THE ASSOCIATION BETWEEN PREGNANCY- RELATED WEIGHT AND OFFSPRING BMI AT CHILD AGE 3 TO 6 YEARS: RESULTS FROM A MID-MICHIGAN COHORT

By

Taylor Seaton

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Epidemiology- Master of Science

2017

ABSTRACT

THE ASSOCIATION BETWEEN PREGNANCY- RELATED WEIGHT AND OFFSPRING BMI AT CHILD AGE 3 TO 6 YEARS: RESULTS FROM A MID-MICHIGAN COHORT

By

Taylor Seaton

To provide a broader perspective on the relationship between maternal and child obesity, associations between several components of pregnancy-related weight and offspring body mass index (BMI) were examined. The Archive for Child Health (ARCH) enrolled and interviewed women at first prenatal visit in three clinics in mid-Michigan. A subset of mothers with singleton children participated in an age 3-6 y follow-up visit (mean=4.8 y) where anthropometric data was collected on both mother and child. Data collection included interview at enrollment (pre pregnancy BMI), birth certificate review (gestational weight gain), and measured height, weight, and waist circumference of mothers and children at follow-up. Multiple linear regressions were used to examine the association between maternal weight and waist circumference and offspring BMI. Maternal body composition at follow-up was also tested as a mediator. Characteristics of the study sample (n=114) included: 54% White, 13% Black, 18% Hispanic, and 15% other race/ethnicity; 82% had household incomes < $50,000/year; 84% reported no history of smoking. After adjusting for race and smoking history, only pre pregnancy BMI (β=0.84, 95% CI 0.1, 1.6) and maternal follow-up BMI (β =0.69, 95% CI 0.03, 1.3) were significantly associated with childhood BMI, with no evidence of mediation as tested. Our findings add to recent literature by revealing associations between a measure of maternal postpartum body composition (i.e. follow-up BMI) and offspring BMI. These associations may represent the influence of lifestyle and other environmental factors.

ACKNOWLEDGEMENTS

Completing this thesis would not have been possible without the help of several dedicated people. I would like to thank my advisor and thesis committee chair, Dr. Jean Kerver, for her guidance and support throughout this entire process, as well as taking the time to talk with me every week. I would like to thank Dr. Zhehui Luo for her time in guiding me through the statistical analysis and providing me the means to understand mediation analysis. To my committee member Dr. Nigel Paneth, I am very grateful for his expertise and valuable insight. Without him this thesis would not have been possible. I would also like to thank Dr. Shobha Mehta for taking the time to be a part of this committee as it surely was not easy to call in from out of state. Her experience and resources were immensely helpful when developing the framework for this thesis. Lastly, I would like to thank my loved ones for their continuous support. To my mom and dad, I would not be where I am today without their unwavering encouragement. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO ABBREVIATIONS

aOR	Adjusted Odds Ratio
ARCH	Archive for Research on Child Health
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
GWG	Gestational Weight Gain
IOM	Institute of Medicine
OR	Odds Ratio
PDWC	Post Delivery Weight Change
PPWD	Postpartum Weight Difference
RR	Relative Risk
SES	Socioeconomic Status
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

According to the World Health Organization (WHO) "Childhood obesity is one of the most serious public health challenges of the 21st century" (1). Obesity is a multifaceted issue that is caused by several factors including genetics, environment, and behavior. Obese is a term to describe a person who has excess body fat and is most often estimated by body mass index (BMI). For children, a BMI in the 95th percentile or higher using age and sex specific categories is considered obese (2). Approximately 17% of adolescents are considered obese in the United States based on data from 2011-2014 (3). Obese children are more likely to have health problems throughout childhood such as asthma, diabetes, and liver disease (4). These children are also likely to remain obese into adulthood and have more severe health consequences compared to adults who were not obese during childhood. These health consequences include coronary heart disease, stroke, cancer, and a lower quality of life (5). It has become clear that an early start to obesity prevention, perhaps as early as in utero is a crucial step in decreasing overall obesity rates.

Pregnancy is a critical time period for child development. Several studies have shown that high pre pregnancy body mass index (BMI) and excessive gestational weight gain (GWG) are associated with high birth weight and later childhood obesity, which has been attributed to fetal programming during pregnancy (6). Mothers who are overweight often have increased levels of insulin, growth hormones, and leptin and are more likely to have higher insulin resistance compared to women of a normal BMI (7). Because the fetus receives all its nutrients through the placenta, it is extremely susceptible to any changes in the mother's hormones. Insulin is involved in the development of the central nervous system and is suggested to influence the development of the infant's metabolism (7). If a child is at higher risk of becoming obese because the mother is overweight, this transgenerational cycle may explain some of the increase in obesity rates over the past few decades.

Although many studies have examined the relationship between pre pregnancy BMI and childhood BMI, post pregnancy factors have rarely been taken into account in those same studies. When assessing factors related to child BMI, it is important to consider post pregnancy factors to account for the child's environment. Information is lacking about whether home and social environment may contribute to the risk of childhood obesity as much as or more than metabolic programming in utero. Literature on breastfeeding has been inconclusive but some studies have found breastfeeding for more than 4 months to have a significant protective effect against childhood obesity (8). Consideration of maternal post pregnancy body composition can also provide insight into post birth behavior. A healthy post pregnancy body composition could be indicative of a healthier lifestyle, which may indicate a healthier childhood environment. By taking into account pre and post pregnancy factors, a more complete picture of the relationships between maternal size and body composition at these time points and child BMI may be elucidated.

CHAPTER 2: BACKGROUND

2.1 Childhood Obesity

Obesity is most often defined by a categorization of body mass index (BMI--weight in kilograms divided by height in meters squared). Because normal body composition of children differs by age and sex, BMI is ranked in relation to a reference population to take into account these variables. In 2000 the CDC revised the standard growth charts based on pooled data from five cross sectional nationally representative health examination surveys: NHES II (1963-1965), NHES III (1966-70), NHANES I (1971-74), NHANES II (1976-80), NHANES III (1988-94). To calculate the percentile charts for child BMI the national data was smoothed with a variety of parametric and nonparametric procedures (9). The cut-off points for the BMI percentiles were defined in 1997 and were reviewed again in 2006 by an expert committee that represented 15 different health care organizations (10). The cut-off points capture different risk levels and roughly correspond to the BMI categorization for adults. Overweight is defined as being at or above the 85th percentile and below the 95th percentile (2). Obesity is defined as at or above the 95th percentile for children of the same age and sex (2). Extreme obesity is defined as a BMI at or above 120% of the age and sex-specific 95th percentile on the CDC BMI-for-age growth charts (3). In the United States in 2011-2014, 17% of youth aged 2 to 19 were classified as obese and 5.8% of youth were classified within the extreme obesity category (3).

Results from the National Health and Nutrition Examination Survey (NHANES) from 1988-1994 and 2013-2014 indicate higher odds of obesity for children between the ages of 6 to 11 compared to the ages of 2 to 5 (OR 2.29) (3). The odds were also higher for non-Hispanic Black children and Hispanic children compared to White children (OR 1.34 and 1.48

respectively) (3). Although the prevalence of childhood obesity has remained relatively stable since 2007, the prevalence of extreme obesity is significantly increasing (3).

Childhood obesity has been associated with an increased risk of sleep apnea, hypertension, abnormal glucose intolerance, and type 2 diabetes (4). Subsequently, children who are obese are also at an increased risk for depression and impaired social and emotional functioning (11). Obese children are more likely to be obese in adulthood and have more severe health consequences compared to obese adults who were not obese as children (12). One study looked at children's obesity status from 1 year of age to 17 years and compared that to the subject's obesity status as an adult. The odds of being obese as an adult if the subject was obese as a child were significant starting at age 3 and greatly increased as the child aged (13). At age three the odds of being obese as an adult was 1.3, at the age of 9 the odds increased to 10.3, and at the age of 17 the odds of being obese as an adult increased to 20.3. Because there is such a strong association between childhood obesity and adult obesity, examining risk factors associated with childhood obesity is critical.

2.2 Maternal and Childhood Body Composition

2.2.1 Pre Pregnancy BMI

For adults, obesity is defined as BMI at or greater than 30 kg/m^2. Approximately 32% of women between the ages of 20 and 39 are classified as obese and 6% are classified as morbidly obese in the United States (5). Accordingly, in recent years, more women are entering pregnancy either overweight or obese. The incidence of women being overweight or obese at the start of pregnancy increased from 25% to 35% and the incidence of obesity at delivery increased from 29% and 39% between the years 1991 and 2001 (6). Therefore, it is important to understand if a mother's pre pregnancy BMI can negatively impact her child.

Research in animal models has suggested that there is a relationship between a mother's pre pregnancy weight and her offspring's body composition. A study by Shankar et al studied the impact of feeding pre pregnancy rats excess calories for three weeks before mating. All of the dams were placed on the same diet for the length of pregnancy. The pups were distributed to normal weight and obese mothers to ensure the nutritional intervention was solely from pre pregnancy. Results from this study showed that offspring from obese dams had a higher body fat percentage compared to the offspring from the lean dams (14).

The relationship between maternal body composition and her offspring's body composition has been studied in humans through prospective studies. In humans it has been found, obesity increases risk for adverse pregnancy outcomes. Prospective studies with human participants have shown that women who enter pregnancy at a higher BMI are more likely to have comorbid conditions, such as diabetes, which can lead to adverse pregnancy outcomes and fetal malformations (7). In addition, maternal obesity is associated with an increased risk of preeclampsia, gestational diabetes, hypertension, and a need for operative delivery (7).

Not only does a high pre pregnancy BMI put the mother at higher risk during pregnancy, but studies have shown that it also negatively impacts the offspring. Maternal obesity is related to an increased risk of macrosomia, fetal distress, jaundice, stillbirth, and congenital malformations (15). Furthermore, some research has shown that a high pre pregnancy BMI can also have a long lasting negative impact on the child. A study by Fuemmeler et al examined the association between pre pregnancy obesity and childhood weight growth trajectories in 704 mother-infant dyads. Measurements of the child were taken throughout the first 24 months of life and the median number of measurements per child was 14. The results showed that children born to women with a pre pregnancy BMI over 40 compared to women with a BMI between 18 and

24.9 were 8% larger during the first 24 months and had a delayed time for maximum growth; all of which are risk factors for obesity and chronic disease later in life (16). Another study by Li et al analyzed the relationship between pre pregnancy BMI and the BMI of children between 2 and 14 years of age (8). After adjusting for several confounders, it was found that compared to children of mothers with a pre pregnancy BMI less than 25, children of mothers with a pre pregnancy BMI between 25 and 29.9 were 2.48 times more likely to have a BMI in the 95th percentile or higher (95% CI: 1.7, 3.4) (8). Children of mothers who had a pre pregnancy BMI over 30 were 3.68 times more likely to have a BMI in the 95th percentile or higher (95% CI: 2.4, 5.5) (8). In a longitudinal study by Li et al, pre pregnancy BMI was found to be significantly associated with offspring BMI Z-score from birth to 5 years of age (β=0.025 ± 0.005) (17).

Although the previous studies all focused on child BMI, several studies have also examined the relationship between pre pregnancy BMI and other anthropometric measures for the child. In a study conducted by Kaar et al, 313 mother child pairs were recruited to examine maternal pre pregnancy BMI and offspring outcomes. The average age of follow up for the child was 10.4 years. In this sample, children of overweight/obese mothers were significantly higher in all anthropometric measurements that were assessed (18). In this study, they measured BMI (95% CI: 1.57, 3.51), waist circumference (95% CI: 3.82, 8.98), visceral adipose tissue (95% CI: 36.14, 81.52), and subcutaneous adipose tissue (95% CI: 3.59, 9.53) (18). In another study by Adriette et al, the main outcome of interest was waist to height ratio for the child at 2 to 6 years of age (19). Their findings showed that maternal pre pregnancy BMI was positively associated with the offspring's waist to height ratio (β=0.025; 95% CI: 0.010, 0.039) (19).

Despite these studies finding statistically significant results, they all had several limitations. One of the major limitations was the lack of data on environmental factors after pregnancy such as breastfeeding (16-18). Additionally, some studies collected the weight measurements through self-report (7, 16-18). Other studies sampled specific populations, such as women at high risk for gestational diabetes, so results were not widely generalizable (18).

2.2.2 Gestational Weight Gain

In addition to examining the relationship between pre pregnancy BMI and child BMI, several studies have examined the relationship between gestational weight gain (GWG) and child BMI. GWG is closely associated with pre pregnancy BMI. It is important to examine both pre pregnancy BMI and GWG because the intrauterine exposure to excessive gestational weight gain may contribute to metabolic programming for the child (20). Because of the growing obesity epidemic and the concern of gaining too much weight during pregnancy, the Institute of Medicine (IOM) set guidelines based on pre pregnancy BMI. Recommendations for weight gain are between 12.5 and 18 kg, 11.5 to 16 kg, 7 to 11.5 kg, and 5 and 9 kg, for women who are classified as underweight, normal weight, overweight, or obese, respectively (21). Additionally, the IOM has recommendations for the rate of GWG for the 2nd and 3rd trimester. Women who are underweight should gain approximately 0.51 kg per week, normal weight women should gain 0.42 kg per week, overweight women should gain 0.28 kg per week, and obese women should gain 0.22 kg per week (21). Women who exceed recommendations are at risk of complications at birth and higher post pregnancy weight retention.

The study previously mentioned by Fuemmeler et al also examined GWG and found that compared to children whose mothers gained adequate weight during pregnancy, children born to mothers who exceeded the recommendation were 5% heavier at follow-up compared to mothers who met the recommendation (95% CI: 0.3%, 8.6%) (16). In a study by Sridhar et al, women who were members of the Kaiser Permanente Northern California group practice and completed a follow-up survey between the years 2007 and 2010 were included in the analysis. Of the 4,145 mothers included, 66.2% of women exceeded the IOM GWG recommendation. Children of mothers who exceeded the recommendation were larger at birth (3475 g vs 3344 g), more likely to be macrosomic (15.0% vs 8.3%), and more likely to be overweight or obese at 2 to 5 years of age (20.4% vs 14.5%) (20). After adjusting for maternal age, education, prepregnancy BMI and race the results were attenuated but children of women who exceeded IOM recommendations were still 1.51 times more likely to be overweight or obese at 2 to 5 years of age (95% CI: 1.23-1.87) (20).

As with examining pre pregnancy BMI, several studies also looked at different measures of child anthropometrics and GWG. The previously mentioned study by Kaar et al also looked at GWG. Similar to the results found for high pre pregnancy BMI, excessive GWG also was significantly associated with child BMI (β=0.34; 95% CI: 0.25, 0.44), waist circumference (β=0.83; 95% CI 0.58, 1.08), visceral adipose tissue (β = 0.72; 95% CI: 0.39, 1.06), and subcutaneous adipose tissue (β=7.26; 95% CI: 4.90, 9.62) (18). Another study by Oken et al examined 1044 mother child pairs 3 years after delivery. A child whose mother gained excess weight during pregnancy had had an increased odds of being obese compared to a child whose mother met the IOM recommendations (OR: 1.30; 95% CI: 1.0, 1.62) (22). This remained significant after adjusting for both sociodemographic and biological variables. This study also measured skinfold thickness in the child and found mothers with a greater GWG had children with more adiposity at age 3, however this finding was not statistically significant (β=0.18; 95% CI: -0.06, 0.42) (22).

Not all studies found a statistically significant relationship between GWG and child BMI. In a study by Olson et al, data was extracted from the Basset Mothers Health Project which was an observational cohort study of 622 health women that were followed from early pregnancy until two years postpartum. Medical records of the offspring of these women were located and audited for anthropometric information and 321 offspring had measured heights and weights between the ages of 3.5 to 4.5. At age 4, there was no relationship found between GWG and child BMI (RR=1.28; 95% CI 0.83, 1.96) (23). Von Kries et al also examined GWG and its association with obesity in the offspring in using data from the German Health Interview and Examination Survey for Children and Adolescents. This study looked at children 3 to 17 and did not find a statistically significant association (RR=1.10; 95% CI: 0.99,1.22) (24). Additionally, in a prospective study by Diesel et al. they used GWG z-scores and looked at the relative risk for childhood obesity when the z-score was 1.5. After adjustment, children at the age of ten whose mother's GWG z-score was 1.5 had a relative risk of 1.50 compared to children whose mother's GWG z-scores were 0 (0.94, 2.40) (25).

Research examining GWG and child obesity has been inconclusive. Studies on GWG have limitations similar to the pre pregnancy BMI literature, the studies on GWG also have limitations. This includes limited data on post pregnancy environmental factors such as breastfeeding (15, 17, 20, 22). Also the calculation of GWG can lead to errors due to not having a true pre pregnancy weight or a true weight at delivery (15,17, 20, 22). Also some studies had a specific population such as an unhealthy population (17) or a population of high socioeconomic status (SES) (22).

2.2.3 Post Pregnancy Maternal Body Composition

The studies previously mentioned did not examine the maternal body composition post pregnancy. Post pregnancy maternal body composition is also an important component when looking at how maternal body composition can influence childhood obesity. Post pregnancy maternal body composition could help explain some of the environmental exposures that influence the child's body composition. Mothers who are at a healthy weight after pregnancy or return close to their pre pregnancy weight may partake in certain healthy lifestyle behaviors and these behaviors could translate to how the child behaves as well. However, very few studies have assessed the relationship with post pregnancy maternal body composition and childhood obesity.

In the study by Whitaker et al, parental obesity status was calculated using a mathematical model that incorporated the parents BMI status at two separate time points. Offspring obesity was measured at 5 different time points: 1-2 years, 3-5 years, 6-9 years, 10-14 years, and 15-17 years. Compared to children of mothers who were not obese, children of obese mothers were more likely to also be obese at all five time points (OR 3.6; 95 % CI: 2.1-5.9, OR 3.6; 95% CI: 2.2-5.7, OR 3.3; 95% CI: 2.2-5.1, OR 3.1; 95% CI: 2.0-4.6, OR 2.8; 95% CI: 1.9-4.1) (13). In a secondary analysis by Robinson et al, weight was measured in children at 4 to 5 years of age and post delivery maternal weight change (PDWC) was defined as the difference in maternal weight 3 to 36 months after delivery and weight at delivery. This study found that a 5 kg increase in PDWC was associated with a 12% increase in the odds of the child being overweight (26). Further examination of this data showed that the relationship between PDWC and child weight was stronger when the PDWC was measured within the first year of delivery.

These two studies also have several limitations. Neither collected data on breastfeeding (13, 26). Also the time frame of when data was collected was variable across the studies (13, 26) Lastly, the way post pregnancy body composition was measured was not ideal. In the study by Whitaker et al the maternal body composition was not directly measured, but predicted (13). To predict maternal BMI the authors abstracted several weight and height measurements from the medical record and linear interpolation was used to estimate what the BMI of the mother would be in each time period. The article does not state when the abstracted measurements were from relative to the delivery of the child so it is impossible to know if pregnancy weight was considered. In the study by Robinson et al to examine the post pregnancy environment they used the difference between weight at delivery and post-partum weight which could be misclassified as retained GWG (26). Furthermore, other methods of measuring post pregnancy body composition, such as body fat percentage and waist circumference, to my knowledge, is completely missing from the literature when examining the relationship between post pregnancy body composition and childhood obesity.

2.2.4 Breastfeeding and Childhood Obesity

The majority of the previously mentioned studies did not collect data on breastfeeding. Per the American Academy of Pediatrics, infants should be breastfed for the first 6 months exclusively and be supplemented for at least a year (27). Many studies have identified breastfeeding as a protective factor for childhood obesity, and others have found breastfeeding is not a protective factor. A meta-analysis by Yan et al examined 25 studies that looked at childhood obesity and feeding patterns. Pooling all 25 studies, children who had ever been breastfed where 23% less likely to be overweight compared to children who had never been breastfed (aOR= 0.78; 95% CI: 0.74,0.81) (28). Additionally, 17 of the studies measured the length of time the infant was breastfed and a dose response was found. Infants who breastfed for less than 3 months compared to never breast fed were 10% less likely to be obese. Infants who breastfed 7 or more months were 21% less likely to be obese (28). This meta-analysis does have several limitations. First, it is unclear what the follow up time for calculating childhood obesity was for each study. Second, the results only report the adjusted findings. Some of the studies may have over adjusted. Lastly, the meta-analysis did not distinguish between infants who were exclusively breastfed and those who were partially breastfed.

2.3 Conceptual Framework

As obesity in children and adults becomes increasingly more severe, it is important to study various risk factors associated with both. Because previous research has shown children who are obese are more likely to be obese as adults and have more severe consequences, examining childhood obesity is critical if we want to reduce the prevalence of obesity for all ages (12).

Although there have been numerous experiments using animal models and several prospective cohort studies examining the effect of pre pregnancy maternal weight composition on childhood obesity, less research has been done on the association between post pregnancy body composition and child BMI. Where the pregnancy related weight could give insight into the biological context of a child's BMI, post pregnancy body composition could help explain the environmental context. When researching the potential driving force for the obesity epidemic it is important to examine all time points. Post pregnancy body composition can give insight on environmental factors such as diet and activity level. By examining pre pregnancy BMI, GWG, and post pregnancy body composition, a fuller picture of how the maternal body composition affects the child can be accomplished.

2.4 Specific Aims

This study assessed components of maternal obesity and its association with childhood obesity. The aims for this study were as follows:

2.4.1 Aim 1:

To describe the relationship between components of maternal body composition and the outcome of childhood obesity in offspring at ages 3 to 6 years with the separate components of maternal composition being defined as:

1. Pre Pregnancy BMI
2. GWG
3. Follow-Up Maternal BMI
4. Postpartum Weight Difference (PPWD)
5. Post Delivery Weight Change (PDWC)
6. Waist Circumference (WC)

2.4.2 Aim 2:

To assess mediation by maternal body composition measurements (PPWD, PDWC, WC) at 3 to 6 year post pregnancy follow-up in the relationship between pre pregnancy BMI and childhood BMI percentile.

CHAPTER 3: METHODS

3.1 Study Population

The study population consisted of a subset of women who participated in the Archive for Research on Child Health (ARCH). Results are from an ongoing prospective pregnancy cohort initiated in 3 mid-Michigan prenatal care clinics that began recruitment in 2008. The goal of ARCH is to archive urine and blood samples from pregnancy and placenta samples for the purpose of etiological research on adverse maternal and child health outcomes. Both mothers and offspring are followed throughout childhood and are asked to complete annual questionnaires. These data are intended to be used for future research questions regarding pregnancy and childhood development. Women were recruited from participating clinics, which included a university faculty obstetric clinic, hospital residency clinic, and a county health clinic. Women were approached prior to 14 weeks' gestation, and were eligible if they were 18 or older and could complete the survey in English. The Institutional Review Board for Michigan State University approved the protocols and procedures of the ARCH study.

A sub study of ARCH, ARCH Child Development, was initiated in 2014 and collected anthropometric data on the child and woman three to seven years post pregnancy. Of the 132 women and child pairs enrolled in ARCH Child Development, 130 pairs had available data on height and weight. For this analysis only singleton pregnancies were included and women who were not pregnant at the time of the follow up measurement, which resulted in an analytic sample of 114 mother-child pairs.

3.2 Pre Pregnancy BMI

At time of enrollment, women were asked to report their pre pregnancy weight and height. Additionally, height and weight of the woman was extracted from the birth certificate.

Both sources of height and weight were examined for this analysis and are termed ‘intake pre pregnancy BMI’ and ‘birth certificate pre pregnancy BMI’. A correlation test was done to determine if the intake pre pregnancy BMI differed from the birth certificate BMI. Pre pregnancy BMI from the intake questionnaire was used when analyzing pre pregnancy BMI due to the sample being larger compared to the birth certificate BMI sample. BMI was calculated by taking weight in kilograms and dividing it by the height in meters squared.

3.3 Child BMI

Children ranged from 36 months to 83 months at the time of anthropometric data collection. Height and weight were both measured twice and the average of these two measurements was used to calculate BMI. CDC’s ‘Children’s BMI tool for schools’ was used to convert each child’s BMI into the appropriate percentile based on the child’s age and gender (29). Children who were below the 85th percentile were classified as normal weight, children between the 85th and 94.99th percentile were classified as overweight, and children in the 95th percentile or higher were classified as obese.

3.4 Gestational Weight Gain

Gestational weight gain (GWG) was reported in kilograms and calculated by subtracting the women’s pre pregnancy weight from the reported weight at delivery. The source for both weights came from the birth certificate. GWG examined as both a continuous variable and a categorical variable. GWG was categorized as inadequate, adequate, or excessive based on the IOM guidelines which considers the woman’s pre pregnancy BMI (21). *Table 1* shows the categorization for gestational weight gain.

3.5 Follow-up Body Composition

Follow-up anthropometric measurements were taken at 3 to 6 years postpartum. Weight and height were measured without shoes on, and both measurements were taken twice then averaged to calculate BMI for the mother. Postpartum weight difference (PPWD) was calculated by taking the difference between the measured maternal weight at follow up and the self-reported pre pregnancy weight. Post delivery weight change (PDWC) was calculated by taking the difference between the measured maternal weight at follow up and the delivery weight recorded on the Birth Certificate. *Figure 2* represents the various maternal body composition measurements. Waist circumference was measured twice in centimeters and the average was taken.

3.6 Other Variables

The following variables were extracted from the birth certificate: child's race, child's sex, maternal smoking history, maternal age, parity, mode of delivery, gestational age, and birth weight. Child's race was categorized as either Black Non-Hispanic, or Other. Maternal smoking history was coded as a 'yes' if the mother reported ever smoking before pregnancy. Mode of delivery was categorized as either Vaginal or Cesarean.

Two variables to account for socio-economic status, maternal education and household income, were extracted from the intake questionnaire. For analysis, maternal education was categorized into either "High school diploma or less" and "Some college or more." For analysis, income was categorized into either "Less than $50,000" and "$50,000 or more."

Covariates that were extracted from the post-pregnancy follow-up included parity and breastfeeding. Both variables were extracted from the one month follow up, and the yearly follow-up questionnaires. Mothers were asked if they were breastfeeding, and how long they breastfed for. Breastfeeding was then categorized as either: Breastfed for less than 1 month, breastfed for more than 1 month but less than 6 months, breastfed for more than 6 months but less than 12, and breastfed for 12 or more months. No information was collected on whether breastfeeding practices were exclusive or partial at any time point. Mothers were also asked if they had a change in health and reported if they were currently pregnant or had recently delivered a new baby.

3.7 Analytic Plan

The Pearson's correlation coefficient was calculated to examine the correlation between the intake pre pregnancy BMI and the birth certificate BMI to determine which source for pre pregnancy to use. The Pearson's correlation coefficient was also calculated to examine the correlation between all exposure variables and childhood BMI percentile. Descriptive Statistics (means, standard deviations, and proportions) were calculated for all variables for interest.

Three types of models were created using linear regression. The first model was to examine the fetal environment effect on Child BMI where pre pregnancy BMI was the main exposure of interest. The second model was to examine the infant environment where the main exposure of interest was examining the various follow-up maternal body composition measurements separately: Follow-up BMI, waist circumference, PPWD, and PDWC. This second set of models does not allow for causal interpretation but lays groundwork for the third model. The third model was to examine the fetal and infant environment together using the various follow-up maternal body composition measurements as a mediator.

To look at the follow-up maternal body composition measurements as a mediator, a simple mediation model was utilized (30). The following three equations were used:

1. $Y = i_1 + cX + e_1$
2. $Y = i_2 + c'X + bM + e_2$
3. $M = i_3 + aX + e_3$

Where i_1, i_2, i_3 are intercepts, Y is childhood BMI percentile, X is pre pregnancy BMI, and M is the follow-up maternal body composition measurement.

There are several important assumptions that must be met to test for mediation. First, the residuals from equation 2 and 3 are independent and M and the residual in equation 2 are independent. Second, there is no interaction between X and M in equation 3. Third, the specified model includes no misspecification of the causal order (ie., Y→ M→ X instead of X→ M→ Y). Fourth, there is no reciprocal causation between the mediator and the dependent variable. Lastly, there is no misspecification due to imperfect measurement (30).

The direct effect was estimated by the effect pre pregnancy BMI had on child BMI percentile while holding the follow-up maternal body composition measurements constant. The indirect effect was the effect pre pregnancy BMI had on the follow-up maternal body composition measurements that then affected child BMI percentile. Also reported in the mediation analysis is the total effect which was derived from estimating the effect pre pregnancy BMI had on the follow-up maternal body composition measurements without taking into account the follow-up body composition measurement as a mediator (i.e. results from the first model mentioned above). *Table 2* shows a basic derivation of the indirect, direct, and total effect for unadjusted models.

Beta coefficients, a coefficient of determination, and 95% confidence intervals were calculated for all models. The 95% confidence intervals for the indirect effect were calculated by the bootstrapping method where 10,000 samples were taken. Covariates were included in the model if: 1) forward and backward selection found the variable as significant, 2) if there was a biological rationale for including the covariate as a confounder based on previous literature. An alpha level of 0.05 was used to determine statistical significance. All statistical procedures were performed in SAS 9.4 and the mediation analysis was performed by the SAS macro PROCESS (30).

CHAPTER 4: RESULTS

Pre pregnancy BMI was measured in two different ways for this study. Women were asked to report their weight and height at the intake questionnaire. Pre pregnancy weight was also recorded on the birth certificate. A correlation test was performed to examine how these two variables compare. The results from this test showed the two variables were highly correlated (r= 0.85). Pre pregnancy BMI for the following analyses was extracted from the intake questionnaire because there were fewer missing observations for the intake questionnaire compared to the birth certificate (N=131 vs N=124). After excluding women who gave birth to twins and women who were currently pregnant at the time of follow up there was a total of 114 mother-child pairs included in the analysis. *Table 3* compares the demographics and weight component variables from the entire ARCH childhood development sample to the analytic sample.

4.1 Demographic Variable Description

For the analytic sample at the time of delivery, maternal age ranged from 18 to 39 with the mean age of 26.7 years. Fifty four percent of the mothers had given birth before the index pregnancy. Approximately 61% of the mothers had more than a high school education, and 60% reported a household income of less than $23,000 a year. From the birth certificate, 15% of mothers had reported a history of smoking. In this population, 53% of children were White, Non-Hispanic, 12% were Black, Non-Hispanic, 18% were Hispanic, and 17% were classified as other race/ethnicity. The mean gestational age was 39.2 weeks, the mean birth weight was 3,400.9 g, and 73% of the children were delivered vaginally. In the follow-up questionnaires, 44% of mothers reported breastfeeding for less than 1 month, 31% reported breastfeeding between 1 and 6 months, 7% reported breastfeeding between 7 and 12 months, and 18% reported breastfeeding for more than 1 year. The mean age at follow up was 58.2 months with a range of 36 months to 82 months.

4.2 Maternal Weight Description

The mean pre pregnancy BMI was 27.9; 23% of women were classified as overweight and 33% were classified as obese. *Table 4* shows the characteristics among women of a normal BMI and women who were classified as overweight or obese. Women who were classified as overweight (N=64) were more likely to have delivered a girl (RR 1.5, 95% CI:1.0-2.2). The mean gestational weight gain was 15.0 kg with 58% of women exceeding the IOM recommendation of gestational weight gain (N=66). Women who were classified as overweight or obese were more likely to gain excessive weight during pregnancy (RR 2.1, 95% CI: 1.5,2.8). The mean BMI for follow-up for the mother was 30.3, which was significantly higher than the pre pregnancy BMI (mean difference= -2.28, 95% CI -3.10, -1.47). When looking at the weight difference between delivery and at the follow up visit, the mean difference was -4.8 kg. The most weight lost was 69 kg, and the most weight gained was 61 kg. When looking at the difference between pre pregnancy weight and the follow up weight, the mean difference was 5.9 kg with one woman weighing 31.8 kg more than her pre pregnancy weight and one woman weighing 51.7 kg less than her pre pregnancy weight.

4.3 Childhood BMI Description

The mean percentile, compared to the national percentiles, for this study population was the 55th percentile. Twenty four percent of children were classified as being overweight or obese (N=27). *Table 5* shows the sociodemographic and perinatal characteristics of children who were classified as normal compared to those classified as overweight or obese. None of the characteristics examined were significantly different between children classified as a normal weight compared to children classified as overweight or obese.

4.4 Pre Pregnancy BMI Model

The relationship between pre pregnancy BMI and child BMI percentile was statistically significant before adjusting for confounding (β=0.86; 95% CI: 0.1, 1.6). For the pre pregnancy BMI model there were 10 additional covariates that could be examined. By using both forward and backwards selection procedures only 2 covariates were significant at α= 0.2. Both race/ethnicity and smoking history remained significant when using α =0.05. Once race and smoking history were controlled, pre pregnancy BMI remained significant (β=0.84; 95% CI: 0.1, 1.6). Because GWG has been found to be an important confounder in previous research, a third model controlled for GWG, race, and smoking history. After adjusting for GWG, race, and smoking history, 37% of the variation in childhood BMI percentile was explained. The coefficient for pre pregnancy BMI increased and remained significant after controlling for the significant covariates (β=0.99; 95% CI: 0.3, 1.7). *Table 6* shows a summary of the results for this model. A model to examine gestational weight gain was also constructed. GWG in the unadjusted model was statistically insignificant and remained insignificant after controlling for race and smoking status. *Table 7* shows the results for the GWG model.

4.5 Follow-up Maternal Body Composition Models

Follow-up maternal BMI was not significantly associated with child BMI percentile (β=0.63; 95% CI: -0.04, 1.3). However, after adjusting for race, follow-up BMI became statistically significantly associated with childhood BMI percentile (β=0.69; 95% CI: 0.03, 1.3). After adjusting for race, 26% of the variation in childhood BMI was explained. *Table 8* shows the results of this relationship.

The relationship between waist circumference and child BMI percentile was significant in the unadjusted model (β=0.26; 95% CI: 0.01, 0.5). After performing selection procedures, none of the nine possible covariates were significant at α =0.2. To compare to other models race/ethnicity was controlled for in model 2 where waist circumference no longer remained significant; T*able 9* shows the results of both models.

When examining the relationship between PPWD, no statistically significant relationship was found in the unadjusted model (β=0.19: 95% CI: -0.3, 0.7). Through selection procedures race/ethnicity was the only covariate that was found to be significant. After adjusting for race/ethnicity, PPWD remained insignificant (β=0.20: 95% CI: -0.3,0.7). This adjusted model, shown in *Table 10,* explains 17% of the variation in childhood BMI percentile.

The relationship between PDWC and childhood BMI percentile was also found to be statistically insignificant in the unadjusted model (β=0.17; 95% CI: -0.2, 0.5). Using both backward and forward selection procedure, race/ethnicity was the only covariate that was significant. After adjustment PDWC remained statistically insignificant (β=0.17; 95% CI: -0.2,0.5). After adjusting for race/ethnicity the model explained 20% of the variation in childhood BMI percentile; *Table 11* shows these results.

4.6 Mediation Analysis

After examining the relationship between each maternal body composition variable and childhood BMI percentile, mediation models were explored. Covariates for the adjusted mediation model were chosen by forward and backwards selection procedure by looking at the following three models where follow-up maternal body composition is defined as one of the following: follow-up maternal BMI, waist circumference, PPWD, or PDWC. The following models are written in the format of dependent variable= independent variable.

1. Follow-up maternal body composition= Pre pregnancy BMI
2. Childhood BMI percentile= Pre pregnancy BMI + Significant covariates from equation 1
3. Childhood BMI percentile= Pre pregnancy BMI + follow-up maternal body composition + Significant covariates from equation 1+ Significant covariates from equation 2

From this process GWG, race, and smoking history were found to be significant at alpha=0.20 and remained significant at alpha=0.05. *Figure 3* provides a visual representation of the mediation model.

All four of the follow-up maternal body composition measurements were examined. From the previously mentioned analysis of pre pregnancy BMI and childhood BMI shown in *Table* 6, the total effect of pre pregnancy BMI on childhood BMI was significant in the unadjusted model and remained significant after adjusting for GWG, race/ethnicity, and smoking history (β=0.98; 95% CI 0.28, 1.69).

Looking at the direct effect of pre pregnancy BMI when controlling for follow-up maternal BMI, pre pregnancy BMI was no longer statistically significant (β=0.98; 95% CI:-0.43, 2.40). Looking at the indirect effect, follow-up maternal BMI was statistically insignificant, indicating that there is no evidence of this variable being a mediator (β=0.10; 95% CI: -1.13, 1.29). *Table 12-14* summarizes the findings for the mediation model with follow-up maternal BMI. Similar results were found for maternal waist circumference. After controlling for waist circumference, pre pregnancy BMI no longer remained significant (β=0.73; 95% CI: -0.42, 1.88). The indirect effect for waist circumference was also insignificant, indicating no evidence of mediation (β=0.24; 95% CI: -0.68, 0.91). *Table 15-17* shows the summary of the analysis using waist circumference as a mediator.

After controlling for postpartum weight difference, pre pregnancy BMI remained statistically significant and also remained statistically significant after further controlling for the other covariates (β=1.00; 95% CI: 0.29, 1.72). The indirect effect of PPWD was statistically insignificant indicating no evidence of mediation (β=-0.01; 95% CI: -0.21, 0.06). *Table 18-20* shows the results for the analyses of PPWD as a mediator. Post delivery weight difference had similar results to PPWD. After controlling for PDWC, pre pregnancy BMI remained statistically significant (β=0.99; 95% CI: 0.25, 1.73). The indirect effect of PDWC was statistically insignificant suggesting that this variable does not act as a mediator between pre pregnancy BMI and childhood BMI percentile (β=0.005; 95% CI: -0.24, 0.31). *Table 21-23* shows the results from the analysis of PDWC as a mediator.

CHAPTER 5: DISCUSSION

5.1 Interpretations

In this study of 114 mother and child pairs, the relationship between maternal body composition and childhood BMI was examined. By examining maternal body composition before pregnancy, at delivery, and 3 to 6 years after delivery, a fuller picture can be created to help explain how maternal body composition relates to childhood BMI. Looking at all three time points gives us the opportunity to begin to account for both biological and environmental factors that could impact the child.

In the analysis, prepregnancy BMI was significantly associated with childhood BMI percentile and this relationship remained after controlling for GWG, race/ethnicity, and smoking history. This finding supports previous research. Follow-up maternal BMI was also significantly associated with childhood BMI percentile after controlling for race, and maternal waist circumference was statistically significantly associated in the unadjusted model. Both variables had a weaker relationship with childhood BMI percentile, however, as compared to pre pregnancy BMI. After adjustment, one unit increase in pre pregnancy BMI was associated with an increase in childhood BMI percentile of 0.99. A one unit increase in follow-up maternal BMI was associated with an increase in childhood BMI percentile of 0.69 and waist circumference was associated with an increase in childhood BMI percentile of 0.24. Postpartum weight difference and post delivery weight change both had little effect on childhood BMI percentile, even after controlling for race/ethnicity.

The next step for this study was to examine if follow-up maternal body composition measurements served as a mediator between prepregnancy BMI and childhood BMI as there is no literature to our knowledge examining this relationship. In the first analysis using follow-up maternal BMI as a mediator, pre pregnancy BMI no longer is statistically significant after adjusting for follow-up maternal BMI. This suggests that there is no evidence that pre pregnancy BMI influenced child BMI percentile independent of follow-up maternal BMI. However, because pre pregnancy BMI and follow-up maternal BMI are highly correlated this result should be interpreted with caution (r=0.86). Due to the highly-correlated nature of these two variables the chance of a type II error is increased. The indirect effect for this model is also statistically insignificant; thus, there is no evidence in these data that follow-up maternal BMI acts as a mediator between prepregnancy BMI and childhood BMI. Similar results were found when analyzing maternal waist circumference as a mediator. After controlling for waist circumference, pre pregnancy BMI no longer remained significantly associated with childhood BMI percentile however waist circumference and pre pregnancy BMI were also highly correlated and thus skewing the results (r=0.77). The indirect effect for this model was also insignificant indicating there is no evidence maternal waist circumference serves as a mediator.

The analysis of postpartum weight difference resulted in prepregnancy BMI remaining statistically significant after adjusting for PPWD indicating that prepregnancy BMI is associated with childhood BMI percentile independent of PPWD. The same results were found when looking at post delivery weight change.

These results indicate that pre pregnancy BMI is the strongest predictor of childhood BMI despite examining maternal body composition at multiple time points throughout her life and using different techniques (i.e. mediation) to attempt to examine causality. It is likely that a woman’s lifestyle and home environmental factors, such as socioeconomic status, are similar before, during, and after pregnancy. The factors that lead to a woman’s body composition before pregnancy most likely remain after pregnancy and helps explain why after pre pregnancy BMI, follow-up maternal BMI and waist circumference impact child BMI the greatest. Working under the assumption that a woman's lifestyle habits that contributed to her pre pregnancy BMI are similar to her post pregnancy lifestyle habits, post pregnancy BMI and waist circumference do not necessarily provide a better insight into the home environment post pregnancy compared to her pre pregnancy BMI.

Examining change in maternal weight provides a slightly different picture because it allows us to see if the environmental factors that led to the mother's BMI allows her to lose the weight gained from pregnancy. When investigating post delivery weight change there was a significant difference between women who had a pre pregnancy BMI less than 25, a BMI between 25 and 29.9, and over 30. Women who were classified as obese before pregnancy lost less weight between the follow-up measurement and delivery. For women who did not have subsequent pregnancies, women classified as having a normal or overweight BMI before pregnancy lost, on average, 9.5 kg and 10.7 kg respectively between follow-up and delivery. Women classified as being obese before pregnancy on average lost 1.3 kg between follow-up and delivery. The in-home environment of the mother likely explains this finding. If unhealthy behavior contributed to a women's obesity status before pregnancy, the unhealthy behavior likely remains after pregnancy and therefore would make it difficult for the mother to lose the pregnancy weight. This potential unhealthy behavior at home could translate to a poor diet or physical inactivity in the child. However, in our results examining weight change affected the child BMI very little. Pre pregnancy BMI remains to be the best predictor of child BMI but it is difficult to differentiate how pre pregnancy BMI is affecting the child in-utero versus how the behaviors that led to the pre pregnancy BMI is affecting the child's BMI do to the home environment.

5.2 Strengths

There were several strengths of this study. Unlike previous literature, this study measured maternal body composition after pregnancy. To our knowledge, this is the first study that assessed the association between measured maternal body composition after pregnancy and childhood BMI. Additionally, many of the previously mentioned studies examining the relationship between pre pregnancy BMI and childhood BMI did not account for post pregnancy factors such as breastfeeding. This study did collect information on breastfeeding as well as the parity of the mother at the time of the follow up visit; however, both variables did not significantly influence the final models. As a second strength, we had access to several measurements to attempt to capture post pregnancy maternal weight composition.

5.3 Limitations

There are limitations in this study. First off, using maternal body composition as a variable to help explain the in-home environment after pregnancy is not ideal. Theoretically, a desirable maternal body composition after pregnancy could indicate healthy eating habits at home as well as other healthy behaviors; however, the home environment after pregnancy could be measured in a more accurate way such as examining the child's diet and physical activity. Also, the data collected on smoking history is limited. This is a known important covariate when examining pre pregnancy BMI and childhood BMI, however in our data we only know if the mother had a history of smoking. Only 40% of mothers with a history of smoking reported the date they had quit smoking. For the 60% of mothers who did not report a quit date, it is unknown if they had smoked through pregnancy and never quit smoking or if this is missing data. Also, there was no follow-up questions on smoking so it is not known if any of the mothers smoked after pregnancy. Next, the breastfeeding data did not differentiate between mothers who solely breastfed from mothers who supplemented with bottle feeding. More complete breastfeeding data could result in the breastfeeding variable significantly impacting the analysis. Furthermore, the variable waist circumference was only measured post pregnancy; a better variable to examine how central adiposity affects child BMI percentile would have been the difference between post pregnancy waist circumference and pre pregnancy waist circumference. Also as a limitation, most mothers in this population have a household income under $50,000 a year and are White, non-Hispanic. Lastly, this study had a small sample size. The results of this study may not be generalizable to the general population.

CHAPTER 6: CONCLUSION

In this study, we aimed to look at maternal body composition at various points throughout her life and how that can affect her child's BMI. By examining body composition before, at, and after delivery through different methods we can start to explore how a mother can impact a child's weight status. The results from this study showed that pre pregnancy BMI is the strongest predictor of childhood BMI. When using follow-up maternal body composition as a mediator, no mediation was observed. All three time periods for maternal body composition could potentially affect a child's risk but there is no evidence that follow-up maternal body composition can better explain the child's BMI compared to pre pregnancy BMI. Pre pregnancy BMI can affect the in-utero environment and cause the child to be at an increased risk for obesity at a biological level, but pre pregnancy BMI can also be reflective of a mother's lifestyle and habits. Unhealthy habits before pregnancy are likely to remain after pregnancy.

To tease out the complexity of the mechanism in which pre pregnancy BMI affects child BMI future studies need to be performed. It is difficult to understand if the effect of fetal programming caused by a high pre pregnancy BMI is the driving force for child obesity, or if it is the home environment that is contributing to the obesity status of the child, or some combination of both. If possible, it would be worth studying women who either lost a significant amount of weight or gained a significant amount of weight between pregnancies and how this impacted their offspring. By doing this type of experiment, a better understanding of how fetal programming may affect child BMI can be attained.

Despite not fully knowing the complexity of factors that lead to a specific pre pregnancy BMI, there remains a strong relationship between a high pre pregnancy BMI and childhood obesity. This study supports the hypothesis that overweight mothers provide an environment that is a risk factor for offspring obesity. Interventions should be developed to help women lose weight if they are planning to become pregnant and to help women stay healthy throughout pregnancy. Further studies should also look at other in-home environmental factors such as diet and physical activity at a young age and how these measurements influence the relationship between pre pregnancy BMI and childhood BMI.

APPENDICES

APPENDIX A:

Tables

Table 1: Recommendations for Total Weight Gain During Pregnancy by Pre Pregnancy BMI [a]

Pre Pregnancy BMI	**Weight Gain Range (kg)**	
Underweight (<18.5 kg/m^2)	12.5	18.0
Normal Weight (18.5-24.9 kg/m^2)	11.5	16.0
Overweight (25.0-29.9 kg/m^2)	7.0	11.5
Obese (≥30.0 kg/m^2)	5.0	9.0

[a] Recommendations are from the Institute of Medicine (IOM) (21)

Table 2: Explanation of Terminology Used for Mediation Analysis

Effects
Total Effect = (a*b)+c'
Direct Effect = c'
Indirect Effect = (a*b)

a is the path between the exposure and mediator

b is the path between the mediator and outcome

c' is the path between exposure and outcome when controlling for the mediator

Table 3: Comparison of Mother and Child Characteristics Between the ARCH Child Development Cohort and Analytic Sample

	ARCH Child Development N=132	**Analytic Sample N=114**	**P value**
	N (%)	**N (%)**	
Child Characteristics			
Child Race/ Ethnicity			
White	72 (55)	60 (53)	0.8047
Black	18 (14)	14 (12)	
Hispanic	22 (16)	21 (18)	
Other	20 (15)	19 (17)	
Child Gender			
Male	66 (50)	54 (47)	0.9314
Female	66 (50)	60 (53)	
Child Age at measurement			
3 Years	27 (20)	22 (19)	
4 Years	47 (36)	40 (35)	
5 Years	47 (36)	41 (36)	
6 years	11 (8)	11(10)	
Gestational Age (Weeks)	39.3 (2.9) [a]	39.2 (3.0) [a]	0.8217
Birth Weight (Grams)	3411.7 (545.4) [a]	3400.9 (541.60) [a]	0.8313
Mode of Delivery			
Vaginal	92 (74)	83 (73)	0.7715
Cesarean	32 (26)	31 (27)	
Breastfeeding			
Less than 1 Month	57 (43)	50 (44)	0.5908
1 Month to 6 Months	38 (29)	35 (31)	
7 to 11 Months	14 (11)	8 (7)	
≥ 12 Months	23 (17)	21 (18)	
Child BMI	16.0 (2.0) [a]	16 (2.0) [a]	0.7715
Child BMI percentile [b]			
Less than 85th percentile	96 (75)	88 (76)	0.8978
85th to 94.99th	18 (14)	16 (14)	
95th and above	14 (11)	10 (10)	

Table 3 (cont'd)

	ARCH Child Development N=132	Analytic Sample N=114	P value
	N (%)	**N (%)**	
Maternal Characteristics			
Maternal Education			
Less than High School	16 (13)	12 (11)	0.8914
High School Graduate or Equivalent	33 (25)	30 (26)	
Some College	47 (36)	40 (36)	
College Graduate or More	34 (26)	30 (27)	
Household Income			
Under $25,000	74 (58)	67 (60)	0.9487
$25,000 to $49,000	30 (23)	23 (21)	
$50,000 to $74,999	13 (10)	11 (10)	
$75,000 or Above	11 (9)	10 (9)	
Maternal History of Smoking [c]			
No	105 (85)	96 (84)	0.8134
Yes	18 (15)	18 (16)	
Parity During Index Pregnancy			
0	57 (46)	52 (46)	0.9341
≥1	67 (54)	62 (54)	
Parity at Follow-Up			
1	41 (33)	37 (32)	0.8920
≥2	83 (67)	77 (68)	
Maternal Age at Delivery	26.8 (5.2) [a]	26.7 (5.0) [a]	0.8335
Pre Pregnancy BMI	28.4 (7.8) [a]	28.0 (7.7) [a]	0.5627
Pre Pregnancy BMI Distribution			
Normal	53 (41)	50 (44)	0.7939
Overweight	33 (25)	26 (23)	
Obese	45 (34)	38 (33)	
Gestational Weight Gain (kg)	14.8 (7.1) [a]	15.0 (7.3) [a]	0.8139
Gestational Weight Gain Distribution			
Inadequate	31 (23)	22 (19)	0.6061
Adequate	31 (23)	26 (23)	
Excessive	70 (54)	66 (58)	
Follow-up Maternal BMI	30.7 (8.7) [a]	30.3 (8.6) [a]	0.6298

Table 3 (cont'd)

	ARCH Child Development N=132	Analytic Sample N=114	P value
	N (%)	**N (%)**	
Follow-up Maternal BMI Distribution			
Normal	37 (28)	32 (29)	0.9232
Overweight	39 (30)	35 (31)	
Obese	54 (42)	45 (40)	
Follow-up Waist Circumference (cm)	101.3 (24.6) [a]	100.2 (24.2) [a]	0.6308
Postpartum Weight Difference (kg)	6.3 (11.8) [a]	6.3 (12) [a]	0.9994
Post Delivery Weight Change (kg)	-6.7 (17.7) [a]	-7.5 (17.1) [a]	0.6002

Note: Observations missing for education (n=2), income (n=4), follow-up BMI (n=2), follow-up waist circumference (n=12), postpartum weight difference (n=3), post delivery weight change (n=10)

[a] Presented as Mean (Standard Deviation)

[b] Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population

[c] Smoking History is defined as having ever smoked

Table 4: Maternal and Child Sociodemographic Characteristics by Pre Pregnancy BMI Category

	Normal BMI [a] N=50		Overweight/Obese BMI [b] N=64		P value
	N	**%**	**N**	**%**	
Child Characteristics					
Child Race/ Ethnicity					0.7634
White, Non-Hispanic	29	58	31	48	
Black, Non-Hispanic	6	12	8	13	
Hispanic	8	16	13	20	
Other	7	14	12	19	
Child Gender					0.0445
Male	29	58	25	39	
Female	21	42	39	61	
Child Age at Measurement					0.7932
3 Years	8	16	14	22	
4 Years	18	36	22	34	
5 Years	18	36	23	36	
6 Years	6	12	5	8	
Gestational Age (Weeks)	50	39.4 (2.7) [c]	64	39.1 (3.2) [c]	0.6988
Birth Weight (Grams)	50	3322.3 (537.6) [c]	64	3462.2 (540.9) [c]	0.1721
Mode of Delivery					
Vaginal	37	74	46	72	0.8002
Cesarean	13	26	18	28	
Breastfeeding					0.2789
≤ 1 month	25	50	25	39	
1 to 6 months	12	24	23	36	
7 to 11 months	2	4	6	9	
≥ 12 months	11	22	10	16	
Maternal Characteristics					
Maternal Education					0.1092
Less than High School	7	14	5	8	
High School Graduate or Equivalent	11	22	19	31	
Some College	14	28	26	42	
College Graduate or More	18	36	12	19	
Household Income					0.2338
Under $25,000	25	52	42	67	
$25,000 to $49,000	14	29	9	14	
$50,000 to $74,999	4	8	7	11	
$75,000 or above	5	10	5	8	

Table 4 (cont'd)

	Normal BMI [a] N=50		Overweight/Obese BMI [b] N=64		P value
	N	**%**	**N**	**%**	
Maternal History of Smoking [d]					0.1249
No	45	90	51	79	
Yes	5	10	13	21	
Parity at Intake Pregnancy					0.0491
0	28	56	24	37	
≥1	22	44	40	63	
Parity at Follow-up					0.2830
1	21	42	16	25	
≥2	29	48	48	75	
Maternal Age (Years)	50	25.9 (4.6) [c]	64	27.4 (5.3) [c]	0.1120
Gestational Weight Gain (kg)	50	14.54 (6.4) [c]	64	15.29 (7.9) [c]	0.8385
Gestational Weight Gain Categorized					<0.0001
Inadequate	17	34	5	8	
Adequate	19	38	7	11	
Excessive	14	28	52	81	

Note: Observations missing for education (n=2), income (n=3),
[a] Normal BMI defined as a having a Body Mass Index of less than 25
[b] Overweight/ Obese BMI defined as having a Body Mass Index of 25 or higher
[c] Presented as Mean (Standard Deviation)
[d] Smoking history is defined as having ever smoked

Table 5: Maternal and Child Sociodemographic and Perinatal Characteristics by Childhood BMI Percentile Category

	Normal BMI [a] N=88		Overweight/ Obese BMI [b] N=26		P value
	N	%	N	%	
Child Characteristics					
Child Race/ Ethnicity					0.3957
White, Non-Hispanic	46	52	14	54	
Black, Non-Hispanic	11	13	3	12	
Hispanic	14	16	7	27	
Other	17	19	2	8	
Child Gender					0.8877
Male	42	48	12	46	
Female	46	52	14	54	
Child Age at Measurement					0.5676
3 years	17	19	5	19	
4 Years	30	38	10	38	
5 Years	34	39	7	27	
6 Years	7	8	4	15	
Gestational Age (Weeks)	88	39.2 (3.0) [c]	26	39.4 (3.0) [c]	0.7190
Birth Weight (Grams)	88	3376.0 (555.9) [c]	26	3484.9 (490.7) [c]	0.3701
Mode of Delivery					0.6409
Vaginal	65	74	18	69	
Cesarean	23	26	8	31	
Breastfeeding					0.4937
≤ 1 month	20	23	6	24	
1 to 6 months	18	20	5	20	
7 to 11 months	36	41	7	28	
≥12 months	4	16	7	28	
Maternal Characteristics					
Maternal Education					0.5079
Less than High School	9	10	3	12	
High School Graduate or Equivalent	21	24	9	36	
Some College	34	39	6	24	
College Graduate or more	23	26	7	28	
Household Income					0.4176
Under $25,000	51	60	16	62	
$25,000 to $49,000	18	21	5	19	
$50,000 to $74,999	10	12	1	4	
$75,000 or above	6	7	4	15	

Table 5 (cont'd)

	Normal BMI [a] N=88		Overweight/ Obese BMI [b] N=26		P value
	N	%	N	%	
Maternal History of Smoking [d]					0.9913
No	14	16	4	16	
Yes	74	84	22	84	
Parity at Intake Pregnancy					0.0837
0	44	50	8	31	
≥ 1	44	50	18	69	
Parity at Follow-up					
1	69	78	20	77	0.9073
≥2	19	22	6	23	
Maternal Age (Years)	88	26.3 (5.0) [c]	26	28.2 (5.0) [c]	0.0832
Gestational Weight Gain (kg)	88	14.72 (6.47) [c]	26	15.77 (9.59) [c]	0.5198
Gestational Weight Gain Categorized					0.6762
Inadequate	18	20	4	15	
Adequate	21	24	5	19	
Excessive	49	56	17	65	

Note: Descriptive Results shown for the analytic sample (N=114)
Observations missing for education (n=2), income (n=3),
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
[a] Normal BMI defined as having a Body Mass Index less than the 85th percentile
[b] Overweight/ Obese defined as having a Body Mass Index at the 85th percentile or higher
[c] Presented as mean (standard deviation)
[d] Smoking history is defined as having ever smoked

Table 6: Association between Pre Pregnancy BMI and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.05		Model 2[c] R^2=0.13		Model 3[d] R^2=0.14	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**	**β**	**95 % CI**
Pre Pregnancy BMI[e]	114	0.86*	0.1,1.6	0.84*	0.1, 1.6	0.99*	0.3, 1.7
Race: Black [f]	16	-	-	-22.21	-38.72, 5.70	-21.76*	-38.2, -5.3
Smoking History: Yes [g]	18	-	-	-16.66	-38.72, -5.70	-17.1*	-32.2, -2.0
GWG (kg) [h, i]	114	-	-	-	-	0.41	-0.3, 1.1

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = gestational weight gain
[a] Pearson Coefficient for pre pregnancy BMI and Child BMI percentile r=0.22
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for race and smoking history
[d] Model 3: Adjusted for race, smoking history, and gestational weight gain
[e] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[f] Referent Group non-Black N=98
[g] Referent Group No Smoking History N=96
[h] Beta Coefficient interpreted as a 1 kg increase in weight gained during pregnancy
[i] Pearson Coefficient for pre pregnancy BMI and GWG is r=0.01
* Indicates p<0.05

Table 7: Association between Gestational Weight Gain and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.008		Model 2[c] R^2=0.08		Model 3[d] R^2=0.14	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**	**β**	**95 % CI**
GWG (kg) [h, i]	114	0.36	-0.4, 1.1	0.42	-0.3, 1.2	0.41	-0.3, 1.1
Race: Black [f]	16	-	-	-20.9*	-37.9, -3.9	-21.76*	-38.2, -5.3
Smoking History: Yes [g]	18	-	-	-14.13	-29.5, 1.2	-17.1*	-32.2, -2.0
Pre Pregnancy BMI[e]	114					0.99*	0.3, 1.7

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = gestational weight gain
[a] Pearson Coefficient for pre pregnancy BMI and Child BMI percentile r=0.36
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for race and smoking history
[d] Model 3: Adjusted for race, smoking history, and pre pregnancy BMI
[e] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[f] Referent Group non-Black N=98
[g] Referent Group No Smoking History N=96
[h] Beta Coefficient interpreted as a 1 kg increase in weight gained during pregnancy
[i] Pearson Coefficient for pre pregnancy BMI and GWG is r=0.01
* Indicates p<0.05

Table 8: Association between Follow-up Maternal BMI and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.03		Model 2[c] R^2=0.07	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**
Follow-up Maternal BMI [d]	112	0.63	-0.04, 1.3	0.69*	0.03, 1.3
Race: Black [e]	13	-	-	-17.7	-35.1, -0.4

Results from Linear Regression using the analytic sample – 2 for missing data on Follow-up BMI (N=112) Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population

[a] Pearson Coefficient for follow-up BMI and Child BMI percentile r=0.19

[b] Model 1: Unadjusted

[c] Model 2: Adjusted for race

[d] Beta Coefficient interpreted as a 1 unit increase in follow-up BMI

[e] Referent Group non-Black N=98

* Indicates p<0.05

Table 9: Association between Follow-up Waist Circumference and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.04		Model 2[c] R^2=0.06	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**
Waist Circumference (cm) [d]	103	0.26*	0.01, 0.5	0.24	-0.02, 0.5
Race: Black [e]	12	-	-	-16.0	-34.4, 2.4

Results from Linear Regression using the analytic sample – 11 for missing waist circumference data (N=103)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
[a] Pearson Coefficient for Waist Circumference and Child BMI percentile r=0.20
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for race
[d] Beta Coefficient interpreted as a 1 cm increase in waist circumference
[e] Referent Group non-Black N=91
* Indicates p<0.05

Table 10: Association between Postpartum Weight Difference and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.0005		Model 2[c] R^2=0.03	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**
PPWD (kg) [d]	112	0.19	-0.3, 0.7	0.20	-0.3, 0.7
Race: Black [e]	13	-	-	-15.96	-33.5,1.6

Results from Linear Regression using the analytic sample – 2 for missing data for follow-up weight (N=112)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: PPWD=Post partum weight difference (defined as the difference between pre pregnancy weight and follow-up weight)
[a] Pearson Coefficient for PPWD and Child BMI percentile r=0.05
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for race
[d] Beta Coefficient interpreted as a 1 kg increase in the difference between (follow-up – pre pregnancy weight)
[e] Referent Group non-Black N=98
* Indicates p<0.05

Table 11: Association between Post Delivery Weight Change and Childhood BMI Percentile [a]

		Model 1[b] R^2=0.009		Model 2[c] R^2=0.04	
Variables	**N**	**β**	**95 % CI**	**β**	**95 % CI**
PDWC [d]	112	0.17	-0.2,0.5	0.17	-0.2, 0.5
Race: Black [e]	13	-	-	-16.0	-33.6, 1.5

Results from Linear Regression using the analytic sample – 2 for missing data for follow up weight (N=112)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: PDWC = Post Delivery Weight Change (defined as the difference between weight at delivery and weight at follow up)

[a] Pearson Coefficient for PDWC and Child BMI percentile r=0.02
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for race
[d] Beta Coefficient interpreted as a 1 kg increase in the difference between (follow-up– delivery weight)
[e] Referent Group non-Black N=98
* Indicates p<0.05

Table 12: Effects of Pre Pregnancy BMI on Childhood BMI Percentile: Influence of Follow-up Maternal BMI [a]

Total Effect Model		Model 1[b]		Model 2[c]	
		R^2 =0.05		R^2=0.13	
	N	β	95% CI	β	95% CI
Pre Pregnancy BMI [d]	112	0.84*	0.12, 1.56	0.98*	0.28, 1.69
GWG [e]	112	-	-	0.44	-0.33, 1.20
Race: Black [f]	13	-	-	20.34*	3.20, 37.48
Smoking History: Yes [g]	18	-	-	-17.21*	-32.43, -1.99
Controlled Direct Effect Model		R^2 = 0.05		R^2=0.13	
	N	β	95% CI	β	95% CI
Pre Pregnancy BMI [d]	112	0.74	-0.70, 2.18	0.98	-0.43, 2.40
Follow-up BMI [h]	112	0.10	-1.20, 1.41	-0.01	-1.29, 1.28
GWG [e]	112	-	-	0.44	-0.33, 1.20
Race: Black [f]	13	-	-	20.33*	3.03, 37.64
Smoking History: Yes [g]	18	-	-	-17.21	-32.57, -1.85

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
[a] Pearson Coefficient for pre pregnancy BMI and Follow-up BMI r=0.86
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race, and Smoking history
[d] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[e] Beta Coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent Group no smoking history N= 94
[h] Beta Coefficient interpreted as a 1 unit increase in Follow-up BMI
* Indicates p<0.05

Table 13: Effect of Pre Pregnancy BMI on Follow-up Maternal BMI [a]

Mediation Model	N	Model 1[b] R^2 =0.75 β	95% CI	Model 2[c] R^2=0.75 β	95% CI
Pre Pregnancy BMI [d]	112	0.95*	0.85, 1.05	0.96*	0.85, 1.06
GWG [e]	112	-	-	0.03	-0.08, 0.15
Race: Black[f]	13	-	-	-1.25	-3.83, 1.33
Smoking History: Yes[g]	18	-	-	-17.21*	-32.43, -1.99

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
[a] Pearson Coefficient for pre pregnancy BMI and follow-up BMI is r=0.86
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race and smoking history
[d] Beta coefficient interpreted as a 1 BMI unit increase
[e] Beta coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent group is no smoking history N=94
* Indicates p<0.05

Table 14: Summary of Total, Direct and Indirect Effect for Prepregnancy BMI on Childhood Percentile BMI Percentile: Influenced by Follow-up Maternal BMI

	Model 1[a]		**Model 2[b]**	
	β	**95% CI**	**β**	**95% CI**
Total Effect [c]	0.84*	0.12, 1.56	0.99*	0.28, 1.69
Controlled Direct Effect [d]	0.74	-0.70, 2.18	0.92	-0.49, 2.34
Indirect Effect [e]	0.10	-1.13, 1.29	0.07	-1.12, 1.21

[c] The coefficient reported is for pre pregnancy BMI from the total effect model in Table 11

[d] The coefficient reported is for pre pregnancy BMI from the Controlled direct effect in Table 11

[e] The coefficient reported is the product of pre pregnancy BMI from the controlled direct effect in Table 11 and follow-up BMI from Table 12

Table 15: Effects of Pre Pregnancy BMI on Childhood BMI Percentile: Influence of Maternal Waist Circumference [a]

		Model 1[b]		**Model 2[c]**	
Total Effect Model		R^2 =0.04		R^2=0.13	
	N	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	103	0.79*	0.04, 1.53	0.97*	0.24, 1.70
GWG [e]	103	-	-	0.44	-0.34, 1.22
Race: Black [f]	12	-	-	21.74*	3.53, 39.94
Smoking History: Yes [g]	17	-	-	-19.17*	3.29, 35.05
Controlled Direct Effect Model		R^2 = 0.05		R^2=0.14	
	N	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	103	0.48	-0.70, 1.66	0.73	-0.42, 1.88
Waist Circumference [h]	103	0.13	-0.26, 0.52	0.10	-0.28, 0.48
GWG [e]	103	-	-	0.45	-0.33, 1.24
Race: Black [f]	12	-	-	21.37*	3.05, 39.69
Smoking History: Yes [g]	17	-	-	-19.00*	-34.95, -3.05

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
[a] Pearson Coefficient for pre pregnancy BMI and Waist Circumference is r=0.77
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race, and Smoking history
[d] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[e] Beta Coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=91
[g] Referent Group no smoking history N= 86
[h] Beta Coefficient interpreted as a 1 cm increase in waist circumference
* Indicates p<0.05

Table 16: Effect of Pre Pregnancy BMI on Maternal Waist Circumference [a]

Mediation Model		Model 1[b]		Model 2[c]	
		R^2 =0.59		R^2=0.60	
	N	β	95% CI	β	95% CI
Pre Pregnancy BMI[d]	103	2.33*	1.95, 2.71	2.35*	1.97, 2.74
GWG[e]	103	-	-	-0.15	-0.57, 0.27
Race: Black[f]	12	-	-	3.56	-6.14, 13.25
Smoking History: Yes[g]	17	-	-	1.69*	-6.77, 10.14

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
[a] Pearson Coefficient for pre pregnancy BMI and waist circumference is r=0.77
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race and smoking history
[d] Beta coefficient interpreted as a 1 BMI unit increase
[e] Beta coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=91
[g] Referent group is no smoking history N=86
* Indicates p<0.05

Table 17: Summary of Total, Direct and Indirect Effect for Prepregnancy BMI on Childhood BMI Percentile: Influenced by Maternal Waist Circumference

	Model 1[a]		**Model 2[b]**	
	β	**95% CI**	**β**	**95% CI**
Total Effect [c]	0.79*	0.04, 1.53	0.97*	0.24, 1.70
Controlled Direct Effect [d]	0.48	-0.70, 1.66	0.73	-0.42, 1.88
Indirect Effect [e]	0.31	-0.56, 1.08	0.24	-0.67, 0.94

[c] The coefficient reported is for pre pregnancy BMI from the total effect model in Table 14

[d] The coefficient reported is for pre pregnancy BMI from the Controlled direct effect in Table 14

[e] The coefficient reported is the product of pre pregnancy BMI from the controlled direct effect in Table 14 and waist circumference from Table 15

Table 18: Effects of Pre Pregnancy BMI on Childhood BMI Percentile: Influence of Postpartum Weight Difference [a]

		Model 1 [b]		Model 2 [c]	
		R^2 =0.05		R^2=0.13	
Total Effect Model	**N**	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	112	0.84*	0.12, 1.56	0.99*	0.29, 1.70
GWG [e]	112	-	-	0.46	-0.30, 1.22
Race: Black [f]	13	-	-	20.78*	3.62, 37.93
Smoking History: Yes [g]	18	-	-	-17.72*	-32.94, -2.50
		R^2 = 0.05		R^2=0.13	
Controlled Direct Effect Model	**N**	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	112	0.85*	0.13, 1.58	1.00*	0.29, 1.72
PPWD [h]	112	0.11	-0.36, 0.59	0.08	-0.38, 0.54
GWG [e]	112	-	-	0.45	-0.31, 1.22
Race: Black[f]	13	-	-	20.81*	3.58, 38.04
Smoking History: Yes[g]	18			-17.57*	-32.88, -2.27

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
PPWD = post partum weight difference(defined as follow-up weight – pre pregnancy weight)
[a] Pearson Coefficient for pre pregnancy BMI and PPWD r=-0.10
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race, and Smoking history
[d] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[e] Beta Coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent Group no smoking history N= 94
[h] Beta Coefficient interpreted as a 1 kg increase in the change between follow-up and pre pregnancy weight
* Indicates $p<0.05$

Table 19: Effect of Pre Pregnancy BMI on Post Partum Weight Difference [a]

Mediation Model		Model 1[b]		Model 2[c]	
		R^2 =0.01		R^2=0.12	
	N	β	95% CI	β	95% CI
Pre Pregnancy BMI[d]	112	-0.16	-0.45, 0.13	0.99*	0.29, 1.70
GWG[e]	112	-	-	0.46	-0.30, 1.22
Race: Black[f]	13	-	-	20.78*	3.62, 37.93
Smoking History: Yes[g]	18	-	-	17.72*	2.50, 32.94

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviations: GWG = Gestational Weight Gain,
PPWD = post partum weight difference (defined as the difference between follow-up and pre pregnancy weight)
[a] Pearson Coefficient for pre pregnancy BMI and PPWD is r=-0.10
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race and smoking history
[d] Beta coefficient interpreted as a 1 BMI unit increase
[e] Beta coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent group is no smoking history N=94
* Indicates p<0.05

Table 20: Summary of Total, Direct and Indirect Effect for Prepregnancy BMI on Childhood BMI Percentile: Influenced by Post Partum Weight Difference

	Model 1[a]		**Model 2[b]**	
	β	**95% CI**	**β**	**95% CI**
Total Effect[c]	0.84*	0.12, 1.56	0.99*	0.29, 1.70
Controlled Direct Effect[d]	0.85*	0.13, 1.58	1.00*	0.29, 1.72
Indirect Effect[e]	-0.02	-0.24, 0.05	-0.01	-0.23, 0.06

[c] The coefficient reported is for pre pregnancy BMI from the total effect model in Table 17

[d] The coefficient reported is for pre pregnancy BMI from the Controlled direct effect in Table 17

[e] The coefficient reported is the product of pre pregnancy BMI from the controlled direct effect in Table 17 and Post Partum Weight Difference from Table 18

Table 21: Effects of Pre Pregnancy BMI on Childhood BMI Percentile: Influence of Post Delivery Weight Change [a]

Total Effect Model		**Model 1[b]** R^2 =0.05		**Model 2[c]** R^2=0.13	
	N	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	112	0.84*	0.12, 1.56	0.99*	0.29, 1.70
GWG [e]	112	-	-	0.46	-0.30, 1.22
Race: Black [f]	12	-	-	20.78*	3.62, 37.93
Smoking History: Yes [g]	17	-	-	-17.72	-32.94, 2.50
Controlled Direct Effect Model		R^2 = 0.05		R^2=0.13	
	N	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	112	0.84*	0.09, 1.59	0.99*	0.25, 1.73
PDWC [h]	112	-0.01	-0.36, 0.33	0.01	-0.34, 0.35
GWG [e]	112	-	-	0.46	-0.33, 1.26
Race: Black[f]	12	-	-	20.78*	3.54, 38.01
Smoking History: Yes[g]	17	-	-	-17.69*	-33.03, -2.36

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
PDWC = post delivery weight change (defined as the difference between follow-up weight and weight at delivery)

[a] Pearson Coefficient for pre pregnancy BMI and PDWC r=0.27
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race, and Smoking history
[d] Beta Coefficient interpreted as a 1 unit increase in pre pregnancy BMI
[e] Beta Coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent Group no smoking history N= 94
[h] Beta Coefficient interpreted as a 1 unit increase in the difference between follow-up weight and weight at delivery
* Indicates $p<0.05$

Table 22: Effect of Pre Pregnancy BMI on Post Delivery Weight Change [a]

Mediation Model		**Model 1[b]**		**Model 2[c]**	
		R^2 =0.07		R^2=0.15	
	N	**β**	**95% CI**	**β**	**95% CI**
Pre Pregnancy BMI [d]	112	0.59*	0.19, 0.99	0.62*	0.23, 1.01
GWG [e]	112	-	-	-0.63	-1.05, -0.20
Race: Black[f]	13	-	-	0.54	-8.97, 10.05
Smoking History: Yes[g]	18	-	-	3.20	-5.24, 11.63

Results from Linear Regression using the analytic sample (N=114)
Percentiles were defined by the Centers for Disease Control and Prevention and based on the United States' population
Abbreviation: GWG = Gestational Weight Gain
PDWC = post delivery weight change (defined as the difference between follow-up weight and weight at delivery)
[a] Pearson Coefficient for pre pregnancy BMI and PDWC is r=0.27
[b] Model 1: Unadjusted
[c] Model 2: Adjusted for GWG, race and smoking history
[d] Beta coefficient interpreted as a 1 BMI unit increase
[e] Beta coefficient interpreted as a 1 kg increase in GWG
[f] Referent Group non-Black N=99
[g] Referent group is no smoking history N=94
* Indicates p<0.05

Table 23: Summary of Total, Direct and Indirect Effect for Prepregnancy BMI on Childhood BMI Percentile: Influenced by Post Delivery Weight Change

	Model 1[a]		**Model 2[b]**	
	β	**95% CI**	**β**	**95% CI**
Total Effect[c]	0.84*	0.12, 1.56	0.99*	0.29, 1.70
Controlled Direct Effect[d]	0.84	-0.9, 1.59	0.99	0.25, 1.73
Indirect Effect[e]	-0.01	-0.28, 0.23	0.01	-0.23, 0.06

[c] The coefficient reported is for pre pregnancy BMI from the total effect model in Table 20

[d] The coefficient reported is for pre pregnancy BMI from the Controlled direct effect in Table 20

[e] The coefficient reported is the product of pre pregnancy BMI from the controlled direct effect in Table 20 and Post Delivery Weight Change from Table 21

APPENDIX B:

Figures

Figure 1: Inclusion and Exclusion Criteria Used for Analytic Sample

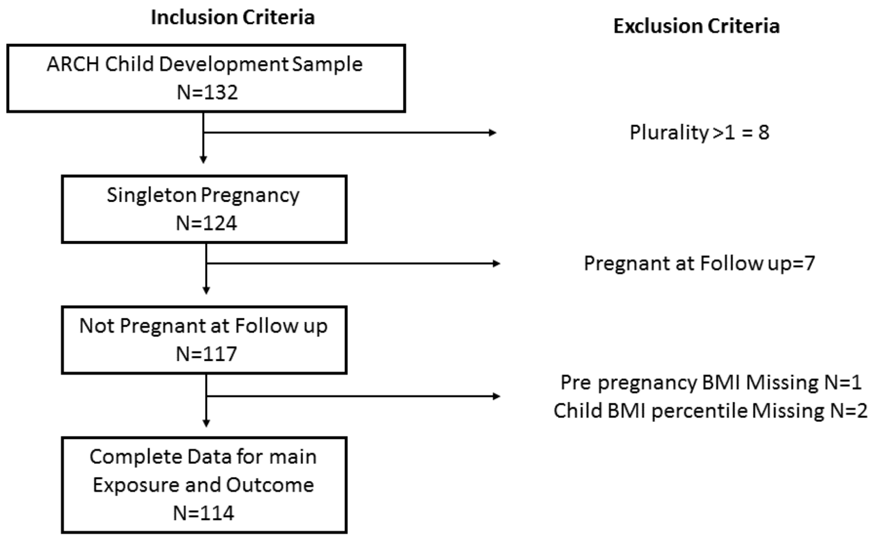


Figure 2: Timing and Definitions of Maternal Body Composition Measurements

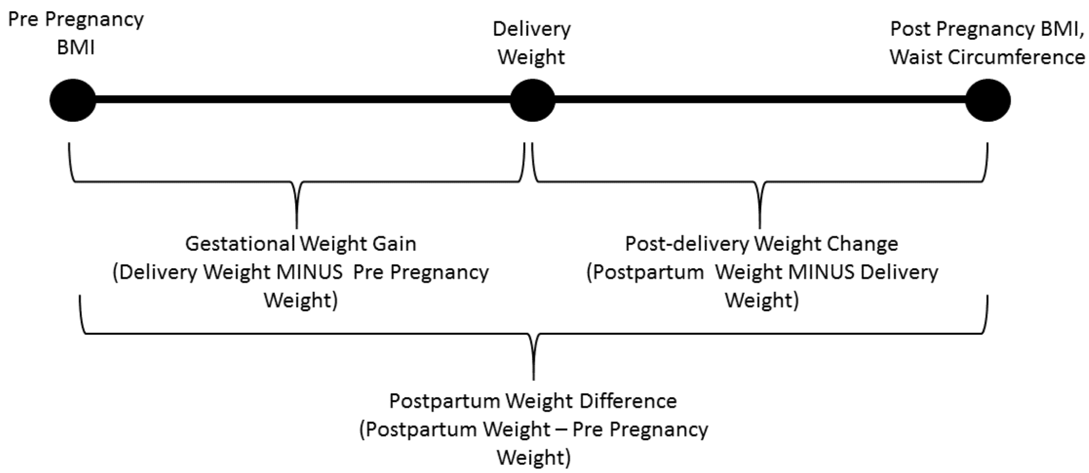


Figure 3: Conceptual Model of Pre Pregnancy BMI and Childhood BMI with Follow-up Maternal Body Composition as a Mediator

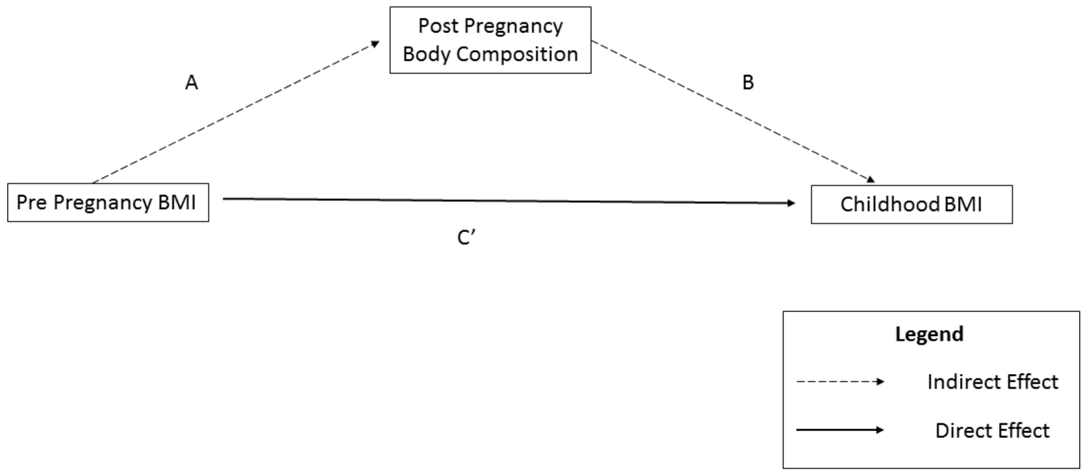
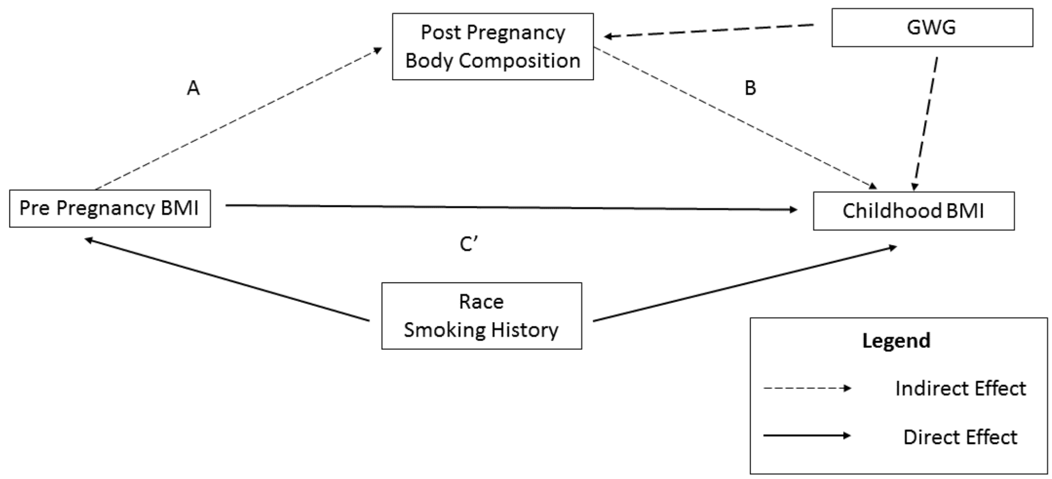


Figure 4: Conceptual Model of Pre Pregnancy BMI and Childhood BMI with Follow-up Maternal Body Composition as a Mediator and Adjusted for Confounders



REFERENCES

REFERENCES

1. World Health Organization. World Health Organization. [Online]. [cited 2016 12 16. Available from: http://www.who.int/dietphysicalactivity/childhood/en/.

2. Center for Disease Control. Center for Disease Control. [Online].; 2016 [cited 2016. Available from: https://www.cdc.gov/obesity/childhood/index.html.

3. Ogden C. Trends In obesity prevalence mong children and adolescents in the United States, 1988-1994 Through 2013-2014. JAMA. 2016; 215(21): p. 2292-2299.

4. Daniels S. Complications of Obesity in Children and Adolescence. International Journal of Obesity. 2009; 33: p. S60-S65.

5. Center for Disease Control. Centers for Disease Control and Prevention. [Online].; 2013 [cited 2016. Available from: https://www.cdc.gov/nchs/data/databriefs/db131.htm.

6. Zhang S. Maternal Obesity and the Early Origins of Childhood Obesity: Weighing up the benefits and costs or maternal weight loss in the periconceptional period of the offspring. Experimental Diabetes Research. 2011.

7. Lessa N, Berard A. Update on Prepregnancy Maternal Obesity: Birth Defects and Childhood Outcomes. J Pediatr Genet. 2015; 4: p. 71-83.

8. Li C. Additive Interactions of Maternal Prepregnancy BMI and Breast-feeding on Childhood Overweight. Obestiy research. 2005; 13(2): p. 362-371.

9. Kuczmarski RJ, Ogden CL, Guo SS. 2000 CDC Growth Charts for the United States: Methods and Development. National Center for Health Statistics. 2002; 11(246).

10. Barlow S. Expert Committee Recommendations Regarding the Prevention, Assessment and treatment of Child and Adolescent Overweight and Obesity: Summary Report. Pediatrics. 2007; 120(4).

11. Morrison K. Association of Depression and Health Related Quality of Life with body Composition in CHildren and youth with Obesity. Journal of Affective Disorders. 2015 February; 172: p. 18-23.

12. Must A. Morbidity and Mortality Associated with Elevated Body Weight in Childre and Adolescents. The American Journal of Clinical Nutrition. 1996; 63(3).

13. Whitaker R. Predictuing preschooler obesity at birth: the role of maternal obesity in early pregnancy. Pediatrics. 2004; 114(1).

14. Shankar K, Harrell A, Liu X. Maternal Obesity at Conception Programs Obesity in the Ofsspring. American Journal of Physiology. 2008; 294(2).

15. Galliano D, Bellver J. Female Obesity:short and long term consequences on the offspring. Gynecological Endocrinology. 2013; 29(7).

16. Fuemmeler B, Wang L, Edwin IS. Size Tempo and Velocity of Infant Growth: Analysis of Newborn Epigenetic Study Cohort. Childhood Obesity. 2016; 12(3): p. 210-218.

17. Li A, Teo K, Morrison K. A Genetic Link Between Prepregnancy Body Mass Index, Postpartum Weight Retention and Offspring Weight in Early Childhood. Obesity. 2017; 25: p. 236-243.

18. Kaar J, Crume T, Brinton J. Maternal Obesity, Gestational Weight Gain and Offsrping Adiposity: The Exploring Perinatal Outcomes among Children Study. J Pediatr. 2014; 165: p. 509-15.

19. Adriette J, Oostvogels JM, Stronks K. Maternal Prepregnancy BMI, Offspring's Early Postnatal Growth, and Metabolic Profile at Age 5-6 Years: the ABCD Study. JCEM. 2014; 99(10): p. 3845-3854.

20. Sridhar S, Darbinian J, Ehrlich S. Maternal gestational weight gain and offspring risk for childhood overweight or obesity. Am J obstet Gynecol. 2014; 211.

21. Center for Disease Control. Weight Gain During Pregnancy. [Online].; 2016. Available from: https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-weight-gain.htm.

22. Oken E, Taveras E, Kleinman K. Gestational Weight gain and child adiposity at age 3 years. Am J Obstet Gynecol. 2007; 196.

23. Olson C, Demment M, Carling S. Associaitons Between Mothers and Their Children's Weights at 4 years of age. Childhood Obesity. 2010; 6(4).

24. Von Kries R, Ensenauer R, Beyerlein A. Gestational Weight Gain and overweight in children: results from the cross sectional German KiGGS study. Internationaly Journal of Pediatric Obesity. 2011; 6: p. 45-52.

25. Diesel JC, Eckhardt CL, Day NL. Gestational Weight Gain and the risk of offspring obesity at 10 and 16 years: a prospective cohort study in low income women. International Journal of Obsterics and Gynaecology. 2015 September; 122(10).

26. Robinson C, Cohen A, Rehkopf D. Pregnancy and post-delivery maternal weight changes and overweight in preschool children. Preventive Medicine. 2014 March; 60: p. 77-82.

27. American Academy of Pediatrics. [Online].; 2017 [cited 2017. Available from: https://www2.aap.org/breastfeeding/faqsBreastfeeding.html.

28. Yan J, Liu L, Zhu Y. The association between breastfeeding and childhood obesity: a meta-analysis. BMC Public Health. 2014 December; 14.

29. Center of Disease Control. Children's BMI Tool for Schools. [Online].; 2015. Available from: https://www.cdc.gov/healthyweight/assessing/bmi/childrens_BMI/tool_for_schools.html.

30. Hayes A. Introduction to Mediation, Moderation, and Conditional Process Analysis New York: The Guildford Press; 2013.

31. Iessa N. Update on Prepregnancy Maternal Obesity: Birth Defects and Childhood Outcomes. J Pediatr Genet. 2015; 4: p. 71-83.