Associations Between Pre-Pregnancy Weight Status and/or Gestational Weight Gain and Obesity in Older Children

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ASSOCIATIONS BETWEEN PRE-PREGNANCY WEIGHT STATUS AND/OR GESTATIONAL WEIGHT GAIN AND OBESITY IN OLDER CHILDREN

by

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Abstract

Childhood obesity is a global health concern that puts children at risk for developing serious health complications. With increasing rates worldwide, it is important to determine how to decrease its prevalence and promote prevention in future generations. Emerging evidence indicating that pre-pregnancy weight status and/or gestational weight gain (GWG) may be linked with overweight/obesity in children. Much of this body of research focused on weight status of offspring at birth and at preschool age. The purpose of this study is to: (1) analyze the research findings regarding obesity in children 5 to 18 years and their mother's pre-pregnancy weight status and/or GWG, and (2) make recommendations for prevention based on a review of current research. A database search of CINAHL, Medline, ERIC and PsycInfo was conducted. A total of 14 articles were identified based on their relevance to key search terms and meeting criteria. This literature review indicated support for associations between an underweight/overweight/obese pre-pregnancy weight status combined with greater than recommended total GWG and higher overweight/obesity in older children and adolescent offspring. Findings also supported the associations between pre-pregnancy weight status with high GWG during early pregnancy and increased offspring overweight/obesity. Pre-pregnancy overweight/obese weight status of mothers was the single factor consistently found to be strongly associated with risk for overweight and obesity in children 5 to 18 years of age. Results of this review support the need for further education, interventions, and policies aimed at healthy nutrition for women during and prior to pregnancy to prevent childhood obesity.

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Introduction

Childhood obesity is a global health concern. Since the 1980's, the number of obese children in the U.S. has more than doubled, and the number of obese adolescents has quadrupled (Centers for Disease Control and Prevention [CDC], 2015a). In 2012, 16.9% of U.S. children and adolescents, aged 2 to 19 years, were considered obese, and another 14.9% were considered overweight (CDC, 2015a). Although the number of overweight and obese children in the U.S. is alarming, childhood obesity is an epidemic that is observed worldwide. Globally, more than 200 million school-age children and over 40 million children under the age of five were overweight in 2010 (International Association for the Study of Obesity [IASO], 2013).

Childhood obesity is a complex and multifactorial health problem. Awareness and knowledge of the factors that lead to obesity in children is vital to decreasing its prevalence and promoting prevention in future generations. The main factors analyzed by researchers include genetic, behavioral, environmental and educational. Emerging evidence indicates that pre-pregnancy weight status and gestational weight gain (GWG) may also be linked with obesity in children at different ages. Recent studies found a connection between obesity in children 5 years and older and their mothers' pre-pregnancy weight status and/or GWG. It is important that this body of research involving older children is reviewed and analyzed to determine the magnitude of these associations.

Background and Significance

Overweight and obese children are at an increased risk for developing serious health complications, such as hypertension, hyperlipidemia, type 2 diabetes and depression (CDC, 2015b). Identifying children at risk for obesity is vital to preventing these health complications. The process of identifying overweight and obese children is conducted with the use of screening tools. One of the most widely used screening tools is body mass index (BMI). BMI is a good indicator of body fat in most populations and is also strongly correlated with the metabolic diseases found to be associated with body fat (CDC, 2015c).

BMI is used to determine a child's weight status by comparing it to the BMI-for-age percentile growth charts for each sex. The percentages used for comparison came from American children who participated in national surveys that were conducted from 1963-65 to 1988-94 (CDC, 2015c). The BMI tool is used to screen children rather than to diagnose them. Further assessments must be performed to classify a child as obese and to determine if a child's BMI puts him/her at risk for associated health-related issues. Further assessments that may be performed include skinfold thickness measurements, waist circumference, and evaluation of diet and physical activity (CDC, 2015c). A child's muscle mass must also be evaluated to determine health risks because a high BMI may be the result of high lean body mass rather than body fatness (CDC, 2015c). A child over the age of 2 years is considered overweight when their BMI is between the 85^{th} and 95^{th} percentile and obese when their BMI is $\geq 95^{th}$ percentile for children and adolescents of the same sex and age (American Heart Association, 2013).

Obesity prevalence is rising in countries around the world in children of all ages, ethnicities, and socioeconomic statuses (Caprio et al., 2008). However, obesity rates are found to

be higher in school-aged children, age 5 to 12 years, and adolescents, age 13 to 19 years, than in infants and preschoolers. In the U.S., one in three school-aged child is considered overweight or obese, and nearly 18% are already classified as obese (National Institute of Diabetes and Digestive and Kidney Diseases, 2012). It is vital that actions are taken to prevent childhood obesity because overweight and obese children are at a much greater risk for becoming obese adolescents and adults (CDC, 2015a). According to Cunningham, Kramer, and Narayan (2014), overweight 5-year-olds are four times more likely to become obese when they reach adolescence than normal-weight children. When childhood obesity continues into adolescence, 80% are more likely to continue to be obese when they reach adulthood (Hoey, 2014). Obesity in adolescence and adulthood is associated with greater health risks, which is why obesity prevention efforts should be implemented as early as possible. Preventing obesity in childhood will lead to less obesity in adulthood and decrease individuals' risk for developing obesity-related health complications. However, a greater understanding of the complex factors that contribute to obesity in older children is needed for more focused preventative efforts to be implemented. Pre-pregnancy weight status and GWG are two of these complex factors.

Research shows that the number of overweight and obese women of reproductive age is increasing worldwide. According to the National Health and Nutrition Examination Survey, 34% of American women of reproductive age, aged 20 to 39 years, were classified as obese between 2007 and 2008 (Honein et al., 2013). This number increased from the 1999-2000 survey, which reported 28% of women aged 20 to 39 years as obese. According to the IASO (2013), more than 250 million women of reproductive age worldwide are considered overweight, and over 100 million are considered obese. These numbers indicate that many women are overweight or obese

at time of conception. This is an issue because women with an overweight or obese pre-pregnancy weight status were observed to gain more than the recommended amount of weight during their pregnancies compared with women of normal pre-pregnancy weight (Deputy, Sharma, Kim, & Hinkle, 2015). In a recent study, 47.2% of women gained more than the recommended amount of weight during their pregnancies, and approximately 63.5% of those women were overweight or obese at time of conception (Deputy, Sharma, Kim, & Hinkle, 2015). Gaining more than the recommended amount of weight during pregnancy increases health risks for mothers and their infants (American Congress of Obstetricians and Gynecologists [ACOG], 2016). Consequently, there has been an increased interest in research analyzing the associations between pre-pregnancy weight status and/or GWG with the risk of childhood obesity.

Guidelines for total GWG and rate of weight gain during pregnancy were updated in 2009 (Institute of Medicine [IOM], 2009). Prior to this modification, recommended pregnancy weight gain and rate of weight gain were determined from the IOM's 1990 guidelines. There were several problems with the 1990 guidelines that indicated a need for reexamination. One of the main problems was that the recommendations were based on the association between GWG and low birth weight, focusing on the short-term welfare of the infant alone (Rasmussen, Catalano, & Yaktinec, 2009). Consequently, a greater number of outcomes, both short- and long-term, were examined, including both the wellbeing of the infant and the mother (IOM, 2009).

The new guidelines recommend that underweight women gain 28 to 40 pounds, normal weight women gain 25 to 35 pounds, overweight women gain 15 to 35 pounds and obese women gain 11 to 20 pounds. Women are classified as underweight, normal weight, overweight, or obese based on their pre-pregnancy BMI, and teenagers who are pregnant should use the same

adult BMI categories during their pregnancies (IOM, 2009). All of the recommendations listed are for women who have singleton pregnancies and are the same regardless of racial or ethnic backgrounds. Women who are pregnant with multiples are given provisional guidelines (IOM, 2009).

Problem

Childhood obesity is a condition contributing to multisystem diseases that puts children at an increased risk for developing premature onset of illnesses (World Health Organization [WHO], 2016). As BMI increases, the likelihood of developing comorbidities increases. Excess body fat is also associated with poor health during childhood itself (Onis & Lobstein, 2011). Overweight and obese children have a higher risk to develop hypertension, insulin resistance, fatty liver disease, orthopedic dysfunction, and psychosocial distress (Onis & Lobstein, 2011). Obese children and adolescents are also more likely to continue to be obese when they reach adulthood. When obese children become obese adults, they are at risk for developing more serious complications, including cardiovascular disease, stroke, type 2 diabetes, osteoarthritis, and some cancers (WHO, 2016).

Research shows a small decrease in the number of obese children aged 2 to 5 years but no notable decrease in the prevalence of obesity among children and adolescents of other ages (Dietz & Economos, 2015). Lack of improvement among obesity prevalence in children older than 5 years of age is a problem that requires attention because a high BMI in childhood is associated with many adverse biochemical, physiological, and psychological effects (Deckelbaum & Williams, 2012).

Purpose

Research findings suggest that there is an association between childhood obesity and both pre-pregnancy weight status and/or GWG. The purpose of this research was to (1) analyze associations between obesity in children 5 years of age and older with their mothers' pre-pregnancy weight status and/or GWG; and (2) make recommendations for prevention based on a review of current research.

Method

A systematic literature review was conducted to analyze articles that examine pre-pregnancy weight status and/or GWG with obesity in children 5 years of age and older (Figure 1). The databases that were used to search for relevant articles were CINAHL, Medline, ERIC and PsycInfo. The key words and terms used in this search included, (“weight gain" or weight increas* OR "Weight Gain In Pregnancy" OR "Obesity In Pregnancy”) AND (pregnan* OR maternal OR gestational) AND ("Body Mass Index" OR obes* or MH "Obesity") OR overweight OR BMI OR adiposity) AND (offspring OR Pediatric*) NOT (Infant OR Newborn OR neonat* OR Adult*). Inclusion criteria included: English language, peer-reviewed, and published within the last ten years. Articles that did not analyze pre-pregnancy weight status and/or GWG with obesity in children 5 to 18 years of age were excluded. An ancestry approach was also used to identify relevant articles that met the criteria of this literature search.

Results

A total of fourteen articles were identified through a systemic review of the literature (Table 1). Most articles reported consistent findings regarding the association between pre-pregnancy weight status and/or GWG and childhood obesity. However, the studies often measured, analyzed, and reported results for both of the maternal variables (pre-pregnancy weight status and GWG) somewhat differently. To better understand the findings, results were organized into subcategories: pre-pregnancy weight status, early-pregnancy GWG, mid-pregnancy GWG, late-pregnancy GWG, and total GWG.

Pre-Pregnancy Weight Status

An overweight or obese pre-pregnancy weight status appears to be significantly associated with overweight/obesity in children ages 5 to 18 years. Studies also support stronger associations between an overweight/obese pre-pregnancy weight status and childhood overweight/obesity than between GWG and childhood overweight/obesity (Castillo et al., 2015; Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015; Laitinen et al. 2012).

A large, prospective study in Brazil used air plethysmography to measure the adiposity of offspring at the age of 6 years and found that children born to mothers who were overweight or obese before pregnancy presented with a higher amount of fat mass (FM) than children born to mothers who were underweight or normal weight pre-pregnancy (Castillo et al., 2015). In this study, maternal weight was retrieved from medical records or was self-reported, and height was taken at the first follow up visit after delivery. The study discovered that children born to mothers with a normal or overweight pre-pregnancy BMI and with a greater than recommended

GWG had higher FM compared with children of mothers at the same pre-pregnancy BMI who had GWG within recommended guidelines ($p < .001$; Castillo et al., 2015). Although these findings show a direct association between both pre-pregnancy BMI and GWG with offspring FM, the association of pre-pregnancy BMI on offspring adiposity was stronger than the effect of GWG (Castillo et al., 2015). This finding was consistent with findings from other similar studies (Fraser et al., 2010; Gaillard et al., 2014, 2015; Laitinen et al., 2012) .

Another large, prospective study based in the United Kingdom found a stronger association between pre-pregnancy weight status and childhood BMI at the age of 9 years than any measure of GWG (Fraser et al., 2010). In this study, children's heights and weights were measured using scales and stadiometers, but maternal height and weight measurements were self-reported or retrieved from obstetric medical records. Laitinen et al. (2012) also reported overweight/obese pre-pregnancy weight status as the highest risk factor for childhood overweight/obesity when compared to GWG with a four-fold risk. This finding was supported by two other studies that analyzed the association between GWG and pre-pregnancy weight status with childhood overweight/obesity at the age of 6 and 17 years ($p < .05$), respectively (Gaillard et al., 2014; Gaillard et al., 2015).

Pre-pregnancy BMI also was a strong predictor of childhood obesity in a study that analyzed the association between pre-pregnancy BMI and childhood obesity at different life stages (Rooney et al., 2010). The study obtained height and weight measurements from the medical records of 777 children from ages 4 to 20 years and found pre-pregnancy obesity to be a very strong predictor of childhood, adolescent, and early adulthood obesity (Rooney et al., 2010).

Among the mothers in this study who had an obese pre-pregnancy BMI, 52% of children were obese during childhood, 62% during adolescence, and 44% during adulthood.

A more recent study that only included women who abused substances during their pregnancy reported results that differed from the other studies regarding associations between pre-pregnancy BMI and childhood obesity (Diesel et al. 2015). The study found an association between a pre-pregnancy BMI $\leq$ 25, along with a GWG $\geq$ 30kg (approximately 66 pounds) by 40 weeks, with an increased risk for childhood obesity. Contrary to findings in other studies (Castillo et al., 2015; Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015), Diesel et al. (2015) found no associations with women who had an overweight or obese pre-pregnancy BMI and childhood overweight/obesity risk.

There were mixed findings among the studies regarding pre-pregnancy weight status and its moderation of the association between GWG and offspring overweight/obesity. In a retrospective study of 26,506 mother-daughter pairs, pre-pregnancy BMI was associated with GWG ($p < .03$; Stuebe et al. 2009). Mothers with a normal pre-pregnancy BMI who gained < 15 pounds or > 19 pounds had a modest association with offspring overweight/obesity, whereas mothers with an overweight or obese pre-pregnancy BMI had a strong association with the same amount of GWG ($p < .03$; Stuebe et al., 2015). In this same study, women with an obese or overweight pre-pregnancy BMI had a strong association between GWG > 40 pounds and offspring overweight/obesity, whereas women with a normal pre-pregnancy BMI had a statistically insignificant association with GWG and offspring overweight/obesity. Another study supports these findings reporting that pre-pregnancy BMI is associated with increased risk of

offspring obesity especially among women with greater then recommended GWG ($p < .001$; Kaar et al., 2014).

Contrary to the two studies above (Kaar et al. 2014; Stuebe et al. 2009), an association between GWG and offspring overweight/obesity was found to be moderated by a normal or underweight pre-pregnancy weight status rather than an overweight/obese pre-pregnancy weight status (Diesel et al., 2015). In this study with mothers who abused substances during pregnancy, Diesel et al. (2015) found that offspring were at risk for obesity when mothers with a BMI < 25 gained more than 30 kg (66 pounds), but no risk was found between high GWG in women with a BMI of 25 or greater. Consistent with these findings, Wrotniak et al. (2008) found that high GWG and overweight in offspring was strongest for women with an underweight pre-pregnancy BMI ($p < .01$). Contrary to all four studies, Fraser et al. (2010) and Castillo et al. (2015) found no evidence that would support any moderation of the association between GWG and offspring overweight/obesity by pre-pregnancy weight status.

Gestational Weight Gain

The independent variable of GWG was categorized as early, mid, and late pregnancy GWG, as well as Total GWG. In the studies that analyzed GWG in three different periods of pregnancy, greater early-pregnancy GWG appeared to have stronger associations with offspring obesity, mid-pregnancy GWG had mixed results, and late-pregnancy GWG had consistent results that concluded there was no association.

Early Pregnancy

Early pregnancy can be defined as the first trimester of pregnancy which is between 0 and 13 weeks gestation (ACOG, 2015). However, the definition of early pregnancy varied among the studies, and many measured early pregnancy up to a few weeks past the first trimester. After analyzing the results, the evidence supports a strong association between early-pregnancy GWG and obesity in offspring between the ages of 6 and 17 years. In the studies that included pre-pregnancy weight status as a variable, pre-pregnancy weight status appeared to be more significant than early-pregnancy GWG in predicting offspring overweight/obesity; however, early-pregnancy was significant nonetheless.

In a large study that measured women's weight at 13.2 weeks gestation, higher maternal GWG in early pregnancy was associated with higher offspring BMI and FM at the age of 6 years ($p < .05$; Gaillard et al., 2014). The study concluded that the association between early pregnancy GWG and offspring BMI was independent of pre-pregnancy BMI, weight gain in later pregnancy, and pregnancy complications or offspring growth characteristics. Similar results were found in a 17-year-long prospective study that measured weight gain in early pregnancy as up to 16 weeks gestation (Gaillard et al., 2015). This study found greater GWG rate during early pregnancy to be associated with higher offspring BMI at the age of 17 years. After analyzing other time periods during pregnancy, only early pregnancy GWG rate and pre-pregnancy BMI were associated with adolescent offspring BMI.

Another study (Fraser et al., 2010) discovered similar findings supporting the aforementioned two studies (Galliard et al., 2014; Galliard et al., 2015). However, conclusions were strengthened

by the amount of GWG during early pregnancy. The study defined early pregnancy as 0 to 14 weeks gestation and found GWG in early pregnancy to be associated with offspring BMI at the age of 9 years (Fraser et al., 2010), and the magnitude of the association was greater when mothers gained > 500g/week. (1.1 pounds). There was no evidence that the association between GWG in early pregnancy and offspring BMI was modified by pre-pregnancy BMI or weight (Fraser et al., 2010).

Rather than dividing GWG into three periods of pregnancy, Laitinen et al. (2012) only studied the first half of pregnancy, which they defined as the beginning of pregnancy to 20 weeks gestation. The study found GWG > 7.0kg (15.4 pounds) in the first 20 weeks to be independently associated with a 1.5-fold risk for increased adolescent overweight and obesity. The study also found a stronger association between pre-pregnancy obesity and offspring overweight/obesity with a four-fold risk (Laitinen et al., 2012). Results from this study cannot easily be compared to the studies above because it is unknown if the results were related to GWG in the first 13 weeks of pregnancy or if GWG after the first trimester had a significant impact.

Mid Pregnancy

Mixed results were found between mid pregnancy GWG and offspring BMI. According to ACOG (2015), the second trimester is defined between 14 and 27 weeks gestation. When mid pregnancy GWG was measured between 13.4 and 29.9 weeks gestation, there was an association between mid-pregnancy GWG and offspring BMI at the age of 6 years that was partly explained by birth characteristics (sex, birth weight, caesarean delivery; Gaillard et al., 2014). The study

concluded that only early pregnancy GWG and pre-pregnancy BMI were associated with increased risk for overweight/obesity in children at the age of 6 years (Gaillard et al., 2014). Another study conducted in a different country by the same researcher defined mid pregnancy as occurring between 16 and 34 weeks gestation and found no association between mid-pregnancy GWG and childhood BMI (Gaillard et al., 2015).

Findings from another study support the association between mid-pregnancy GWG and offspring BMI, but only when women gained > 500 kg a week (1.1 pounds; Fraser et al., 2010). This was different from their findings on early pregnancy, because the association between early pregnancy GWG and offspring BMI was only strengthened by GWG > 500kg a week, but not dependent upon it.

Late Pregnancy

None of the studies that analyzed pregnancy in three periods of pregnancy (Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015; Laitinen et al., 2012) found an association between late pregnancy GWG and offspring overweight/obesity that was not fully explained by birth characteristics (sex, birth weight, caesarean delivery; Gaillard et al., 2014).

Total Gestational Weight Gain

Overwhelming evidence from the studies indicated that children of mothers with greater than recommended total GWG were more likely to be overweight or obese than those born to mothers with recommended GWG (Crozier et al., 2010; Fraser et al., 2010; Margerison-Zilko et al., 2010; Oken et al., 2008; Rooney et al., 2010; Stuebe et al., 2009; Wrotniak et al., 2008). With the exception of two studies, the IOM's 2009 recommendations were referenced when analyzing

GWG. The studies that did not reference the IOM's 2009 guidelines were conducted prior to the changes made in 2009; thus, the IOM's 1990 guidelines were used (Oken et al., 2008; Wrotinak et al., 2008). Comparable results were found regardless of offspring ages during the 5 to 18 year age period.

All of the studies found an association between greater than recommended GWG and offspring overweight/obesity, but some studies found statistically stronger associations when a specific amount of weight was gained (Oken et al., 2008; Stuebe et al., 2009; Wrotniak et al., 2008). In a study that used self-reported data, it was discovered that mothers who gained at least 45 pounds had a substantially higher chance of having overweight/obese offspring at the ages of 9 and 14 years (Oken et al., 2008). A second study that depended on self-report for all GWG measures and offspring height and weight found a significant association with mothers who gained at least 40 pounds and childhood overweight/obesity at the age of 18 years ($p < .03$; Stuebe et al., 2009). This study only analyzed female offspring and, after adjusting for pre-pregnancy weight status, found that only those women who gained > 40 pounds had an association that was statistically significant. Any weight gain that was $\leq$ 40 pounds but above recommendations was attributed to pre-pregnancy weight status (Stuebe et al., 2009). An association found between an underweight pre-pregnancy weight status and offspring overweight/obesity also discovered that, for every 1 kg (2.2lbs) gained over recommended weight, the odds of being overweight/obese increased by 3% for children at the age of 7 years (Wrotniak et al., 2008).

Similar results were found among studies that had varying percentages of women with greater than recommended GWG. When weight status was determined in women approximately one year prior to conception, it was found that nearly half (49%) had weight gain that exceeded the recommendations. The offspring of those women had a 10% increase in FM compared to 6-year-old offspring of mothers with recommended or less than recommended GWG (Crozier et al., 2010). Greater than recommended GWG also was observed in a surprisingly large percentage of women in another study with 68% of overweight/obese women and 50% of normal weight women ($p < .01$; Kaar et al., 2014). This study found that women with GWG had offspring with a significantly higher BMI at the ages of 5 and 10 years compared to offspring of mothers with recommended GWG ($p < .001$). Compared to the two studies above, a slightly lower percentage of women were found to have greater than recommended GWG (40%) in a study that analyzed offspring between the ages of 2 and 18 years (Marerison-Zilko et al., 2010). Similar results were found after adjustments were made for maternal demographics and pregnancy characteristics (cesarean delivery, sex). Children born to the women who exceeded GWG recommendations were more likely to be overweight/obese than those born to mothers who gained the recommended amount of GWG. Contrary to all three, Wrotniak et al. (2008) analyzed GWG in the 1960's and found only 11% of their population gained more than the recommended amount of weight during pregnancy. Despite the low percentage of women with greater than recommended GWG, the study found comparable results with the strongest association between more than recommended GWG and offspring overweight/obesity among women with an underweight pre-pregnancy BMI ($p < .01$; Wrotniak et al., 2008)

Discussion

Pre-Pregnancy Weight Status

Many studies that analyzed the association between pre-pregnancy weight status and GWG with offspring overweight/obesity focused primarily on an overweight or obese pre-pregnancy weight status. However, two studies reported GWG to have a greater impact on offspring overweight/obesity in women with an underweight or normal weight pre-pregnancy weight status, suggesting that underweight women should not be ignored (Diesel et al., 2015; Wrotniak et al., 2008). Notably, both studies included populations with unique characteristics, so findings may not be generalizable to other populations of women.

Diesel et al. (2015) used secondary data from a prospective cohort that was originally designed to study the association between prenatal alcohol and marijuana use and child development. Therefore, that population consisted mainly of low-income women in the U.S. who reported substance abuse early in their pregnancies. According to data from the National Survey on Drug Use and Health, only 5.4% of pregnant women in the U.S. abused illicit drugs from 2012-2013, and 10.2% of pregnant women reported drinking alcohol (CDC, 2015). The percentage of U.S. women who abuse alcohol is higher than the percentage of women who abuse illicit drugs, but the percentages are still low enough to limit generalizability of study findings. It is unclear how the influence of drug and alcohol use during pregnancy may affect fetal development as a contributing factor to later associations with childhood obesity. Further research is needed to explore these associations.

The second study examined a population of women who were pregnant in the U.S. during the 1960's (Wrotniak et al., 2008). Only 11% of these women had more than recommended

GWG, which is considerably low compared to the populations in other studies which were analyzed in more recent years (Castillo et al., 2014; Kaar et al. 2014; Stuebe et al. 2009;). Since 1960, the percentage of obese adults at the age of 20 years and older increased from 13.4% to 35.7% (U.S. Department of Health and Human Services, 2012). The increase in the prevalence of obese adults indicates that the lifestyles today are different than the 1960's when exceeding GWG recommendations was less common. The women in this study were probably more likely to have lifestyle habits (diet, exercise) prior to pregnancy that promoted a healthy weight status. These habits were likely continued during pregnancy and later adopted by their offspring, explaining why only 5.7% of children in this study were overweight at the age of 7 years.

In more recent studies, women with an overweight/obese pre-pregnancy weight status had a greater risk of having overweight/obese offspring (Castillo et al., 2015; Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015; Laitinen et al., 2012). The consistency in the results from more recent studies may be partially explained by lifestyle characteristics. As mentioned above, the prevalence of overweight and obesity in the U. S. and other developed countries increased over the years. Only 13% of Americans consume the recommended one and a half to two cups of fruit every day, and less than 9% eat the recommended two to three cups of vegetables a day (CDC, 2015). Furthermore, only 20.6% of Americans met the total recommended amount of exercise a week (CDC, 2013). These data elucidate how the lifestyles of many Americans do not promote a healthy weight status. If women are overweight/obese prior to pregnancy, they will likely impart their lifestyle choices to their offspring.

Another study that provides supporting evidence for a strong association between pre-pregnancy weight status and offspring overweight/obesity included a population that differed from the others in regard to socioeconomic status and geographic location ($p < .001$; Castillo et al., 2015). The population in this study was from the middle class country, Brazil. Other studies that analyzed pre-pregnancy weight status were conducted in high-income countries such as the U.S., United Kingdom, and Australia. This suggests that regardless of socioeconomic status or geographic location, pre-pregnancy weight status may be a very strong influence on offspring overweight/obesity.

Gestational Weight Gain

Associations between early pregnancy GWG and offspring overweight/obesity were consistent among studies that divided GWG into three periods of pregnancy (Fraser et al. 2010; Gaillard et al., 2014; Gaillard et al., 2015; Laitinen et al., 2012). All four studies found a strong association between high early pregnancy GWG and offspring overweight/obesity. These consistent findings suggest physiological occurrences in utero may be part of the explanation. However, a limitation in all but one study (Gaillard et al., 2014) is that early pregnancy GWG was measured at least one week past the 13th week of gestation. This difference in measurements could have led to an overestimation for observed associations between GWG in early pregnancy and offspring overweight/obesity and an underestimation for mid-pregnancy GWG. Laitinen et al. (2012) studied GWG up to 20 weeks gestation rather than analyzing each trimester separately or as total GWG. This measurement makes it more difficult to attribute the association found between GWG and offspring overweight/obesity to weight gained in the first trimester or weight gained in the second trimester.

There were mixed results among the three studies that analyzed GWG in mid-pregnancy (Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015). As with early pregnancy, the studies analyzed GWG past the second trimester cut off. When mid-pregnancy GWG was measured up to 36 weeks gestation, an association was found between mid-pregnancy GWG and offspring overweight/obesity that was not explained by birth characteristics (Fraser et al., 2010). The association only existed when women gained > 500 grams/week, which suggests that lifestyle characteristics may play a part in the offspring overweight/obesity. Intrauterine factors likely played a role in the associations between early pregnancy GWG in this study because it was true for women regardless of the amount of excess GWG. In this study, the women who gained > 500 grams/week in the second trimester may have been more likely to lack adequate physical activity and eat a less healthy diet than those who gained < 500 grams/week. Considering these lifestyle characteristics were presumably maintained throughout pregnancy, it is probable that they were passed on to their offspring leading to overweight/obesity. The average weight gain in the other two studies (Gaillard at al., 2014; Gaillard et al., 2015) was < 500 grams/week, suggesting why there was no independent association found between mid-pregnancy GWG and offspring overweight/obesity. However, in both studies, socially disadvantaged and lower educated participants were more likely to drop out of the research. This leaves room to question whether an association between mid-pregnancy GWG and offspring overweight/obesity would result if these socioeconomically disadvantaged and lower educated women had stayed in the study.

A limitation found among the majority of the studies was the use of self-reported data. Each study, with the exception of two (Crozier et al., 2010; Rooney et al., 2010), relied on data

for at least one of their variables that was obtained through a survey, an interview, or a journal. One study that did not use self-reported data studied women approximately a year before they became pregnant, giving them the advantage of assessing and obtaining maternal measurements before conception (Crozier et al., 2010). The other study had trained research associates review and extract data from maternal and offspring medical records (Rooney et al., 2010). In contrast, there were two studies that completely relied on self-reported data for both maternal variables and offspring height and weight (Oken et al., 2008; Stuebe et al., 2009), and another four studies relied on self-reported data only for both maternal variables and obtained offspring measurements during follow-up visits (Castillo et al., 2015; Diesel et al., 2015; Margerison-Zilko et al., 2010). The remainder of the studies used self-reported pre-pregnancy measurements and acquired GWG and offspring measurements through medical records and/or follow-up visits (Beyerlein et al., 2012; Fraser et al., 2010; Gaillard et al., 2014; Gaillard et al., 2015; Wrotniak et al., 2008).

Self-reported data may lead to inaccuracies in data analyses and the interpretation of findings. According to a study that analyzed the accuracy of maternal recall of GWG, a large proportion of women are misclassified into GWG categories when they were asked to recall GWG an average of eight years after delivery (McClure, Bodnar, Ness, & Catov, 2011). Another study found that when women of all BMI categories were asked to recall their pre-pregnancy weight, they consistently recalled a weight that was 1.52 kg less than their actual weight (Russel, Gillespie, Satya, & Gaudet, 2013). This study also found that those same women over reported their GWG by 1.61 kg. This suggests that the studies that relied on self-reported maternal

measurement may have inaccurate data interpretations if the women they analyzed under-reported or over-reported their measurements.

The articles analyzed in this literature review analyzed populations that were primarily of mixed racial and ethnic backgrounds. None of the articles focused their research on a particular race or ethnic group with regard to the association between childhood obesity and pre-pregnancy weight status and/or GWG. One study did, however, find that the majority of children who were born to overweight/obese mothers were of the Hispanic or African American descent ($p < .004$; Kaar et al., 2014). However, further research needs to be conducted to evaluate the influence of racial and ethnic background on the associations between childhood obesity and pre-pregnancy weight status and/or GWG.

Nursing Implications

Educating is an important aspect of nursing care, especially during pregnancy because it is a new experience for many patients. The profound association found between pre-pregnancy weight status and GWG with offspring overweight/obesity suggests that the education provided by nurses should focus on helping women of childbearing age achieve a healthy weight status prior to conception and maintain a healthy weight gain rate during pregnancy, with an emphasis on the first trimester. Nurses can do this by educating women about recommended GWG goals, a well-balanced diet, and other lifestyle choices that promote a healthy pregnancy.

Nurses can refer women to reliable sources, such as the Pregnancy Weight Gain Calculator and the MyPlate Daily Checklist, to help them attain their goal GWG and maintain it throughout their pregnancy (United States Department of Agriculture, 2017). Since the first trimester was observed to have the strongest association between GWG and childhood overweight/obesity, it is important to begin education at the first prenatal visit or as early as possible. The accessibility and ease of the Pregnancy Weight Gain Calculator provides women the opportunity to determine their GWG goals early in their pregnancy based on pre-pregnancy measurements. The second tool is a checklist that is individualized to women's age, height, weight and activity level. The checklist is used to show women the types and amount of food they should consume on a daily basis depending on the number of weeks gestation in their pregnancy.

In addition to consuming a nutritious diet, participating in regular physical activity can help women reach their GWG goals (ACOG, 2015). Nurses should encourage women to ask

health care providers about being evaluated for physical activity during their pregnancy. ACOG (2015) recommends women with uncomplicated pregnancies to participate in both aerobic and strength-conditioning exercise before, during, and after their pregnancies to help with weight management and gestational diabetes prevention.

Nurses also should focus on integrating family planning into women's health care to educate women about their individual nutritional needs before trying to conceive. Family planning helps give women the choice regarding when they want to begin trying to conceive, which gives the patient and the healthcare team time to assess nutritional status and activity behaviors to develop individualized plans and interventions. Advocating for family planning with timely patient education may help decrease children's risk for overweight/obesity by promoting a healthy pre-pregnancy weight status.

Conclusion

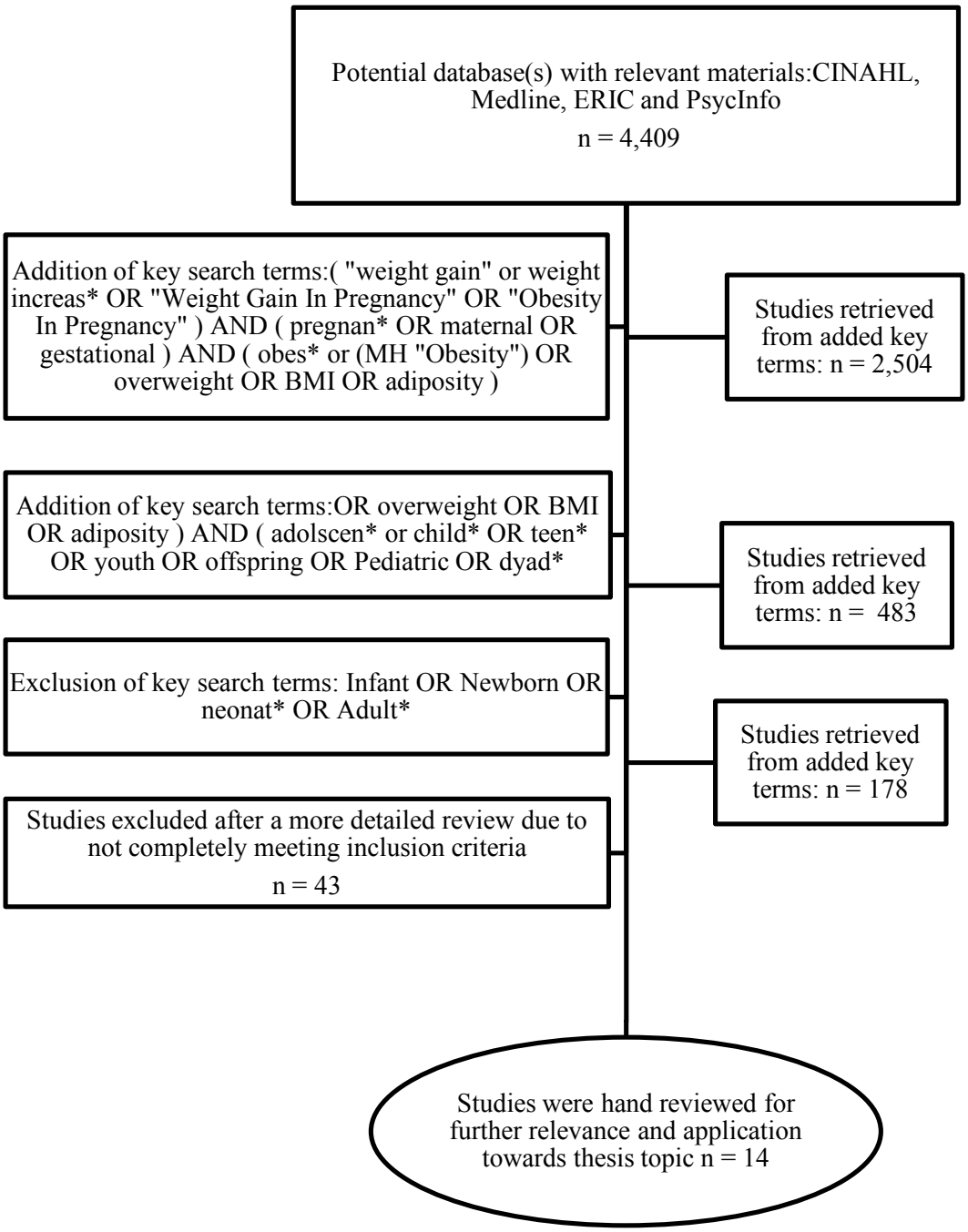
After analyzing the body of literature about the associations between pre-pregnancy weight status and/or GWG with obesity in older children, the findings suggest that both maternal factors may contribute to offspring overweight/obesity. An underweight and overweight/obese pre-pregnancy weight status and greater than recommended GWG, especially in early pregnancy, revealed a strong association with increased risk for offspring overweight/obesity between 5 and 18 years old. These findings support adhering to the IOM's 2009 recommendations for GWG and lend endorsement for furthering education and interventions aimed at healthy nutrition and physical activity for women of childbearing age prior to conceiving and during early pregnancy. Due to the strength of the association found between both an underweight and overweight/obese pre-pregnancy weight status and offspring risk for obesity, an emphasis should be put on achieving and maintaining a healthy weight status for women of childbearing age who plan to become pregnant. Early pregnancy should also be seen as a critical time for managing GWG in pregnant women, even in women with a normal pre-pregnancy weight status. Mixed results among GWG in other periods of pregnancy supports furthering research focused on analyzing GWG in different periods of pregnancy.

Appendix A: Flow Chart - Article selection process

Figure 1.1

Key terms: (“weight gain" or weight increas* OR "Weight Gain In Pregnancy" OR "Obesity In Pregnancy”) AND (pregnan* OR maternal OR gestational) AND ("Body Mass Index" OR obes* or (MH "Obesity") OR overweight OR BMI OR adiposity) AND (offspring OR Pediatric*)

Limiters used: Published Date: 01/01/2006 – 12/31/2016; Scholarly (Peer Reviewed) Journals; English Language; Research Article



Appendix B: Table of Evidence

Author, Year, Geographic Location	Study Design Sample Size Child Age	Variables	Methods	Key Findings	Other
Beyerlein et al. (2012) Germany	Prospective 6,254 mother-child pairs 5-6 y	GWG Offspring BMI	**Pre-pregnancy BMI** Obtained from three German cohort datasets **Gestational Weight Gain** Combined individual data from 3 German cohort datasets. Wt. and ht. self-reported or obtained from medical records Total GWG calculated as difference btwn maternal pre-pregnancy wt. and wt. at delivery wt. from the 1st prenatal visit (10.3wks.) to wt. just prior to delivery. **Offspring BMI** Ht. and wt. reported on questionnaire by parent and pediatrician	Excessive GWG was associated w/ a 28% ↑ risk for childhood overweight in mothers w/ normal pre-pregnancy wt. status ($p < .05$) Similar associations unclear in mother w/ overweight/obese pre-pregnancy wt. status	

Castillo et al. (2015) Brazil	Prospective 3156 mother-child pairs for pre-pregnancy 3129 mother-child pairs for GWG 6 yo	Pre-pregnancy BMI GWG Fat Mass (FM) Fat Free Mass Fat Mass Index (FMI) Body Fat % (BF%)	**Pre-pregnancy BMI** Ht. and wt. obtained from perinatal record or, when absent, by self-report. **Gestational Weight Gain** Total GWG calculated as difference between pre-pregnancy wt. and last recorded wt. just before delivered. Defined as adequate/inadequate based on IOM guidelines. **Offspring FM, FFM, FFM & BF%** Obtained through air displacement plethysmography. Wt. measured w/ Tanita scale. Ht. measured w/ Harpenden Stadiometer	↑ pre-pregnancy BMI and ↑ GWG directly associated w/ ↑ FM, FFM, FFI and BF%. Children from mothers with normal or overweight pre-pregnancy BMI who gained excessive wt. during pregnancy had ↑ FM, FFM and FMI. ($p < .001$) Pre-pregnancy BMI showed stronger association w/ FM, FMI, BF%, and FFM than GWG Children born to mothers who were overweight/obese before pregnancy had ↑ amount of FM than children of normal or underweight pre-pregnant mothers.	

Crozier et al. (2010) UK	948 mother-child pairs 6 y	Pre-pregnancy GWG Child FM	**Pre-pregnancy BMI** Ht. and wt. measured during home visits about 1.1 YEARS before conception by research nurses **Gestational Weight Gain** Measured at 11, 19, and 34 wks. gestation Total GWG calculate as difference between pre-pregnancy wt. and wt. at 34 wks. gestation **Offspring Fat Mass** Measured using whole body Dual-energy X-ray absorptiometry (DXA) scans	Offspring of mother who gained excessive wt. compared to those of mothers who gained adequate wt. had ↑ FM ($p = .05$)	

Diesel et al. (2015) USA	Prospective 514 mother-child pairs 10 & 16 y	Pre-pregnant GWG Child BMI Race/Ethnicity	**Pre-pregnancy BMI** Calculated form self-reported ht. and wt. **Gestational Weight Gain** Total GWG self-reported at delivery **Offspring BMI** Measured by research nurses using a calibrated scale	Risk of offspring obesity ↑ when GWG ≥ 30kg (66.1lbs) by 40 wks. No relationship w/ child obesity risk when gains < 30kg (66.1lbs) by 40 wks. Pre-pregnancy BMI < 25 w/ GWG ≥ 30kg (66.1lbs) by 40 wks. associated w/ ↑risk of obesity in offspring at ages 10 and 16 If pre-pregnancy BMI ≥ 25, no association found between GWG and offspring obesity	Low income mothers-child pairs only 68% unmarried 61% household income < $400 per month 13% >12 years of schooling Marijuana use common in first trimester 29% overweight/obese pre-pregnancy BMI

Fraser et al. (2010) UK	Prospective 5154 mother-child pairs 9 yo	Pre-pregnancy wt. GWG Child BMI	**Pre-pregnancy Wt.** Self- reported questionnaire **Gestational Weight Gain** Obtained from medical records Early pregnancy measured between 0-14 wks. Mid pregnancy measured between 14-36 wks. Late pregnancy measured between 36 wks. until delivery **Offspring BMI** Calculated from wt. measured w/ Tanita scales and ht. measured w/ Harpenden stadiometer.	Women with excessive GWG were more likely to have offspring w/ ↑ BMI ↑ GWG in early pregnancy associated w/ ↑ childhood BMI but even greater if mother gained > 500g/wk (1.1lbs) GWG mid pregnancy was only associated w/ offspring BMI in women who gained >500 g/wk. (1.1lbs) Unclear association btwn GWG in late pregnancy and offspring adiposity Pre-pregnancy wt. positively associated w/ offspring BMI but no interaction found between pre-pregnancy wt. and GWG in their associations w/ offspring BMI Stronger associated found btwn pre-pregnancy wt. and offspring BMI than any measures of GWG	

Gaillard et al. (2014) Rotterdam The Netherlands	Prospective Study 5908 mother-child pairs 6 y	Rates of early pregnancy, mid-pregnancy and late pregnancy GWG Total GWG Pre-pregnancy Weight Child BMI	**Pre-pregnancy BMI** Self-reported questionnaire. 4874 of the mothers had information on pre-pregnancy ht. and wt. **Gestational Weight Gain** Early pregnancy measured at 13.2 wks. Mid-pregnancy measured **btwn** 13.4 - 29.9 wks. Late pregnancy measured **btwn** 29.9 - 39.0 wks. **Offspring BMI** Wt. defined by the international Obesity Task Force (IOTF) cutoffs	Associations of pre-pregnancy wt. w/ childhood BMI was stronger than associations of GWG GWG in early and mid, but not late pregnancy associated w/ childhood overweight and obesity Only pre-pregnancy wt. and GWG in <u>early</u> pregnancy were independently associated w/ overweight/obesity in offspring. ($p < .05$) GWG in mid-pregnancy explained by birth characteristics	Mothers without childhood follow up data often lower educated thus creating a study limitation Association of wt. gain later in pregnancy partly explained by birth characteristics (newborn wt.)

Gaillard et al. (2015) Western Australia	Prospective study 1,392 mother-child pairs Age 17 y	Rates of early-pregnancy and mid-pregnancy GWG Total GWG Pre-pregnancy Weight Child BMI	**Pre-pregnancy BMI** Ht. measured at enrolment, wt. obtained through questionnaire **Gestational Weight Gain** Gestational weight obtained from medical records at 16wks and 34wks. Early- pregnancy wt. gain rate defined as the avg. weekly weight gain between the start of pregnancy and 16 wks. Mid-pregnancy weight gain rate defined as the avg. weekly weight gain between 16wks -34 wks. Total GWG <u>rate</u> defined as the avg. weekly weight gain between start of pregnancy and 34 wks. gestation **Offspring BMI** Electronic chair scales and a stadiometer used to measure wt. and ht.	↑ Pre-pregnancy BMI associated w/ ↑ adolescent BMI ($p < .05$) Higher wt. gain in early pregnancy (but not mid pregnancy) associated w/ ↑ adolescent BMI Higher Total GWG associated w/ ↑ adolescent BMI Pre-pregnancy BMI had stronger association w/ adolescent BMI than early pregnancy weight gain rate. Mid-pregnancy wt. gain rate showed no association w/ child BMI	Socially disadvantaged participants more likely to drop out of the study especially within the first 3 years 17 year follow up attrition was mainly from socially disadvantaged participants

Kaar et al. (2014) Colorado United States	Prospective 313 mother-child pairs Age 10 y	Pre-Pregnancy weight GWG Child BMI Race/ethnicity	**Pre-pregnancy BMI** Wt. measured before last menstrual cycle preceding pregnancy. Ht. measured at research visit. **Gestational Weight Gain** Measured during each trimester and as total GWG. Categorized as meeting or exceeding IOM's recommendations based on pre-pregnancy BMI. **Offspring BMI** Ht. and wt. measured twice at each visit w/ SECA scale and SECA stadiometer.	Overweight/obese mothers at prepregnancy exceeded the IOM's GWG recommendations (68%) more than normal pre-pregnant weight women (50%) ($p < .01$) Pre-pregnancy BMI associated w/ increased BMI, particularly among mothers w/ excessive GWG ($p < .001$) Effect of pre-pregnancy BMI on childhood BMI outcomes is weak for offspring of mothers w/ adequate vs. excessive GWG	Part of larger EPOCH study designed to analyze long term effects of GDM on offspring. Cohort is enriched in offspring of GDM mothers but is not all inclusive. More offspring of overweight/obese mothers were of Hispanic or African American descent ($p = .004$)

Laitinen et al. (2012) Finland	Prospective Mother-child pairs 3265 males 3372 females 16 y	Pre-pregnancy weight GWG Child BMI	**Pre-pregnancy BMI** Self- reported HT & WT **Gestational Weight Gain** Wt. gain during the 1st 20 wks. of gestation based on difference BTWN weight at 20 wks. gestation and self-reported pre-pregnancy weight and THEN classified into 4 quartiles. **Offspring BMI** Calculated from measured height and weight, classified according to the IOTF	Wt. gain > 7kg (15.4 lbs.) during the 1ST half of pregnancy was associated w/ 1.5 fold ↑ risk for adolescent overweight/obesity Pre-pregnancy obesity associated w/ 4-fold ↑risk for adolescent offspring overweight/obese	Only measured GWG up to 20 wks.
Margerison-Zilko et al. (2010) USA	Prospective cohort 4,496 mother-child pairs 2-20 y	Pre-pregnancy GWG Child BMI	**Pre-pregnancy BMI** Self-report **Gestational Weight Gain** Self-report by survey. Total GWG Calculated as the difference between maternal pre-pregnancy weight and weight at delivery. **Offspring BMI** Ht. and wt. taken by interviewer or reported by mother	Gaining > recommended GWG ↑ the risk for child overweight Overweight/obese women pre-pregnancy more likely than normal weight women to have overweight offspring Results suggest that ↓ than IOM 2009 recommended gains in overweight/obese women may ↓ offspring overweight	GWG associated w/ child overweight independent of maternal demographic (income, education, marital status, smoking) and pregnancy characteristics.

Oken et al. (2008) USA	Prospective 11,994 mother offspring pairs 9-14 yo	Pre-pregnancy weight GWG Child BMI	**Pre-pregnancy BMI** Ht. and wt. self- reported on questionnaire **Gestational Weight Gain** Self- reported. Categorized in 5lb increments according to IOM 1990 Guidelines **Offspring BMI** Ht. and wt. self- reported on questionnaire	Pre-pregnancy BMI and GWG significant predictors of offspring obesity. Gain of >40 lbs. significantly associated w/ ↑child BMI z-score based on age and gender Mothers w/ excessive GWG had children w/ ↑ odds of obesity In adjusted regression models, child BMI z-scores ↑ by 0.03 units for each 5 pounds of GWG. Pre-pregnancy BMI category not associated w/ offspring BMI (P = 0.69 for offspring obesity and 0.63 for offspring overweight)	Mothers who were obese prior to pregnancy and mothers who had never smoked gained ↓ wt. than their peers

Rooney et al. (2010). USA	Prospective 777 4-20 y	Pre-pregnancy GWG Child BMI Offspring Age Group	**Pre-pregnancy BMI** Ht. and wt. obtained from medical records **Gestational Weight Gain** Medical records Total GWG defined as difference in wt. from the 1st prenatal visit (10.3wks.) to wt. just prior to delivery. Obtained at 10.3 wks., 20 wks., and just prior to delivery. **Offspring BMI** Medical records reviewed from original birth cohort **Offspring Age Groups** Childhood- birth to 5 yrs. Adolescence- 9 to 14 yrs. Early Adulthood0 18-20 yrs.	Pre-pregnancy obesity was a significant predictor of childhood, adolescent and early adulthood obesity % of obese offspring of mothers w/ obese pre-pregnancy BMI:: childhood (52%), adolescence (62%) and early adulthood (44%) Children with obese prepregnant mothers more likely to be obese compared to those of mothers with normal pre-pregnancy BMI Pre-pregnancy obesity and excess GWG related to an ↑ risk of obesity at adolescence and early adulthood (9-20) but not childhood	

Stuebe et al. (2009) USA	Retrospective 26,506 mother-child pairs 18 y	Pre-pregnancy weight GWG Child BMI	**Pre-pregnancy BMI** Self-reported ht. and wt. questionnaire 36-56 yrs after delivery **Gestational Weight Gain** Self-reported on questionnaire 36-56 yrs after delivery **Offspring BMI** Self-reported on questionnaire at age 18	Pre-pregnancy BMI significantly associated w/ GWG. GWG > or < 15-19lbs associated w/ ↑ risk of offspring obesity at age 18. Association modest w/normal pre-pregnancy BMI and strong among higher pre-pregnancy BMI ($p < .03$) ↓ risk of offspring obesity w/ GWG btwn 15-19lbs. > 40lbs GWG associated w/ a 2.13 fold ↑ in odds of obesity in offspring. Associations stronger in women with overweight/obese pre-pregnancy BMI ($p < .03$)	All females

Wrotniak et al. (2008) USA	Retrospective 10,266 7 yo	Pre-pregnancy GWG Child BMI	**Pre-pregnancy Weight BMI** Ht. and wt. obtained through questionnaire **Gestational Weight Gain** GWG determined as the difference between measured wt. at delivery and reported pre-pregnancy wt. **Offspring BMI** Measured at pediatric exam	Children of mothers w/ more than recommended GWG more likely to be overweight than those whose mothers who gained recommended GWG Mothers with an underweight pre-pregnancy BMI showed a stronger association btwn GWG and offspring overweight/obesity compared to mothers with a normal or overweight pre-pregnancy BMI ($p < .01$)	Magnitude of association between GWG and childhood overweight/obesity ↓ after infant birth wt. was added to logistic regression model, but is unlikely to entirely explain the association found.

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