, and those who gained 16 kg or more, 5 kg was retained. At six months postpartum, they found that 63% of the women remained above their pre-pregnancy weight. They found no significant weight loss differences between lactating and non-lactating women

To evaluate the effect of pregnancy weight gains according to the IOM recommendations after taking BMI into account, Luke et al re-analyzed data previously published (17). The data were obtained between 1974 and 1979 from women who delivered between 38 to 42 weeks' gestation and received care in a NYC hospital clinic. They found a significant increase in retained weight as pregnancy weight gain increased from less than recommended to greater than recommended for all BMI categories. The amount of retained weight ranged from 5.0 kg to 8.3 kg.

To examine the risk of becoming overweight from the onset of the first pregnancy to the onset of the second pregnancy in 2000, Gunderson et al prospectively followed 1,300 women at a San Francisco hospital-based clinic who delivered two consecutive liveborn, full term singletons (61). They found an odds ratio of 3.19 (95% CI 1.97-5.44) of becoming obese if pregnancy weight gain in the 1st pregnancy was greater than the IOM recommendation for the BMI category. For those who became obese, mean weight increased 10.4 kg, whereas mean weight increased only 1.6 kg for those who did not become obese (p<0.001).

In Quebec, Muscati, et al performed retrospective record abstractions from 1979 to 1989 of low-income white women who delivered a liveborn singleton of at least 37 weeks gestation in order to evaluate weight retention at six months post partum (62). The women were categorized as underweight, normal weight or over weight based on a <90%, 90 – 120%, or >120% percentage of standard weight, respectively. For those with a pregnancy weight gain of greater than 26 pounds as compared to those who gained 26 pounds or less, underweight women retained 14 pounds more, normal weight women retained 32 pounds more, and overweight women retained 22 pounds more (p <0.001). For the entire sample, 75% retained at least 5.5 pounds postpartum.

As can be seen from these studies, the majority of women retain weight after pregnancy. Postpartum weight retention can lead to long-term overweight and obesity, which can lead to life long physiologic consequences. The subsequent development of diabetes, hypertension and other chronic diseases need to be examined for their relationships to long-term overweight and obesity in women.

The proportion of U.S. women who are overweight is increasing. CDC Surveillance Summaries utilized data from the Behavioral Risk Factory Surveillance System (BRFSS) to determine state specific prevalence of overweight and specific chronic diseases for 1996 and 1997 (63). The BRFSS is a state-based surveillance system in which each state (including the District of Columbia and Puerto Rico) utilizes random-digit-dialing to sample each state's civilian, non-institutionalized adult population every month. The State of Michigan was found to have much higher incidences of overweight and chronic diseases as compared to all states. In 1996, 44% of women were overweight for all states, while in Michigan it was 47.6%. In 1997, this incidence rose for all states to 44.5%, as well as in Michigan to 47.8%. In all states in 1996 and 1997 respectively, 4.7% and 4.9% of women were diagnosed with diabetes mellitus. These values were much higher in Michigan, 6.3% and 6.4% for the same time periods. For all states, 23.6% of the women were told they had high blood pressure and 28.8% were told they had high blood cholesterol. Michigan again was much higher for both, with 24.2% told they had high blood pressure and 30.9% told they had high blood cholesterol.

In the past inconsistent weight category definitions have made it difficult to compare results across studies. Since the late 1990's, the majority of studies have adopted the definitions of the National Heart, Lung and Blood Institute or from the World Health Organization (64,65). The only difference between the two organizations is what title they give the overweight category, even though the values are identical for each category. Normal weight, as defined by the National Heart, Lung and Blood Institute, is classified as a BMI of 18.5 to 24.9 kg/m^2, under weight is less than 18.5 kg/m^2, overweight is 25.0 to 29.9 kg/m^2, obesity class 1 is 30.0 to 34.9 kg/m^2, obesity class 2 is 35.0 to 39.9 kg/m^2, and obesity class 3 is at least 40.0 kg/m^2.

NHANES III data from 1988 to 1994 was used to provide nationally representative prevalence estimates of major diseases and potential risk factors. Using this data, Must et al provided estimates of the prevalence of morbid conditions associated with obesity in age groups less than 55 years and 55 years and older, while using normal weight (BMI 18.5-24.9 kg/m^2) as the reference category (22). In women there was an increase in the prevalence with an increasing overweight class for type 2 diabetes mellitus and high blood pressure, regardless of whether aged less than 55 or age 55 years and older. In women less than 55 years of age, an increase in prevalence with increasing overweight class was seen for high blood cholesterol level, whereas in women at least 55 years of age, an increase in prevalence was only seen in the overweight category.

Field et al found similar results in the Nurses' Health Study, although women were not categorized by age (20). Female registered nurses across the United States have been mailed questionnaires on risk factors for cancer and heart disease every other year since 1976. The median age for this analysis was 52.9 years. The reference category for the analyses was a BMI less than 25, with both underweight and normal weight categories combined. After adjusting for age, smoking status and race, the ten-year risk of developing diabetes, hypertension, heart disease, and colon cancer rose significantly as overweight class increased, with the greatest risk seen in diabetes. The risk of developing high blood cholesterol was slightly higher for overweight women when compared to normal weight women.

Lean et al conducted a public health surveillance to monitor chronic diseases and risk factors of the general population living in various parts of the Netherlands; however, the mean age was only 42.2 years (21). Using a BMI of less than 25 as the reference category, high total cholesterol and hypertension were associated with increasing overweight class. An increased risk of non-insulin dependent diabetes mellitus was associated with a BMI of 30 or greater (OR = 5.38, 95% CI 2.77-10.46).

Women are more likely to gain wait as parity increases and as their age increases. Weight retention after pregnancy may be related to women becoming overweight and obese later in life. It appears that women who are overweight or obese later in life are more likely to have type 2 diabetes, hypertension, high blood cholesterol, and/or heart disease.

Optimal Pregnancy Weight Gain and the IOM Recommendations

The appropriateness of the 1990 IOM recommendations on maternal weight gain during pregnancy has been investigated in several studies. A study by Parker and Abrams in San Francisco, examined consecutive, term, singleton births over an eight year period to determine if weight gain outside the IOM recommendations was associated with SGA birth, LGA birth or cesarean deliveries (7). Weight gains within the recommendations were associated with fewer SGA infants, LGA infants, and cesarean deliveries, while weight gains outside the ranges increased the risk. Low pregnancy weight gain was associated with more than double the occurrence of SGA (6.88% for recommended gain *vs* 12.17%). Weight gains higher than the recommended range doubled the occurrence of LGA (6.14% for recommended gain *vs* 13.11%).

Shapiro et al randomly selected cases of women 19 to 37 years of age from retrospective chart reviews of term infants in Brooklyn (4). Women were categorized by pre-pregnant BMI into 2 groups, less than 25 (underweight and average weight women) and greater than 25 (overweight and obese women) with weight gain greater than 35 pounds considered to be excessive for the analyses. All of the groups delivered infants with mean birth weights between 3,300 to 3,800 grams, irregardless of BMI group and the amount of weight gained. They also stated they were not able to detect any effect of ethnicity or parity on birth weight (data not shown). In women with a BMI less than 25, women with a weight gain less than 35 pounds delivered infants with a mean birthweight of 300 grams less than did women with excessive weight gain (P = 0.0019). In women with a BMI greater than 25, women who gained less than 35 pounds delivered infants with a mean birthweight of 200 grams less than did women who gained more than 35 pounds (P = 0.0015).

Other studies have utilized women who were average weight and above in their studies. Edwards et al did retrospective chart reviews of all deliveries from 1977 to 1983 (5). For each obese woman identified, a record of an average weight woman was matched for ethnicity, delivery date, categorical age, and categorical parity. When compared to women who gained of 35 pounds or less, women who gain more than 35 pounds in both average weight (OR = 2.4, 95% CI 1.3-4.7) and obese groups (OR = 2.8, 95% CI 1.4-5.6) were associated with delivering an infant greater than 4000 grams. Obese women who lost or gained no weight were more likely to deliver an infant with a birth weight less than 3000 grams (OR = 3.1, 95% CI 1.4-6.9) or SGA infants (OR = 2.9, 95% CI 1.1-8.4) when compared to obese women who gained 15 to 25 pounds.

Average, over weight and obese women were selected from the Pregnancy Nutrition Surveillance System (PNSS), in which eight states submitted additional information (6). Included were single, liveborn term infants born in 1990 and 1991. High birth weight was defined as greater than 4500 grams. IOM weight gain recommendations for each BMI group were divided into lower and upper halves to see if gains in the upper half of the recommended amount were associated with high birth weight. Average weight women who gained less than the IOM recommendations were associated with LBW when compared to weight gains of 25 to 29 pounds, whereas women who gained more than 40 pounds were associated with high birth weight when compared to women with weight gains of 25 to 29 pounds. Over weight women who gained greater than 40 pounds were highly associated with high birth weight when compared to women who gained of 15 to 19 pounds. Obese women who gained more than the IOM recommendations for over weight women were associated with high birth weight when compared to women who gained of 15 to 19 pounds. In short, weight gains in the upper half of the IOM recommendations for average, over weight or obese groups were not associated with high birth weight.

Based upon these studies, it appears that the recommended amount of pregnancy weight gain for each pre-pregnancy BMI category is appropriate. Women who gained the recommended amount of pregnancy weight were more likely to have infants in appropriate weight gain ranges than were those who gain less than or more than the recommended amount of weight during pregnancy.

Characteristics Associated with Pregnancy Weight Gain Outside the IOM Recommendations

The maternal factors associated with inappropriate weight gain during pregnancy have been examined in only a handful of studies. Three studies investigated maternal factors associated with inadequate pregnancy weight gain. Hickey et al conducted a prospective study to examine the risk factors for fetal growth restriction in 806 low-income women whose pre-pregnancy BMI was 26.0 or less (underweight or normal weight BMI categories) (66,67). Inclusion criteria included a multiparity limited to a maximum of two, presence of one or more study-defined risk factors for fetal growth restriction, enrollment in a prenatal care clinic, and delivery of a liveborn, singleton infant without major congenital anomalies. In 1995, the relationship of psychosocial status to inadequate pregnancy weight gain was examined for African American and Caucasian ethnicity individually, utilizing the IOM recommendations to establish low prenatal weight gain (67). Measured psychosocial scales, Spielberger's State Trait Anxiety, Rosenberg's Self-Esteem, Perlin's Mastery, CESD, Subjective Stress, and Maternal Social Support Index scales were each scored individually and then categorized into quartiles for the analysis. Logistic regression analysis, controlling for the infant's sex and the number of days between the last weight observation and delivery, was used to examine the relationship between inadequate pregnancy weight gain and maternal age, height, pre-pregnancy BMI, smoking, alcohol use, history of previous infant weighing less than 2750 grams. Among Caucasians, the highest quartiles for depression (AOR 3.0, 95% CI 1.2-6.2) and trait anxiety (AOR 2.5, 95% CI 1.2-5.0), the lowest quartiles for mastery (AOR 3.9, 95% CI 1.6-9.4), and the lowest (AOR 7.2 95% CI 2.7-19.2) and middle (AOR 4.4, 95% CI 1.7-11.0) quartiles for self-esteem were associated with low prenatal weight gain. The highest stress quartile was found to have a protective effect (AOR 0.5, 95% CI 0.2-1.1), but this association was not significant. These same factors were not related to prenatal weight gain in African American women.

Using this same sample population, in 1997 Hickey et al examined the relationship of sociodemographic, lifestyle and reproductive characteristics with inadequate pregnancy weight gain individually for African American and Caucasian women (66). However, the IOM recommendations were not used to determine low prenatal weight gain in this analysis. A cutoff of 10 kg or less for both BMI groups was chosen based on their rationale that "underweight and normal weight women who gain $\leq$10 kg are 3-4 times as likely to have a full-term LBW infant as are those who gain >10kg", which was found in two previous studies. Logistic regression analysis was used, adjusting for maternal age, height, pre-pregnancy BMI, smoking, alcohol use, history of previous infant weighing less than 2750 grams, the infant's sex, and the number of days between the last weight observation and delivery. In African American women, a mistimed or unwanted pregnancy (AOR 2.0, 95% CI 1.2-3.2), caring for more than one preschool child (AOR 2.0, 95% CI 1.2-3.3) and not owning a car for errands (AOR 2.1, 95% CI 1.4-3.3) were all associated with inadequate pregnancy weight gain. In Caucasian women, working more than 40 hours per week (AOR 9.1, 95% CI 2.1-38.5) was strongly associated with inadequate pregnancy weight gain, whereas owning a car for errands (AOR 1.7, 95% CI 0.9-3.2) increased their risk slightly.

Siega-Riz and Hobel conducted a prospective study among 4,791 Hispanic women in all pre-pregnancy BMI categories to determine which maternal factors best predicted poor maternal weight gain (68). Women were included if they were primiparous, received care from a public health clinic and delivered a liveborn, singleton infant. Instead of using the IOM recommendations, their own criteria for poor maternal weight gain were established because women who delivered a preterm infant were included in the analysis. Poor maternal weight gain was defined as less than 21 pounds for underweight and normal weight women and less than 10 pounds for overweight and obese women. Linear and logistic regression analyses were utilized, controlling for the gestational age at entry into prenatal care, the gestational age at the last prenatal care visit and nutritional counseling. The gestational age at delivery was not controlled for. Underweight and normal weight women whose height was less than 157 centimeters (AOR 1.5, 95% CI 1.2-1.8) were more likely to be associated with poor maternal weight gain. In underweight and normal weight women, those who were less than 20 years of age (AOR 0.7, 95% CI 0.5-0.9) or were aged 20 to 29 years (AOR 0.6, 95% CI 0.5-0.8) were protected from poor maternal weight gain. Overweight and obese women who were physically abused by the baby's father (AOR 3.2, 95% CI 1.3-8.0) were more likely to have poor maternal weight gain. There are several potential problems with this study. Siega-Riz and Hobel included preterm deliveries, in which women delivering at 32 weeks' gestation would have much less opportunity to gain the same amount of weight as a woman who delivered at 40 weeks' gestation. In combining the lower pre-pregnancy BMI categories together, it was assumed that underweight and normal weight women have similar amounts of fat reserves. Also, they assumed that the factors influencing poor weight gain were the same for underweight and normal weight women as for overweight and obese women.

Maternal characteristics associated with both inadequate and excess pregnancy weight gain have been examined in several studies. A prospective cohort study of 622 primarily white, rural women looked at modifiable maternal psychosocial and behavioral factors related to excessive and insufficient pregnancy weight gain (8). They included women who started prenatal care before the third trimester, were at least 18 years of age at the time of delivery, planned to keep the baby, were "healthy and mentally competent", and delivered a liveborn singleton infant at 37 weeks' gestation or more. Inappropriate maternal weight gain was determined using the IOM recommendations for pre-pregnancy BMI category. Multiple logistic regression adjusting for total weeks' gestation, the number of weeks between the first and last measured weights and the number of weeks from the last measured weight until delivery was utilized. Parsimonious models using backward elimination were developed. They found that only 38% gained within the IOM recommendations for pre-pregnancy BMI category, whereas 21% gained an inadequate amount of pregnancy weight and 41% had excessive pregnancy weight gain. Women who were in the underweight BMI category (AOR 9.5, 95% CI 3.2-28.6) or who reported a little or a lot less food intake during pregnancy (AOR 2.39, 95% CI 1.2-4.8) were more likely to be associated with inadequate pregnancy weight gain. Protective associations were found for women in the obese BMI category (AOR 0.1, 95% CI 0.1-0.3) or who reported much more food intake (AOR 0.3, 95% CI 0.1-0.6). Associations with excessive pregnancy weight gain were found in women who were in the overweight (AOR 5.0, 95% CI 2.7-9.3) or obese (AOR 1.8, 95% CI 1.1-3.0) BMI categories, who reported much more food intake during pregnancy (AOR 2.4, 95% CI 1.2-4.5) or who's family income was less than 185% of the federal poverty line (AOR 2.6, 95% CI 1.6-4.2). Women in the underweight BMI group, were less likely to have excessive pregnancy weight gain (AOR 0.2, 95% CI 0.1-0.6).

Johnson et al conducted a matched retrospective cohort study of women with a full tem pregnancy to examine the differences between women reporting current and past physical or sexual abuse and the association with inadequate or excess pregnancy weight gain (69). Selected from an existing prenatal database and matched by age group (less than 20 years or 20 years and older) and year of delivery, 270 women who reported physical or sexual abuse and 380 women with no reported abuse were included. Inappropriate maternal weight gain was determined using the IOM recommendations. Logistic regression models, adjusted for parity, race, year of delivery, and maternal age group were developed. In women 20 years of age or less, no associations with inadequate or excess weight gain were found. Women age 20 years or higher with a history of physical abuse (AOR 3.1, 95% CI 1.3-7.3) or women with current physical or sexual abuse (AOR 2.2, 95% CI 1.1-4.5) were more likely to be associated with inadequate pregnancy weight gain. Women aged 20 years or higher with a history of sexual abuse with or without physical abuse (AOR 2.4, 95% CI 1.1-5.5) or with a history of or current physical or sexual abuse (AOR 2.1, 95% CI 1.2-3.8) were more likely to be associated with excess pregnancy weight gain. In all subjects, women with a history of physical abuse (AOR 2.0, 95% CI 1.1-3.8) were associated with inadequate pregnancy weight gain whereas no associations with excess pregnancy weight gain were found.

Using an existing obstetric database, Caulfield et al examined the factors influencing the risk of gaining outside IOM recommendations and whether these factors differed between 1,253 Caucasian and 2,617 African American women who delivered a singleton infant of at least 28 weeks' gestation (70). Inadequate, adequate and excess pregnancy weight gain were determined using the IOM recommendations. Multinomial logistic regression models were developed. Twenty-eight percent of African American women and 32% of Caucasian women gained the recommended amount of pregnancy weight. Inadequate weight gain was associated with being African American (AOR 1.5, 95% CI 1.2-1.9) or with smoking (AOR 1.4, 95% CI 1.1-1.7. Protective effects for inadequate gain were seen with each extra week of gestation for normotensive (AOR 0.9, 95% CI 0.87-0.93) or for hypertensive women (AOR 0.4, 95% CI 0.7-0.9), or in hypertensive women who delivered at 40 weeks' gestation (AOR 0.4, 95% CI 0.3-0.8). Excess weight gain was associated with being in the overweight BMI category (AOR 1.9, 95% CI 1.4-2.4), being in the obese BMI category (AOR 1.5, 95% CI 1.2-1.9), with each extra week of gestation for normotensive women (AOR 1.2, 95% CI

1.1-1.3), being a hypertensive women who delivered at 34 weeks' gestation (AOR 3.8, 95% CI 2.1-7.0) or with height per extra 7 centimeters (AOR 1.3, 95% CI 1.2-1.4). Women with a parity of two or more (AOR 0.6, 95% CI 0.5-0.7) or women in the underweight BMI category (AOR 0.3, 95% CI 0.2-0.4) were less likely to have excess gain. A problem with this study is that Caufield et al included preterm deliveries. By including preterm deliveries, women with preterm deliveries are more likely to gain less weight than women with full term deliveries because they have less time to gain weight.

CHAPTER 2

STUDY OF MATERNAL RISK FACTORS ASSOCIATED WITH INAPPROPRIATE PREGNANCY WEIGHT GAIN IN LOW-INCOME WOMEN IN THE UNITED STATES

Design and Methods

In 1995, the Improving the Health and Development of Pregnant Women study was formed with the primary goal of assessing the impact of a comprehensive prenatal and postpartum program had on maternal and infant health outcomes in a low-income population. It was a multi-site controlled, randomized clinical trial that examined two home visiting models. Women who met all the inclusion criteria of the study and signed informed consented received either (1) a nurse-managed community health worker (CHW) team intervention (experimental intervention), or (2) a standard of community care nurse home visiting in the form of state entitlement maternal and infant support services (control intervention). Both interventions functioned under the state's Medicaid entitlement program for pregnant women and infants. Both interventions were expected to provide nutritional services by a registered dietician. Institutional review board approval was received from Michigan State University and Spectrum Health.

The setting of the study was a moderate-sized city in the central Midwest area of the United States. The sample was selected from women who inquired about prenatal care at any one of four clinics that serve Medicaid-eligible women. The four prenatal clinics were hospital and community based and were willing to adhere to the randomization process. Low-income pregnant women who initiated a call to request prenatal care from one of the participating clinics were invited to participate in the study. Inclusion criteria were: 1) Medicaid eligible; 2) a resident of the local county with no stated plans to move out of the county in the next 18 months; 3) initiated a request for prenatal care at one of four participating clinics; 4) less than or equal to 24 weeks' gestation based on the date of the woman's last menstrual period or estimated from the EDC (estimated date of confinement) established by a health care provider; 5) able to read or verbally understand English or Spanish; and 6) at least 17 years of age. Exclusion criteria included: 1) treatment, medications for, or mental health therapy from a social worker, psychologist or psychiatrist within the previous two years for depression, bipolar disorder, schizophrenia, dillusional disorders, multiple personalities, panic attacks, and/or post-traumatic stress syndrome; and 2) a pregnancy estimated greater than 24 weeks gestation at the time of study enrollment.

When a pregnant woman called for an initial appointment for prenatal care she was informed that she would receive a call or a visit (if no phone) to explain the study. The woman was called or visited and invited to participate in the study, if she was 24 weeks or less gestation. The range of services, the random assignment and the research project were fully explained. Computer generated random permutations or tables were used for treatment assignment. Independent randomization schedules were used for each clinic site. Furthermore, a block size of four was used. This is based on a projected enrollment of approximately 36 eligible women on average every two months across the four sites. This blocking over time greatly reduced the likelihood of imbalances in the treatment arms during the course of the trial. Randomization schedules were generated by the biostatistician on the project and kept blinded as much as possible, to all personnel involved in evaluating patients. Subjects were blinded to treatment assignment.

Mothers who were randomized to the nurse-CHW team were assigned to one of the four intervention teams based on the mother's geographic residence, any special ethnic or language considerations and the intervention teams current caseload and capacity. The standard of community care nurse home visiting intervention was assigned to mothers based upon the mother's geographic residence. Both services also provided registered dietician and/or social work professional services to the mothers as needed. Following assignment, the prenatal clinic was notified only of the mothers assigned to the nurse-CHW team. In this case, it was not possible to "blind" the health care providers from experimental intervention status, as the nurse-CHW team intervention was designed to encourage more frequent contact between the nurse-CHW team and the primary care physician. However, clinic staff were not notified of which women were randomized to the standard of community care nurse home visiting intervention.

Following signing of the consent form, an investigator-developed questionnaire was administered via face to face interviews by a community health research assistant in the woman's home, or in a neutral site determined by the study participant. The content of the questionnaire covered general demographics such as her self-reported age, education, employment status, ethnicity, marital status, state-provided entitlements (such as WIC and food stamps), available food in her home, and her current living arrangements.

Pregnancy demographics included her gravidity and parity, whether the pregnancy was planned, and how the mother felt about the pregnancy when she first found out and how she felt at study enrollment. Self-reported risky behavior information was also included. In particular, questions were asked about current smoking status, the amount of alcohol currently consumed, any current illicit or non-prescribed drug use, and the occurrence of any physical abuse and/or any sexual abuse.

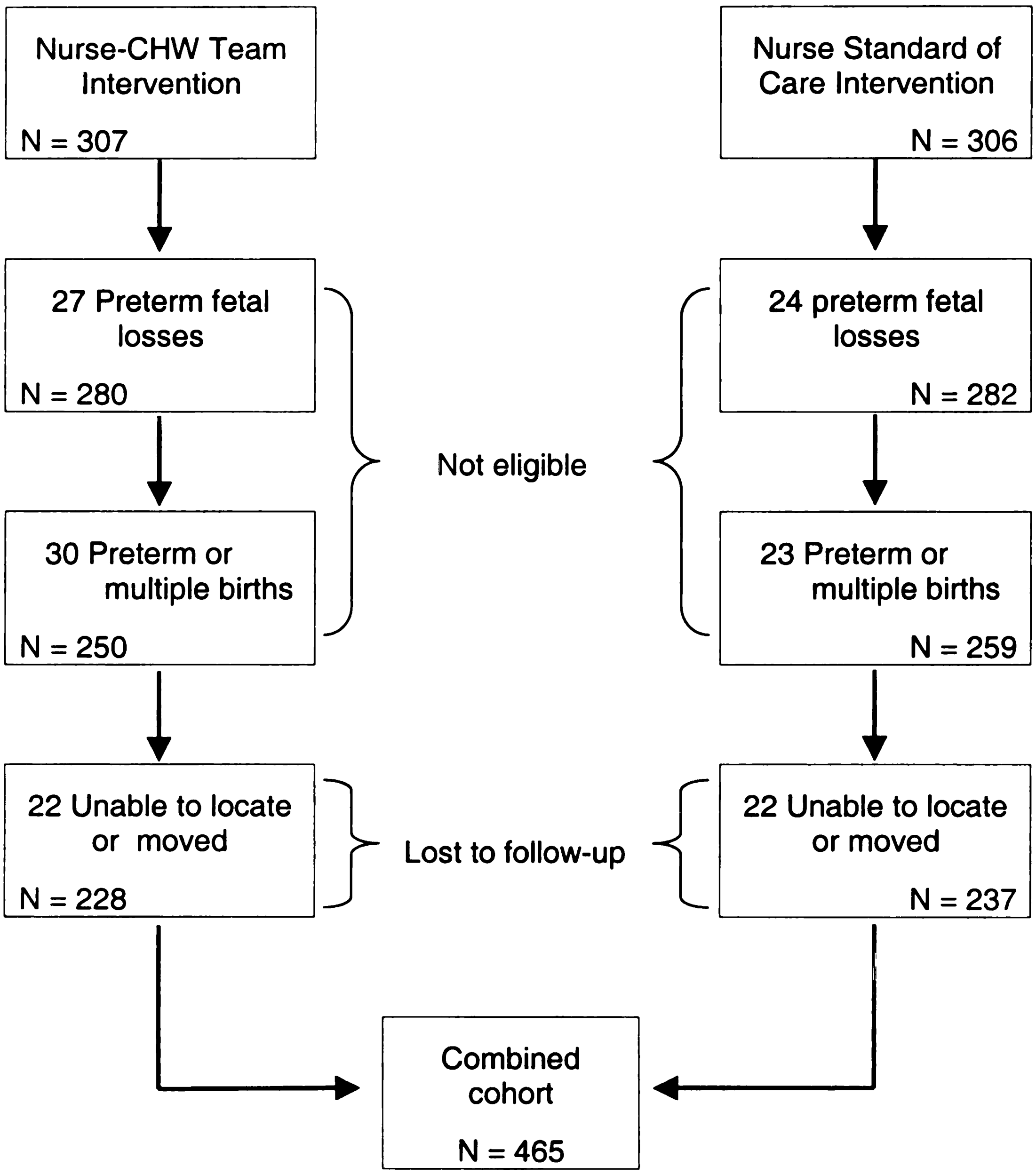
Standardized measurements for mastery, self-esteem, stress and depression were imbedded in the questionnaire. A seven-item Sense of Mastery scale that measured the extent to which a person feels that their life chances are under their own control was included (71). The Sense of Mastery scale used a four-point scale that ranged from strongly agree to strongly disagree. Self-esteem was measured with the Rosenberg 10-item scale that was designed to measure basic feelings of self-worth and used a four-point scale that ranged from strongly agree to strongly disagree (72). The Perceived Stress Scale (PSS) is a 14-item, five-point scale that measures the degree to which situations in one's life are appraised as stressful. The PSS was designed to tap a person's feelings that their lives were unpredictable, uncontrollable and overloading (73). Depression was measured using the Center for Epidemiologic Studies Depression Scale (CES-D), a 20-item scale that measured the current level of depression and depressed mood (74). The CES-D used symptoms of depression and asked respondents to indicate how often they have felt that way during the previous week. Each scale was scored individually and quartiles were determined for the current sample as a whole.

In addition to the maternal interview questionnaire, a medical record abstraction of the mother's prenatal and delivery room records and her infant's birth record(s) were done postnatally, utilizing an investigator-developed instrument. Registered nurses were trained as medical chart abstractors by an obstetrician co-investigator and the project field coordinator, with achievement of at least a 90% inter-rater reliability required. The abstracted information included the mother's self-reported pre-pregnancy weight and height, her weight measured upon admission to the hospital just prior to the delivery, the trimester she began prenatal care, the presence of pre-existing or pregnancy-acquired hypertension and/or diabetes, the gestational age at delivery, and if it was a singleton or multiple birth. The obstetric clinics relied upon the mother's recall of her pre-pregnancy weight and height since measured pre-pregnancy values were not available to them. Each mother was asked how much she weighed and how tall she was just before she became pregnant by the obstetric clinics.

A total of 613 ethnically diverse, low-income pregnant women were enrolled in the initial study. Because of the effect that preterm delivery and/or multiple births have on weight gain during pregnancy, only women delivering fullterm (37 weeks' gestation or greater), singleton, liveborn infants were eligible for this study. Of the initial sample, 53 women delivered prior to 37 weeks or had a multiple birth, 40 experienced a spontaneous abortion, 7 underwent elective abortions, and 4 experienced a preterm stillbirth, leaving an available sample of 509 (Figure 1). This sample was further reduced by 44 women who did not have a complete medical abstraction done because they were not able to be located just prior to or at the time of delivery. A final sample of 465 women remained.

FIGURE 1

STUDY SAMPLE



Statistical Analysis

Each woman's pre-pregnancy body mass index (BMI) was determined as self-reported pre-pregnancy weight in kilograms divided by a squared measure of self-reported pre-pregnancy height in meters. Using the 1990 Institute of Medicine (IOM) guidelines, each woman was categorized as underweight, normal weight, over weight, or obese based on her pre-pregnancy BMI (Table 5). For each pre-pregnancy BMI category, recommendations for weight gain during pregnancy were recommended by the IOM. The IOM did not define an upper limit for the obese group, so it was defined as equivalent to the overweight group, 25 pounds, for this study. Weight gain during pregnancy was calculated by subtracting self-reported pre-pregnancy weight from the last measured weight just prior to delivery. The pregnancy weight gain was then categorized as inadequate, adequate or excess gain and was the dependent variable for all analyses..

All analysis was conducted using SAS statistical program (Statistical Analyses System, SAS Institute, Inc., Cary, North Carolina) and was limited to women who delivered a liveborn, singleton infant between 37 and 41 weeks' gestation. Prior to combining the data of the two intervention groups, the distribution of weight gain between the groups was examined using the Chi Square test. After combining the data of the two intervention groups, all statistical analyses were completed separately for the inadequate and the excess weight gain groups as compared to the adequate weight gain group allowing for discernment of associations specific to each inappropriate weight gain group. Initial analyses examined the distribution of maternal variables among the weight gain groups using the Chi Square test. Variables determined to be important a priori (age and ethnicity) or those with a p value 0.15 or less were selected for inclusion in the separate multi-covariate logistic regression models. Multi-covariate logistic regression models were created to determine the relationships of these maternal variables to either inadequate or excess weight gain as compared to adequate weight gain. These associations were evaluated both before and after adjusting for age and ethnicity. Finally, separate parsimonious logistic regression models, which included all variables in the unadjusted logistic regression models with a p value of 0.15 or less, were used to develop adjusted, reduced models.

Results

In the clinical trial, women were enrolled and the questionnaire was administered if the pregnancy was 24 weeks' gestation or less. The gestational age distribution of when the questionnaire interview was done included 59.8% of interviews occurring in first 12 weeks of pregnancy. During the first three months of pregnancy, 28.6% of the women were interviewed in the first 8 weeks of pregnancy, while 31.2% were interviewed between 9-12 weeks. The remaining 40% of the women were interviewed after 12 weeks' gestation, with 19.3% interviewed between 13-16 weeks, 12.1% between 17-20 weeks and 8.8% between 21-24 weeks.

No significant differences in the weight gain groups were found between the two intervention groups, so the data were combined. When looking at the women as a combined group, the majority of women were in the normal or obese pre-pregnancy BMI group (39% and 30% respectively), while 18% were in the under weight group and 13% in the overweight group (Table 6). The mean pregnancy weight gain for each pre-pregnancy BMI group did not differ significantly, even though the IOM recommendations for pregnancy weight gain decrease greatly as pre-pregnancy BMI increases. On average the women gained 34 pounds during pregnancy, with those in the underweight BMI group gaining well within the recommended range and those in the normal weight group gaining slightly above the recommended range. Women in both the overweight and obese BMI groups, on average, gained more than the recommended amounts by at least 5 to 10 pounds. Based on the IOM weight gain recommendations, only 31% gained an adequate amount of weight, while 47% had excess weight gain and 22% gained an inadequate amount of weight.

Table 6. IOM Recommended Weight Gain and Actual Mean Pregnancy Weight Gain by Pre-Pregnancy BMI Group

Pre-Pregnancy BMI Group	IOM Weight Gain Recommendation*	N (%)	Mean pregnancy gain (lb), $\pm$sd
Underweight (<19.8)	28-40 lb	84 (18)	36.1 ± 18.1
Normal weight (19.8-26.0)	25-35 lb	183 (39)	35.5 ± 12.6
Over weight (26.1-29.0)	15-25 lb	60 (13)	35.0 ± 21.2
Obese (>29.0)	15-25 lb	138 (30)	30.4 ± 21.4
All		465	34.0 ± 18.1

*Upper limit was set at 25lb for the obese pre-pregnancy BMI group for this study

All of the women were Medicaid eligible, at 185% of the federal poverty line or less, and were high risk. Ethnically the women described themselves as White non-

Latina (44%), African American (24%), Latina (23%), and other (9%) (Table 7). The other ethnicity group was made up of women who described themselves as bi-racial, Native American or Asian/Pacific Islander. Thirty percent of the women were aged 17-19 years of age and 51% were 20-25 years of age. Forty-eight percent had less than 12 years of education while 40% had 12 years of education or a GED. Only 18% of the women were married, with the remaining 82% being never married, divorced, separated or widowed.

Table 7. Maternal Demographics

Characteristic	All Groups (n=465) % (n)	Inadequate Gain (n=103) % (n)	Adequate Gain (n=143) % (n)	Excess Gain (n=219) % (n)
Age				
≤19 years	29 (136)	25 (26)	25 (36)	34 (74)*
20 – 25 years	51 (239)	52 (53)	48 (69)	53 (117)*
≥26 years (referant)	20 (90)	23 (24)	27 (38)	13 (28)
Ethnicity				
White, non-Latina (referant)	44 (204)	32 (33)	43 (61)	50 (110)
African American	24 (113)	26 (27)	29 (41)	21 (45)
Latina	23 (107)	33 (34)	23 (33)	18 (40)*
Other	9 (41)	9 (9)	5 (8)	11 (24)
Education				
< 12 yrs	48 (225)	58 (60)*	41 (58)	49 (107)*
12 yrs / GED	40 (186)	33 (34)	41 (58)	43 (94)*
> 12 yrs (referant)	12 (54)	9 (9)	18 (27)	8 (18)
Marital status				
Married	18 (83)	19 (20)	22 (31)	15 (32)
Not married (referant)	82 (382)	81 (83)	78(112)	85 (187)

*p <.05 compared with Adequate Gain Group; column percents add to 100

Only 39% of the women were in the average weight pre-pregnancy BMI category while 30 % were in the obese pre-pregnancy BMI category (Table 8). More than half of the women (55%) had at least one previous livebirth. Almost all of the women (97%) started prenatal care in the 1st or 2nd trimester. For 79% of the women, the pregnancy was not planned. Sixty-five percent of the women had mixed, unhappy or very unhappy feelings about the pregnancy when they initially found out they were pregnant. When enrolled into the study these feelings changed, with only 24% of the women having mixed, unhappy or very unhappy feelings about the pregnancy.

Forty-four percent of the women were not employed (Table 9). Almost half of the women (47%) did not receive WIC and 19% did not receive food stamps. Fifteen percent of the women reported they did not have the amount of food needed sometimes, rarely or never, while the remaining 85% almost always or always had the amount of food they needed. Fifty-seven percent of the women did not live with another adult and only 15% lived with children. Almost half of the women (47%) reported being physically abused at some time in their life, while 22% reported being sexually abused at some time in their life.

Table 8. Maternal Characteristics and Pregnancy Related Factors

Characteristic	All Groups (n=465) % (n)	Inadequate Gain (n=103) % (n)	Adequate Gain (n=143) % (n)	Excess Gain (n=219) % (n)
Pre-pregnancy BMI category				
Underweight	18 (84)	19 (20)	25 (36)	13 (28)*
Average weight (referant)	39 (183)	47 (48)	35 (50)	39 (85)
Overweight	13 (60)	8 (8)	12 (17)	16 (35)
Obese	30 (138)	26 (27)	28 (40)	32 (71)
Parity				
0	45 (207)	34 (35)	43 (61)	51 (111)*
1	29 (135)	33 (34)	24 (35)	30 (66)*
$\geq$ 2 (referant)	26 (123)	33 (34)	33 (47)	19 (42)
Planned Pregnancy				
Yes (referant)	21 (99)	23 (24)	17 (25)	23 (50)
No	79 (366)	77 (79)	83 (118)	77 (169)
Felt about pregnancy initially				
Happy/ very happy	35 (164)	38 (39)	32 (46)	36 (79)
Mixed/very unhappy (referant)	65 (299)	62 (63)	68 (97)	64 (139)
Felt about pregnancy-enrollment				
Happy / very happy	76 (355)	75 (77)	71 (101)	81 (177)*
Mixed/very unhappy (referant)	24 (109)	25 (26)	29 (42)	19 (41)
Trimester started prenatal care				
1st trimester (referant)	48 (221)	42 (43)	44 (63)	53 (115)
2nd trimester	49 (229)	54 (56)	52 (75)	45 (98)
3rd trimester	3 (15)	4 (4)	4 (5)	3 (6)
	Mean $\pm$SD	mean $\pm$SD	mean $\pm$SD	mean $\pm$SD
Height, cm	64.1 $\pm$ 2.8	63.0 $\pm$2.7	64.3 $\pm$2.8	64.4 $\pm$2.9

*p <.05 compared with Adequate Gain Group; column percents add to 100

Table 9. Maternal Resources, Life Circumstances and Behaviors

Characteristic	All Groups (n=465) % (n)	Inadequate Gain (n=103) % (n)	Adequate Gain (n=143) % (n)	Excess Gain (n=219) % (n)
Employed				
Yes (referant)	56 (259)	55 (57)	55 (79)	56 (123)
No	44 (206)	45 (46)	45 (64)	44 (96)
Receiving WIC				
Yes (referant)	53 (248)	60 (62)	50 (72)	52 (114)
No	47 (217)	40 (41)	50 (71)	48 (105)
Receiving Food Stamps				
Yes (referant)	81 (376)	80 (82)	79 (113)	83 (181)
No	19 (89)	20 (21)	21 (30)	17 (38)
Have necessary food				
Almost/always (referant)	85 (394)	79 (81)	90 (128)	85 (185)
Sometimes / never	15 (71)	21 (22)*	10 (15)	15 (34)
Live with other adults				
Yes	43 (201)	40 (41)	44 (63)	44 (97)
No (referant)	57 (264)	60 (62)	56 (80)	56 (122)
Live with children				
Yes	15 (17)	13 (13)	10 (15)	19 (42)*
No (referant)	85 (395)	87(90)	90 (128)	81 (177)
Smoke Cigarettes				
Yes	33 (151)	31 (32)	32 (45)	34 (74)
No (referant)	67 (314)	69 (71)	68 (98)	66 (145)
Ever been physically abused				
Yes	47 (218)	49 (50)	51 (73)	43 (95)
No (referant)	53 (247)	51 (53)	49 (70)	57 (124)
Ever been sexually abused				
Yes	22 (103)	20 (21)	16 (23)	27 (59)*
No (referant)	78 (360)	80 (82)	84 (120)	73 (158)

*p <.05 compared with Adequate Gain Group; column percents add to 100

The psychological scales were scored individually and found the women had a mean depression score of 19.6, a mean stress score of 32.5, a mean self-esteem score of 30.8 and a mean mastery score of 20.7 (Table 10). Quartiles were determined for each scale based on the sample of a whole. The quartiles for depression were a score of 11 or lower (least), 12-18, 19-26 and 27 or higher (most). For stress the quartiles were scores of 29 or lower (least), 30-32, 33-35 and 36 or higher (most). For self-esteem the quartiles were scores of 28 or lower (least), 29-30, 31-33 and 34 or higher (most). The quartiles for mastery were scores of 19 or lower (least), 20-21, 22 and 23 or higher (most).

Table 10. Maternal Psychological Characteristics.

Characteristic	All Groups (n=465)	Inadequate Gain (n=103)	Adequate Gain (n=143)	Excess Gain (n=219)
	mean ±SD	mean ±SD	mean ±SD	mean ±SD
Depression level	19.6±10.9	19.8±11.9	18.5±9.6	20.2±11.3
Stress level	32.5±4.8	31.8±4.7	33.1±4.8	32.4±4.9
Self-esteem level	30.8±4.1	30.2±4.0	31.2±3.9	30.8±4.2
Mastery level	20.7±2.9	20.3±2.7	20.8±2.9	20.7±3.0
	% (n)	% (n)	% (n)	% (n)
Depression level, quartiles				
1st, least (referant)	26 (119)	25 (26)	25 (35)	27 (58)
2nd	25 (117)	28 (29)	27 (39)	22 (49)
3rd	24 (114)	22 (22)	29 (42)	23 (50)
4th, most	25 (115)	25 (26)	19 (27)	28 (62)
Stress level, quartiles				
1st, least (referant)	26 (121)	32 (33)	21 (30)	27 (58)
2nd	26 (119)	21 (21)	27 (38)	27 (60)
3rd	25 (116)	29 (30)	22 (31)	25 (55)
4th, most	23 (108)	18 (19)*	30 (43)	21 (46)
Self-esteem level, quartiles				
1st, least	27 (127)	32 (33)*	19 (27)	31 (67)
2nd	30 (141)	32 (33)	37 (53)	25 (55)*
3rd	19 (87)	19 (20)	20 (28)	18 (39)
4th, most (referant)	24 (110)	17 (17)	24 (35)	26 (58)
Mastery level, quartiles				
1st, least	19 (90)	22 (23)*	18 (26)	19 (41)
2nd	30 (137)	32 (33)*	28 (40)	29 (64)
3rd	31 (142)	35 (36)*	32 (45)	28 (61)
4th, most (referant)	21 (95)	11 (11)	22 (32)	24 (52)

*p <.05 compared with Adequate Gain Group; column percents add to 100
SD = standard deviation
Depression scale quartiles: ≤11, 12-18, 19-26, ≥27.
Stress scale quartiles: ≤29, 30-32, 33-35, ≥36.
Self-esteem quartiles: ≤28, 29-30, 31-33, ≥34.
Mastery quartiles: ≤19, 20-21, 22, ≥23.

Using Chi Square tests, the variables identified for inclusion in the inadequate pregnancy weight gain logistic regression models with a p-value of 0.15 or less were education, height, WIC status, having the necessary food, and stress, self-esteem and mastery levels (age and ethnicity were identified a priori). For the excess pregnancy weight gain logistic regression models, the variables identified for inclusion with a p-value of 0.15 or less were education, marital status, height, pre-pregnancy BMI, parity, feelings about the pregnancy, if living with children, sexual abuse status, and stress and self-esteem levels (age and ethnicity were identified a priori).

Inadequate pregnancy weight gain

In bivariate analysis, women in the inadequate pregnancy weight gain group were more likely to have less than 12 years of education as compared to women in the adequate pregnancy weight gain group (Table 7). As compared to the adequate pregnancy weight gain group, women in the inadequate pregnancy weight gain group were more likely to be of shorter height or have the necessary amount of food sometimes to never (Table 9). Women in the inadequate pregnancy weight gain group were more likely to be in the highest stress quartile, be in the lowest self-esteem quartile, or be in the three lowest mastery quartiles as compared to women in the adequate pregnancy weight gain group (Table 10).

Variables associated with inadequate pregnancy weight gain during univariate analysis (P-value of 0.15 or less) were examined using logistic regression (Table

11). Three of the four quartiles for each of the psychological measures were combined after they were found to be similar, and the separate logistic regression models were rerun. Several characteristics were associated with inadequate pregnancy weight gain with odds ratios ranging between two and three: education less than 12 years (OR 3.1, 95% CI 1.4-7.2); women who felt they had necessary food sometimes to never (OR 2.3, 95% CI 1.1-4.7); a measured self-esteem level in the lowest quartile (OR 2.0, 95% CI 1.1-3.7); and a measured mastery level in three lowest quartiles (OR 2.4, 95% CI 1.2-5.1). Women who were Latina or 'other' ethnicity, or had an education of 12 years were 2 to 3 times more likely to be associated with inadequate pregnancy weight gain, however these were not statistically significant. Women with shorter height (OR 0.8, 95% CI 0.8-0.9) were associated with lower odds ratios for inadequate pregnancy weight gain. A measured stress level in the highest quartile was associated with a lower odds ratio, but was not statistically significant.

When the separate logistic regression models were combined (Table 11), only women who felt they had necessary food sometimes to never (AOR 2.6, 95% CI 1.1-5.8) were associated with inadequate pregnancy weight gain. Women with an education less than 12 years, a measured self-esteem level in the lowest quartile or a measured mastery level in three lowest quartiles were 2 to 3 times more likely to be associated with inadequate pregnancy weight gain, however these were no longer statistically significant. A measured stress level in the highest quartile was associated with a lower odds ratio (AOR 0.4, 95% CI 0.2-0.8). Women with shorter height were associated with a lower odds ratio, but this was no longer statistically significant.

Table 11. Unadjusted and adjusted odds ratios for inadequate weight gain compared with adequate weight gain (n = 246)

Characteristics	Unadjusted		Adjusted+	
	OR	95% CI	OR*	95% CI
Ethnicity				
African American	1.2	0.6-2.3	1.4	0.7-2.0
Latino	1.9	1.0-3.6	1.4	0.6-3.0
Others	2.1	0.7-5.9	2.5	0.8-7.8
White, non-Latina	referant		referant	
Age				
≤ 19 years	1.1	0.6-2.4	1.1	0.5-2.8
20-25 years	1.2	0.7-2.3	1.5	0.7-3.1
≥ 26 years	referant		referant	
Education				
< 12 years	3.1	1.4-7.2	2.6	1.0-6.9
12 years /GED	1.8	0.7-4.2	1.9	0.7-5.0
> 12 years	referant		referant	
Height, per cm[1]	0.8	0.8-0.9	0.9	0.8-1.0
Does not receive WIC (yes/no)	0.7	0.4-1.1	0.6	0.3-1.0
Have necessary food, sometime/never[2]	2.3	1.1-4.7	2.6	1.1-5.8
Stress level				
1st ,2nd, 3rd quartiles	referant		referant	
4th quartile, most	0.5	0.8-1.0	0.4	0.2-0.8
Self-esteem level				
1st quartile, least	2.0	1.1-3.7	1.8	0.9-3.5
2nd , 3rd, 4th quartiles	referant		referant	
Mastery level				
1st , 2nd, 3rd quartiles	2.4	1.2-5.1	1.8	0.7-4.2
4th quartile, most	referant		referant	

OR = odds ratio; CI = confidence interval.
+Adjusted for ethnicity and age.
[1]Height linear.
[2]Have the necessary food sometimes or never versus most of the time, almost always or always.

Variables with a P-value of 0.15 or less in the adjusted logistic regression model were used to create a parsimonious model (education, height, WIC status, necessary food status, stress and self-esteem). After adjusting for ethnicity and age in the reduced logistic regression model (Table 12), women with an education of less than 12 years (AOR 2.9, 95% CI 1.2-7.0) or women who felt they had necessary food sometimes to never (AOR 2.8, 95% CI 1.3-5.9) were two to three times more likely to be associated with inadequate pregnancy weight gain. Height (OR 0.9, 95% CI 0.8-0.9) and measured stress levels in the highest quartile (AOR 0.4, 95% CI 0.2-0.8) were protective for inadequate pregnancy weight gain. Women with 12 years of education or who had a measured self-esteem level in the lowest quartile were almost 2 times more likely to be associated with inadequate pregnancy weight gain, however these were not statistically significant.

Interactions between education and ethnicity with pregnancy weight gain were examined in the modeling process with no statistically significance found. However this may have been limited by power. In examining ethnicity and education, a hint of interaction among women with an education of 12 years or more was seen, with African Americans less likely to have inadequate pregnancy weight gain as compared to White non-Latinas. When ethnicity and age was examined, a suggestion of interaction was observed among women age 19 years or more, with African Americans more likely to have inadequate pregnancy weight gain as compared to White non-Latinas.

Table 12. Adjusted and reduced odds ratios for inadequate weight gain compared with adequate weight gain (n = 246)

Characteristics	Adjusted and Reduced+	
	OR	95% CI
Education		
< 12 years	2.9	1.2-7.0
12 years /GED	1.9	0.8-4.9
> 12 years		referant
Height, per cm[1]	0.9	0.8-0.9
Does not receive WIC	0.6	0.3-1.0
Have necessary food, sometimes/never[2]	2.8	1.2-5.9
Stress level		
1st, 2nd, 3rd quartiles		referant
4th quartile, most	0.4	0.2-0.8
Self-esteem level		
1st quartile, least	1.9	1.0-3.5
2nd, 3rd, 4th quartiles		referant

OR = odds ratio; CI = confidence interval.
+Parsimonious logistic regression model adjusted for ethnicity and age.
[1]Height linear.
[2]Have the necessary food sometimes or never versus most of the time, almost always or always.

Excessive weight gain

In bivariate analysis, women in the excess pregnancy weight gain group were more likely to be less than 25 years of age or have 12 years of education or less as compared to women in the adequate pregnancy weight gain group (Table 7). As compared to the adequate pregnancy weight gain group, women in the excess pregnancy weight gain group were more likely to have a parity of less than two or felt happy to very happy about the pregnancy when enrolled into the study (Table 8). Women in the excess pregnancy weight gain group were more likely to live with children or ever been sexually abused as compared to women in the adequate pregnancy weight gain group (Table 9). There were no significant psychological differences seen when women with excess pregnancy weight gain were compared to women with adequate weight gain (Table 10).

Variables associated with excess pregnancy weight gain during univariate analysis (P-value of 0.15 or less) were examined using logistic regression (Table 13). Three of the four quartiles for each of the psychological measures were combined after they were found to be similar, and the separate logistic regression models were rerun. Several characteristics were associated with increased odds ratios for excess pregnancy weight gain: age 19 years or less (OR 2.8, 95% CI 1.5-5.2); age 20-25 years (OR 2.3, 95% CI 1.3-4.1); less than 12 years of education (OR 3.1, 95% CI 1.4-7.2); one previous live births (OR 2.0, 95% CI 1.2-3.4); two or more previous live births (OR 2.1, 95% CI 1.2-3.8); felt happy to very happy about the pregnancy (OR 1.8, 95% CI 1.1-3.0); lived with children (OR 2.0, 95% CI 1.1-3.8); ever sexually abused (OR 2.0, 95% CI 1.1-3.3); and measured self-esteem level in the least quartile (OR 1.9, 95% CI 1.1-3.2). Although women in the other ethnicity category and those with 12 years of education were almost 2 times more like to be associated with excess pregnancy weight gain, this was not statistically significant. Two characteristics were associated with decreased odds ratios for excess pregnancy weight gain: underweight pre-pregnancy BMI category (OR 0.5, 95% CI 0.3-0.8) or height (OR 0.8, 95% CI 0.8-0.9). Being Latina, married and a measured stress level in the most quartile were associated with lower odd ratios, but these were not statistically significant.

When the separate logistic regression models were combined (Table 13), several characteristics continued to be associated with increased odds ratios for excess pregnancy weight gain: 2 or more previous live birth (AOR 2.2, 95% CI 1.1-4.5); felt happy to very happy about the pregnancy (AOR 2.4, 95% CI 1.3-4.3); ever sexually abused (AOR 2.1, 95% CI 1.1-3.9); or measured self-esteem level in the least quartile (AOR 2.1, 95% CI 1.1-3.8. Women aged 25 years or less, with an education less than 12 years, or with a parity of zero were 2 to 3 times more likely to be associated with excess pregnancy weight gain, however these were no longer statistically significant. Characteristics associated with lower odd ratios included underweight pre-pregnancy BMI category (AOR 0.4, 95% CI 0.2-0.7) and measured stress level in the highest quartile was (AOR 0.5, 95% CI 0.3-0.9). Women with shorter height were associated with a lower odds ratio, but this was no longer statistically significant.

Table 13. Unadjusted and adjusted odds ratios for excess weight gain compared with adequate weight gain (n = 362)

Characteristics	Unadjusted		Adjusted+	
	OR	95% CI	OR*	95% CI
Ethnicity				
African American	0.6	0.4-1.0	0.7	0.4-1.4
Latino	0.7	0.4-1.2	0.6	0.3-1.3
Others	1.7	0.7-3.9	1.8	0.7-5.0
White, non-Latina	referant		referant	
Age				
≤ 19 years	2.8	1.5-5.2	2.0	0.8-5.2
20-25 years	2.3	1.3-4.1	1.7	0.8-3.4
≥ 26 years	referant		referant	
Education				
< 12 years	3.1	1.4-7.2	2.1	0.9-4.8
12 years /GED	1.8	0.7-4.2	2.0	0.9-4.4
> 12 years	referant		referant	
Married	0.6	0.4-1.1	0.9	0.4-1.7
Height, per cm[1]	0.8	0.8-0.9	1.0	0.9-1.1
Pre-pregnancy BMI				
Average weight	referant		referant	
Underweight	0.5	0.3-0.8	0.4	0.2-0.7
Over weight	1.2	0.6-2.4	0.8	0.5-1.5
Obese	1.0	0.6-1.8	1.2	0.5-2.5
Parity				
0	2.0	1.2-3.4	2.0	1.0-4.1
1	2.1	1.2-3.8	2.2	1.1-4.5
≥ 2	referant		referant	
Happy about pregnancy[2]	1.8	1.1-3.0	2.4	1.3-4.4
Live with children (yes/no)	2.0	1.1-3.8	2.0	1.0-4.2
Ever sexually abused (yes/no)	2.0	1.1-3.3	2.1	1.1-3.9
Stress level				
1st, 2nd, 3rd quartiles	referant		referant	
4th quartile, most	0.6	0.4-1.0	0.5	0.3-0.9
Self-esteem level				
1st quartile, least	1.9	1.1-3.2	2.1	1.1-3.8
2nd, 3rd, 4th quartiles	referant		referant	

OR = odds ratio; CI = confidence interval; BMI = Body Mass Index.
+Adjusted for ethnicity and age.
[1]Height linear.
[2]Feeling about pregnancy happy or very happy versus mixed, unhappy, or very unhappy.

Variables with a P-value of 0.15 or less in the adjusted logistic regression model were used to create a parsimonious model (ethnicity, education, pre-pregnancy BMI, parity, feelings about the pregnancy, living with children, sexual abuse status, stress and self-esteem). After adjusting for age in the reduced logistic regression model (Table 14), women with an education of less than 12 years (AOR 2.7, 95% CI 1.2-5.7); 12 years of education (AOR 2.3, 95% CI 1.1-4.9); one previous live births (AOR 2.8, 95% CI 1.5-5.1); two or more previous live births (AOR 2.7, 95% CI 1.4-5.3); felt happy to very happy about the pregnancy (AOR 2.3, 95% CI 1.2-4.1); ever sexually abused (AOR 2.2, 95% CI 1.2-4.1); and a measured self-esteem level in the lowest quartile (AOR 2.1, 95% CI 1.2-3.8) remained associated with higher odds ratios for excess pregnancy weight gain. Although women in the other ethnicity category or lived with children were almost 2 times more like to be associated with excess weight gain, these were not statistically significant. Two characteristics were associated with decreased odds ratios for excess pregnancy weight gain: underweight pre-pregnancy BMI category (AOR 0.4, 95% CI 0.2-0.7) and measured stress level in the highest quartile (AOR 0.5, 95% CI 0.3-0.9). Being Latina was associated with lower odds ratio, but it was not statistically significant.

Interactions between education and ethnicity with pregnancy weight gain were examined in the modeling process with no statistically significance found. However this may have been limited by power. Education did not alter the relationship of ethnicity to excess pregnancy weight gain. When ethnicity and age was examined, a suggestion of interaction was observed among women less than 19 years of age, with Latinas more likely to have excess pregnancy weight gain as compared to White non-Latinas.

Table 14. Adjusted and reduced odds ratios for excess weight gain compared with adequate weight gain (n = 362)

Characteristics	Adjusted and Reduced+	
	OR	95% CI
Ethnicity		
African American	0.8	0.4-1.4
Latino	0.6	0.3-1.1
Others	2.1	0.8-5.2
White, non-Latina	referant	
Education		
< 12 years	2.7	1.2-5.7
12 years /GED	2.3	1.1-4.9
> 12 years	referant	
Pre-pregnancy BMI		
Average weight	referant	
Underweight	0.4	0.2-0.7
Over weight	0.8	0.5-1.4
Obese	1.1	0.5-2.4
Parity		
0	2.8	1.5-5.1
1	2.7	1.4-5.3
≥ 2	referant	
Happy about pregnancy[1]	2.3	1.2-4.1
Live with children (yes/no)	2.1	1.0-4.3
Ever sexually abused (yes/no)	2.2	1.2-4.1
Stress level		
1st, 2nd, 3rd quartiles	referant	
4th quartile, most	0.5	0.3-0.9
Self-esteem level		
1st quartile, least	2.1	1.2-3.8
2nd, 3rd, 4th quartiles	referant	

OR = odds ratio; CI = confidence interval; BMI = Body Mass Index.
+Parsimonious logistic regression model adjusted for ethnicity and age.
[1] Feeling about pregnancy happy or very happy versus mixed, unhappy, or very unhappy.

CHAPTER 3

DISCUSSION

As in other studies, we found that only 31% of the women had pregnancy weight gain within the IOM recommendations (8,9,10). Of concern is that 22% of the women in our study gained an inadequate amount of weight during pregnancy. This lack of appropriate pregnancy weight gain in term deliveries has public health implications because of its association with poor fetal growth and subsequent increase in infant morbidity and mortality.

Also concerning is that 47% of the women in our study gained an excess amount of weight during pregnancy. On average, women retain 3 to 11 pounds 12 months post delivery, with the amount of retained weight increasing as pregnancy weight gain increases. Overweight and obesity has been shown to be related to weight retention after pregnancy, and as women age and as parity increases, the amount of weight retained increases. In older women, diseases such as type 2 diabetes mellitus, hypertension, high blood cholesterol and heart disease are frequently associated overweight and obesity. This is especially important in Michigan where the prevalence of overweight and chronic disease is much higher when compared to that of the United States as a whole (63). By identifying women likely to gain an excess amount of weight during pregnancy, it may be possible to prevent these debilitating chronic diseases and ease the burden on society.

We found that inadequate pregnancy weight gain was associated with having less than 12 years education. Women with low level of education may lack knowledge about healthy diets and adequate caloric intake to meet their nutritional needs. Or they may be less knowledgeable about the importance of gaining an adequate amount of weight during pregnancy. This finding was not consistent with the studies by Hickey, et al or Olsen and Strawderman (8,64) who did not find any associations. This may be explained by differing sample populations. Hickey et al included only Caucasian and African American women with a pre-pregnancy BMI of 26.0 or less (underweight or normal weight BMI categories) while Olsen and Strawderman sample included primarily white rural women. Our study did not exclude any ethnicity or pre-pregnancy BMI group and included urban and rural women.

As one indicator of attainment of resources, the women in our study were asked if they had the amount of food they thought necessary. We found that women who had the necessary food sometimes or never were more likely to have inadequate weight gain. At enrollment into the study, most of the women reported that they were not enrolled in the WIC program. If they did not enroll in the program during their pregnancy, they were missing a substantial nutritional food source that the other women had. Olsen and Strawderman found a strong association between inadequate weight gain and women who reported that their food intake during pregnancy changed to a little or lot less than what they consumed prior to their pregnancy (28).

We found that a high level of stress (highest quartile) had a protective effect against inadequate weight gain, which was consistent with the findings from Hickey et al (67). The women may deal with high levels of stress by increasing their food intake, spending more time sleeping or decreasing their physical activity.

Other studies have reported associations with inadequate weight gain that we did not find. Hickey et al found that employment of more than 40 hours per week was associated with inadequate pregnancy weight gain in Caucasian women (66). We initially examined employment based on hours worked, but did not find any differences between the inadequate and adequate pregnancy weight gain groups. In our final analysis, we included employment status as a yes/no variable and again did not find any associations with inadequate pregnancy weight gain.

The association of pregnancy wantedness in African American women with inadequate pregnancy weight gain found by Hickey et al was not found in our study (66). This may be explained by differences in the actual questions asked of the women. We used planned versus unplanned pregnancy whereas Hickey et al used a wanted versus mistimed or unwanted pregnancy for their analysis. A mistimed pregnancy may not be unwanted by the woman, she may actually want it, just not at that moment.

We did not find any associations between a high level of depression or low levels of self-esteem or mastery with inadequate pregnancy weight gain that Hickey et al found (66). Our lack of results may have been due to a lack of power due to small numbers in each quartile or because of a different sample population than used by Hickey et al. Hickey et al included only Caucasian and African American women with a pre-pregnancy BMI of 26.0 or less (underweight or normal weight BMI categories), whereas our study did not exclude any ethnicity or pre-pregnancy BMI group.

Olsen and Strawderman reported that underweight pre-pregnancy BMI was associated with inadequate pregnancy weight gain, which we did not find (8). In our study, women in the underweight pre-pregnancy BMI category may have been identified by prenatal care providers as being at increased risk for inadequate pregnancy weight gain. Our prenatal care providers may have provided the women with increased nutritional intervention or education on the importance of gaining an adequate amount of weight and/or the relationship between weight gain and low infant birth weight.

While Johnson et al found that a history of physical abuse or any physical or sexual abuse was associated with inadequate pregnancy weight gain, we did not find a similar association (8). Stress and depression resulting from abuse may lead to decreased appetite, increased activity and insomnia in some women, in others it may lead to increased appetite, decreased activity and excess sleeping.

We also found an education of 12 years or less was strongly associated with excess weight gain. This finding was not consistent with the study by Olsen and Strawderman (8). As with inadequate weight gain, these women may not have the knowledge to eat appropriately or how to adjust their intake to meet their nutritional needs. Or they may have been less knowledgeable about the importance of gaining an adequate amount of weight during pregnancy.

A parity of one or more was found to be strongly associated with excess weight gain in our study. This was not found by Olsen and Strawderman (8). Since it's been found that women gain more weight with each successive pregnancy, these women are likely to gain more weight than is recommended.

Our findings of women who reported ever being sexually abused associated with excess weight gain was consistent with those from Johnson et al (69). This could result from the associated stress and depression affecting a woman's appetite, activity level and sleep. However, we also found that women with the highest level of stress were protected from excess weight gain.

Several findings that we found associated with excess weight gain were not included in any other studies. These findings include women who felt happy or very happy about the pregnancy and women with a low level of self-esteem being associated with excess weight gain. The women may be over compensating in an attempt to make sure they are providing adequate nutrition for their infant. They may also be overeating just because they are happy. Women with low self-esteem may not feel they have the ability to seek information on dietary changes or be able to break away from family or cultural beliefs concerning nutrition and pregnancy weight gain. Associated depression may also decrease their appetite or affect their desire to prepare a meal.

We found that women in the underweight pre-pregnancy BMI category had a protective effect against excess weight gain. This was consistent with the findings from Olsen and Strawderman (8). Women who are in the underweight pre-pregnancy BMI category have smaller to no fat reserves, and they may not gain weight as easily as those who are in the other pre-pregnancy BMI categories.

Other studies reported associations with excess weight gain that we did not find. These include women in the obese pre-pregnancy BMI category) and women who reported any sexual abuse being associated with excess weight gain (8,69.)

Since all the obstetric clinics had registered dieticians on staff, the length of time a woman received prenatal care could affect the amount of nutritional intervention a woman received. However, there were no associations seen between the length of time a woman received prenatal care and weight gain group. The mean weeks' gestation the women entered prenatal care was very similar between the groups, ranging from 13.8-15.0 weeks' gestation, and were not significantly different. It remains possible that the women may have received differing amounts of nutritional intervention from the obstetric clinic or the WIC Program, but this data was not available. Irregardless of the provided nutritional intervention, family culture and beliefs may prevent any changes in nutritional intake or pregnancy weight gain. The availability of neighborhood grocery stores, the prices charged and the availability of fresh fruits and vegetables will also greatly influence a woman's nutritional intake. The clinical trial did not collect data on nutritional interventions that were a part of routine care, or on actual food or caloric intake, family culture and beliefs, grocery availability or physical activity.

Retarded blood flow in the lower extremities during the latter part of pregnancy is attributable to the occlusion of the pelvic veins and inferior vena cava by pressure of the enlarged uterus. The retarded blood flow and increased venous pressure in the legs contribute to the dependent edema frequently experienced by women as they approach term. In addition some women tend to accumulate extravascular fluid for reasons unknown. The maternal edema, especially in the last trimester, may add significantly to maternal weight gain. Women categorized into the excess weight gain group due to increased extravascular fluid are different than those without this extra fluid. Any excess fluid is usually lost during birth and immediately postpartum so that it is unlikely to contribute to a permanent increase in maternal body weight and it provides no nutritional benefit to the fetus. We were unable to assess the effect of increased maternal extravascular fluid on weight gain category since weight at the first postpartum visit was not available to us, and less than one-half of the women attended their 6 week postpartum visit.

The use of self-reported pre-pregnancy weight may lead to misclassification of women into pre-pregnancy BMI categories. It is unknown how many underweight women may have been misclassified into higher weight pre-pregnancy BMI categories since underweight women frequently self-report greater pre-pregnancy weight. And, since overweight and obese women tend to underreport their pre-pregnancy weight when asked, the number of overweight and obese women incorrectly assigned to lower weight pre-pregnancy BMI categories is also unknown. Misclassified underweight women would have been instructed to gain 3 to 15 pounds less than recommended by the IOM. Gaining an inadequate amount of weight during pregnancy is associated with poor infant outcomes. Misclassified overweight and obese women would have been instructed to gain 10 to 15 pounds more than the IOM recommendations. Gaining an excess amount of weight during pregnancy has been shown to be associated with weight retention after pregnancy and subsequently an increased risk of chronic disease later in life.

Future studies should be designed so that inappropriate pregnancy weight gain during pregnancy is the primary outcome of the study, in order that comprehensive maternal characteristics relating to resources, life circumstances, behavior, pregnancy, psychosocial status, food or caloric intake, and physical activity would be included. Attention must be paid to sample size so that adequate power can be achieved, not only for the sample as a whole but also for stratification by ethnicity. This is important since interactions by ethnicity in our study were difficult to evaluate due to limited sample size, and studies by Hickey et al found differences between Caucasian and African American women (66,67).

The results from this study show there are easily assessed maternal characteristics that identify low-income pregnant women most likely to gain below or above the IOM recommendations. However, these characteristics differ between the two inappropriate pregnancy weight gain groups. These results cannot be generalized to every pregnant woman. Our study was made up of only women with income less than 185% federal poverty line who initiated prenatal care with a hospital or community-based obstetric clinic by 24 weeks' gestation. Eighteen to 28% of low income women receive late or no prenatal care, and these women may be different from those who have the means to initiate prenatal care earlier (75,76,77). Low income women who receive prenatal care from a publicly funded clinic may be at higher risk than those who arrange for prenatal care from a private obstetrician's office, since they likely have fewer resources available to them.

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