



The impact of maternal BMI, gestational weight gain, and breastfeeding on early childhood weight: Analysis of a statewide WIC dataset[☆]



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ABSTRACT

Early childhood obesity is a persistent health concern with more frequent and significant impact on low-income families. Maternal weight factors impact offspring weight status, but evidence on whether breastfeeding protects against this impact is mixed. This analysis examined a model to predict early childhood obesity risk, simultaneously accounting for maternal pre-pregnancy body mass index (BMI), gestational weight gain, and breastfeeding. The team analyzed 27,016 unique maternal-child dyadic records collected via the Supplemental Nutrition Program for Wisconsin Women, Infants, and Children (WIC) between 2009 and 2011. Generalized Linear Modeling, specifically logistic regression, was used to predict a child's risk of obesity given the mother's pre-pregnancy BMI, gestational weight gain, and duration of breastfeeding. For each 1 kg/m² increase in pre-pregnancy BMI, there was a 4.5% increase in risk of obesity compared to children with mothers of normal BMI. Children whose mothers had excessive gestational weight gain were 50% more likely to have obesity compared to those whose mothers had ideal weight gain. For each week of additional breastfeeding, there was a 1.9% increased risk of obesity. The risk models did not differ by race. In this model, accounting for pre-pregnancy weight, gestational weight gain, and breastfeeding among a diverse, low-income sample, women with pre-pregnancy overweight and obesity or who had excessive gestational weight gain had the highest risk of early childhood obesity. While breastfeeding is healthy for many reasons, providers should focus on maternal weight-related behaviors when counseling mothers about how to avoid risk of early childhood obesity.

1. Introduction

Obesity among young children has lifelong implications, thus early prevention of obesity remains a high priority. Preschool children with lower socioeconomic status (SES) are at higher risk for overweight and obesity and the associated lifespan health risks, including diabetes and heart disease (Centers for Disease Control and Prevention [CDC], 2013; Pulgaron 2013). Both rapid weight gain in infancy and overweight and obesity during the preschool years increase risk for being overweight or obese in adulthood (Andrea et al. 2017; CDC, 2013; Lamb et al. 2010; Shankaran et al. 2011).

In the United States, approximately 14% of preschool-aged children are obese. This rate is higher among African American (20.0%) and Hispanic preschoolers (17.7%) (CDC, 2013; Hales et al. 2017). Nationally, preschool obesity rates have decreased slightly. However, the state of Wisconsin has remained consistently above national preschool-

age obesity averages, with 17% of children overweight and 14.7% obese (CDC, 2013).

Childhood overweight and obesity adds an additional \$14.1 billion in annual healthcare expenditures in the United States, due to extra outpatient visits, prescription drugs, emergency room visits, and extended lengths of stay for children who are hospitalized with obesity related comorbidities compared to those who are not obese (Pelone et al. 2012; Trasande and Chatterjee 2012). Children in low-income families are at a higher risk for overweight and obesity, increasing financial burden to families that can least afford it. Obese children also bear a lower psychosocial quality of life, due to stigma (Wallander et al. 2012). Efforts to prevent childhood obesity tailored to this population that experiences health disparities are a national health priority (U.S. Department of Health & Human Services, 2014).

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1.1. Statement of the problem and literature review

The causes of childhood overweight and obesity and subsequent risk for obesity-related chronic illness include factors beginning as early as the intrauterine environment, continuing through the first year of life and beyond (Norris et al., 2012; Margerison Zilko et al., 2010; Tomar et al. 2015). A complex interplay of genetic predisposition combined with influences on epigenetic expression—including intrauterine exposures to maternal overweight and obesity, gestational weight gain, and feeding practices in the early childhood period—all contribute to the development of childhood obesity and are opportunities for prevention (Langley-Evans 2014; van Dijk et al. 2015).

Known predictors of childhood overweight include: female gender, intrauterine diabetes exposure, large for gestational age at birth, shorter breastfeeding duration, and rapid infant weight gain (Gopinath et al. 2012; Goodell et al. 2009; Santos et al. 2009; Lamb et al. 2010). Maternal weight factors, such as pre-pregnancy obesity, as well as gestational weight gain that exceeds recommendations, have also been identified as contributing to childhood obesity (Kaar et al. 2014; Tie et al. 2014). Some studies have found that breastfeeding lowers risk of childhood obesity (Grummer-Strawn and Mei, 2004; Moss and Yeaton 2014; Umer et al. 2015). However, the evidence is mixed: systematic reviews of breastfeeding have determined that the evidence for lowering childhood obesity risk is limited by the quality of research and variations among vulnerable populations (Hess et al. 2015; Lefebvre and John 2014).

Among the body of evidence, only one study has examined the combined effects of maternal factors including pre-pregnancy weight status and gestational weight gain along with infant feeding choices, like breastfeeding initiation and duration, in relation to childhood risk of overweight. The study was limited in its generalizability as it included only children who had been identified as at risk for diabetes in its sample (Lamb et al. 2010). This study is unique in examining the relationships between all these variables in a more generalized sample of low-income children.

Furthermore, there are limited studies that have examined race/ethnicity as it relates to the effects of pre-pregnancy weight status, gestational weight gain, and infant feeding choice. In a large retrospective cohort study, with an overall diverse sample. Heerman et al. (2014) found that pre-pregnancy obesity combined with excess gestational weight gained increased the likelihood of childhood obesity through the first year of life. The authors however, did not analyze the impact race may have had on childhood weight outcomes. This study will address this gap in understanding.

The aim of this research was to test the hypothesis that maternal pre-pregnancy weight status, gestational weight gain, maternal feeding choices and the weight status of the woman's offspring are interrelated. Specifically, the focus of this research is the relationship between these variables among women and children who participate in the Wisconsin WIC program in order to provide evidence for future targeted interventions for at risk women and children to reduce risk of unhealthy weight and its sequelae.

This study will help perinatal healthcare providers who have an opportunity to influence weight-related behaviors, including nutrition for the maternal-child dyad (Karnon et al. 2013; Streuling et al. 2010). As we better understand these modifiable factors and their contribution to weight-related risk to offspring, we can better plan interventions that can be delivered during pregnancy with the potential to influence multiple generations in a vulnerable population.

2. Research questions

1. What is the relationship between maternal pre-pregnancy body mass index (BMI), gestational weight gain and child overweight during the first 2 years of life?
2. Is the relationship between maternal pre-pregnancy BMI, gestational

weight gain, and child overweight moderated by duration of breastfeeding?

3. Are there differences in the relationship between pre-pregnancy BMI, gestational weight gain, and child overweight based on race/ethnicity?

3. Methods

3.1. Design and sample

This study was a retrospective correlational study. We analyzed the clinic visit records for 27,016 maternal-child dyads enrolled in the Wisconsin WIC program that were collected and reported for the Center for Disease Control and Prevention's Pregnancy Nutrition Surveillance Survey (PNSS) and the Pediatric Nutrition Surveillance Survey (PedNSS) between 2009 and 2011. The datasets contained a randomized code that was used to link the maternal record reported to the PNSS with the child record reported to the PedNSS. The data was provided to the research team directly from the Wisconsin WIC Program and was de-identified and encrypted by the research team for protection of privacy. Institutional Review Board approval was secured from the academic institution before conducting the research.

3.2. Measures

The outcome of interest for this study was early childhood obesity. Child obesity was classified as infants above the 95th percentile of weight-for-length at their chronological age using Centers for Disease Control and Prevention growth charts, up to age 2 years (McCormick et al. 2010; Ogden et al. 2014).

The independent (predictor) variables were represented by the following data points from the dataset: Weeks of breastfeeding, race/ethnicity, pre-pregnancy BMI, and gestational weight gain as reported to PNSS or PedNSS. The data were coded into one of 3 categories for analyses because gestational weight gain is meaningful only when categorized as: 1) less than recommended, 2) appropriate, or 3) excessive based on the woman's pre-pregnancy BMI using the Institute of Medicine (IOM, 2009) guidelines.

3.3. Analytic strategy

Generalized linear modeling was used to analyze the data, specifically using logistic regression (Agresti 2007). Logistic regression specifies a model to predict binary data by the addition of the logit link; this way it predicts the increase/decrease in log-odds to score 1 in the binary outcome. The logit link function transforms continuous predicted values to the range of probabilities [0, 1]. These log-odds are later transformed into odds ratio (OR) and probabilities for interpretation and presentation as effect sizes. The OR represents the multiplicative change in the odds of scoring 1 in the binary outcome variable. The results are presented as OR and probability increase/decrease of child overweight as multiple interpretations of the effect sizes, and with plots representing the expected change in probability in function the predictors (Agresti 2007; Gelman and Hill 2007).

To answer research questions 2 and 3, we tested the moderating/interaction effects by including the interaction between the predictors and the possible moderating variables. For research question 2, we tested if weeks of breastfeeding moderates any relation between predictor and outcome. For research question 3, we tested if race/ethnicity moderated the other relations between predictor and outcome. These interactions were tested by probing and plotting, by both looking at the significance testing for the interaction, and plotting the change in the relations based on the moderating variables (Darlington and Hayes 2017).

The research team established an a priori plan to use Multiple Imputation (MI) to account for missing clinical data (Enders 2010;

Rubin 1987; Baraldi and Enders 2010). Multiple Imputation allows for maintaining every subject in the data without losing power, while decreasing the possible bias of the estimates. For this project we used 100 imputations, which allowed for proper point estimates and for estimation of the standard error. Of the variables included in the analysis, weeks of breast-feeding and gestational weight gain are the ones with missing data, with 53.6% and 12.9% of missing values respectively. With MI the model presents the best estimates, accounting for variability due to missing data.

Data analysis was done with the R platform (R Core Team 2017). Multiple Imputation was performed using the R package, Amelia (Honaker et al. 2011). The results from the logistic regression on the imputations were combined with the R package, Zelig (Choirat et al. 2017).

4. Results

From the sample of 27,016 maternal-child dyads, 977 infants were categorized as obese, representing a 3.6% of the sample. Another 2291 infants were categorized as overweight (between the 85th and 95th percentile of weight-for-length-for-age), representing 8.5% of the sample. On average, mothers were overweight, with a mean BMI of 27.67 (SD = 7.07), and half of mothers had a higher than recommended gestational weight gain. On average, infants in the sample were small for age, with a mean weight-for-age percentile of 46.51 (SD = 29.14).

The number of children who were ever breastfed was n = 1,2519, representing 46.34% of the sample. Among the breastfed children, 5716 (45.66%) were above the 50th percentile of weight-for-age, and the mean duration of breastfeeding was 5.58 weeks (SD = 7.14). The sample was racially diverse and reflected the population of Wisconsin: 19.08% of the sample was African-American and 18.74% were Hispanic (Table 1).

Four theoretical models were analyzed. The first one predicted the probability of child overweight given the mother's BMI, weeks of breast feeding, and weight gain category according to the IOM gestational weight gain recommendations (2009). The second model included weeks of breastfeeding as a moderator of the other relations. The third model added ethnicity to the above predictors. And the last model, included ethnicity as the moderator of the other relations.

Table 2 presents the results for the first model. As is appropriate for

Table 1
Sample descriptors.

	Mean (SD) n = 27,016	Range
Infant age	1.72 (2.11)	0.0–11.83
Mother age (years)	25.07 (5.60)	12.0–53.0
Pre-pregnancy BMI	27.67 (7.07)	15.1–59.9
Infant weight percentile	46.51 (29.14)	0.0–99.9
Weeks of breast feeding	5.58 (7.14)	0.0–47.0
		Percentage (%)
Infant obesity		3.6
Infant sex: male		50.49
Urban area		52.22
Maternal weight gain		
Ideal weight gain		28.37
Less than ideal weight gain		21.32
More than ideal weight gain		50.31
Race/ethnicity		
White		52.82
Black		19.08
Hispanic		18.74
Native American		4.03
Asian/Pacific Islander		5.33

Table 2
Model 1: logistic regression results for the outcome of early childhood obesity.

	Estimate (SE)	OR (95% CI)
Intercept	-3.549 (0.074)	0.028 (0.02, 0.03)
Mother BMI	0.044 (0.004)	1.045 (1.04, 1.05)
Weeks of BF	0.019 (0.004)	1.019 (1.01, 1.03)
Normal GWG	-0.089 (0.114)	0.914 (0.73, 1.14)
Excessive GWG	0.406 (0.088)	1.501 (1.26, 1.78)

generalized linear modeling, both pre-pregnancy BMI and weeks of breastfeeding were mean-centered, so that the intercept could be interpreted as a function of their average. The intercept OR represents the probability of child obesity when the mother has an average BMI, average weeks of breast feeding, and ideal weight gain; with a 2.8% (95% CI = 2%, 3%) chance of child obesity. Given the large sample, this study was considered over-powered; for this reason, the research team interpreted the effect size (OR) of each predictor variable to demonstrate the magnitude of the effects in the models.

Holding weight gain and weeks of breastfeeding constant, as a mother's pre-pregnancy BMI increased by 1 kg/m², the odds of child obesity increased by 1.045 (95% CI = 1.04, 1.05); an increase in 4.5% (95% CI = 4.0%, 5.0%) in the probability of obesity compared to children of mothers with normal pre-pregnancy weight. Holding pre-pregnancy BMI and gestational weight gain constant, as breastfeeding increased by 1 week, the odds of child obesity increased by 1.019 (95% CI = 1.01, 1.03); an increase in 1.9% (95% CI = 1%, 3%) in their probability of obesity.

Analysis of cases where the mother's weight gain was less than recommended by the IOM demonstrated no difference in probability of child obesity compared to the cases where the mothers had ideal weight gain (OR = 0.914, 95% CI = 0.73, 1.14). This represents on average a decrease in the probability of child obesity of 8.6% (95% CI 26.8, 14.2). Among mothers that gained more weight than recommended, the odds of child obesity increased by 1.50 (95% CI 1.26, 1.78); a 50% increase (95% CI = 26%, 78%) in their probability of child obesity compared to mothers with ideal weight gain, keeping mother BMI and weeks of breastfeeding constant.

Fig. 1 shows the results for the first model. With mother's pre-pregnancy BMI constant, probability of child obesity increased as weeks of breastfeeding increased; exhibiting a small effect. With weeks of breastfeeding constant, child obesity probability increased as the mother's pre-pregnancy BMI increased. These plots show the probabilities for participants with ideal weight gain, less than the ideal, and higher than ideal. Keeping weeks of breastfeeding and mother BMI constant, the participants with ideal weight gain did not differ from the participants with less than the ideal weight gain; the greater change in probability was for the participants that gain more weight than ideal. These participants have a higher probability of child obesity.

Interactions between the predictor variables and weeks of breastfeeding were tested to determine whether predictor slopes change in function of the duration of breastfeeding. After probing and plotting these results, we concluded that the relations are not changed in function of duration of breastfeeding with a p-value criterion of 0.05.

For the third model (Fig. 2), the effects of maternal pre-pregnancy BMI, weeks of breast feeding, and weight gain follow the same pattern as the first model, and these are not different across ethnicity groups. We found that Black children were less likely to be obese than White children (OR = 0.792; 95% CI = 0.66, 0.96). Both Hispanic children and the other group (Native American/multiple ethnicity) had an increased risk of child obesity compared to White children: OR 1.364 (95% CI = 1.16, 1.60) and OR 1.404 (95% CI = 1.05, 1.88) respectively. The Asian/Pacific Islander participants are as likely as the White children to be obese, OR 1.045 (95% CI = 0.75, 1.45).

Interactions between the predictor variables and ethnicity were tested to determine whether predictor slopes were different across

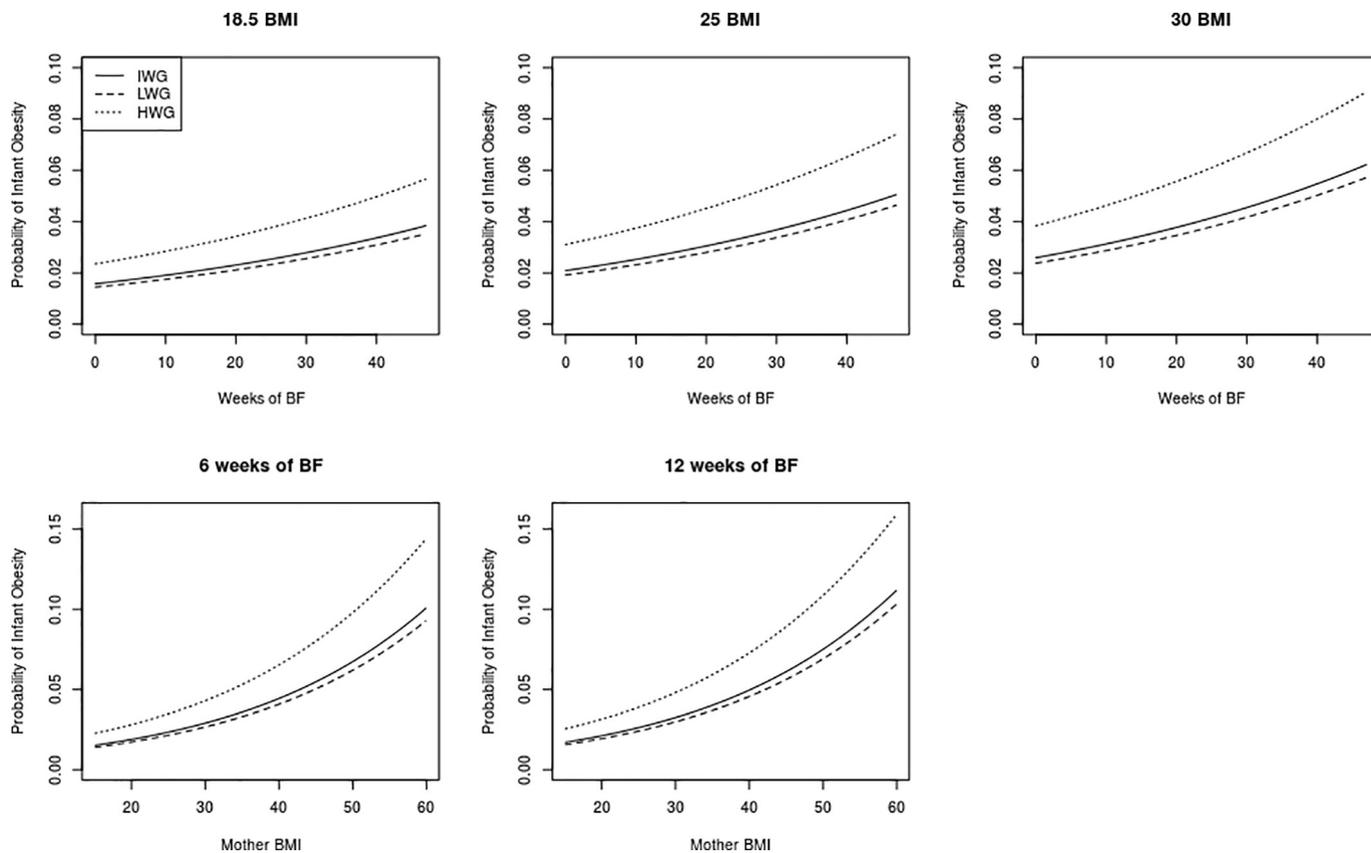


Fig. 1. Plots: mother BMI, weeks of breastfeeding, and weight gain.

ethnicity groups (Table 3). There were no meaningful interactions of ethnicity with the other predictors, tested by probing and plotting this moderation with a p-value criterion of 0.05.

5. Discussion

This is the only study to date to analyze a comprehensive model

with maternal pre-pregnancy BMI, gestational weight gain, and breastfeeding. We found only maternal weight factors had a statistically significant relationship to child weight in the first 2 years after controlling for the other factors. Maternal weight factors are crucial in determining a child's risk of becoming overweight and developing obesity (Kaar et al. 2014; Tie et al. 2014).

In this study, breastfeeding did not have the hypothesized protective

6 weeks of BF, more than ideal weight gain

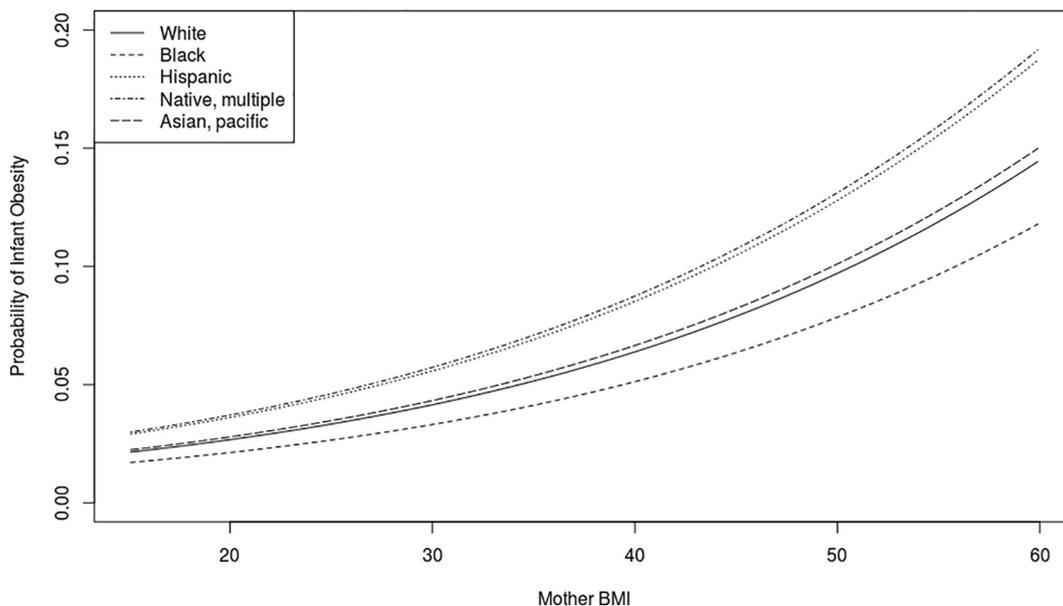


Fig. 2. Plots: differences by race/ethnicity.

Table 3
Model 2: logistic regression results for the outcome of early childhood obesity, analyzed for differences by race.

	Estimate (SE)	OR (95% CI)
Intercept	−3.602 (0.082)	0.027 (0.02, 0.03)
Mother BMI	0.045 (0.004)	1.046 (1.03, 1.06)
Weeks of BF	0.019 (0.004)	1.019 (1.01, 1.03)
Normal GWG	−0.085 (0.114)	0.918 (0.73, 1.15)
Excessive GWG	0.417 (0.088)	1.518 (1.27, 1.80)
Ethnicity		
Black	−0.233 (0.095)	0.792 (0.66, 0.96)
Hispanic	0.311 (0.082)	1.364 (1.16, 1.60)
Native American	0.339 (0.147)	1.404 (1.05, 1.88)
Asian/Pacific Islander	0.044 (0.166)	1.045 (0.75, 1.45)

effect against early childhood obesity after accounting for maternal weight-related factors; and, in fact the opposite relationship emerged in these analyses: breastfeeding of short duration was associated with increased risk of early childhood obesity (Fig. 1). Additionally, in every weight category, this risk was highest among mothers who gained more than recommended for their pre-pregnancy BMI, supporting the evidence that both pre-pregnancy weight and gestational weight gain are the strongest predictors of obesity risk up to age 1 year. Previous evidence for breastfeeding as a protective factor for childhood obesity among low-income families has been mixed, and there has been a wide variation in age of the children in the analyses, the duration of breastfeeding, and the populations.

Large data studies and systematic reviews have found a dose-related negative association between extended duration of exclusive breastfeeding and childhood overweight (Anderson et al. 2014; Grummer-Strawn and Mei 2004; Hess et al. 2015; Moss and Yeaton 2014). Like our study, one of these studies noted that there were variations in the effect of breastfeeding on childhood among racial sub-groups (Grummer-Strawn and Mei 2004). Overall, the evidence has supported breastfeeding as an intervention to promote healthy weight; however, these studies have not included important confounding factors that comprise weight-related risk to children.

Other studies that have accounted for other known childhood obesity risk factors such as SES in their analyses demonstrated no protective effect of breastfeeding (Etevez-Gonzalez et al., 2016; Victora et al. 2016). Studies that did find a protective effect of breastfeeding against child obesity found that the necessary duration of breastfeeding was a minimum of 2.5 months, with a range of 2.5 months–8 months of exclusive breastfeeding necessary to produce the protective effect (Hess et al. 2015; Moss and Yeaton 2014). The mean duration of breastfeeding among breastfed infants in our study was 5.58 weeks (SD = 7.1). It may be that the breastfeeding dose in this sample was not sufficient to provide protection against child obesity.

Additionally, most of the studies examining the effects of breastfeeding on child weight status have not included important confounding variables. In the study by Procter and Holcomb (2008) using Kansas WIC data from 1998–2002, longer duration of breastfeeding lowered the risk of childhood overweight at age 4 but there was no significant effect for breastfeeding after controlling for other obesity-related risk factors like race, environmental factors, and SES. Neither the Procter and Holcomb study nor any other studies have examined the three factors of pre-pregnancy BMI, gestational weight gain, and breastfeeding behaviors.

Our study suggests that maternal weight and gestational weight gain have such a strong impact that breastfeeding of short duration does not protect a child against obesity in the first 2 years of life. In fact, among low-income women who were obese and/or who gained excessive weight in pregnancy, a short duration of breastfeeding may increase obesity risk. This highlights the importance of preventive health behavior education to promote physical activity and dietary practices that comprise weight management throughout the

childbearing years, during pregnancy, and through the early parenting years.

In conclusion, healthcare providers should continue to intervene to support breastfeeding due to the many health benefits for mother and child (Bibbins-Domingo et al., 2016; Ostbye et al. 2010). However, the benefit of reducing early childhood obesity via breastfeeding is not supported by this study. If we are going to work toward an upstream solution to childhood obesity, we should focus efforts on behaviors women can change before and during pregnancy to potentially minimize the intrauterine exposures to maternal obesity and excessive pregnancy weight gain.

5.1. Limitations

Strengths of this study included a robust statistical analysis of a large, diverse sample. In particular, our use of WIC data ensured that we are examining these factors within a population of women and children most at risk for overweight, obesity, and the associated chronic health sequelae (Yang et al. 2017). However, there are limitations to note. This is a retrospective secondary data analysis. The data has already been collected, and the research team could not determine the variables and how they were operationalized. Additionally, there was missing data from some charts. We chose to impute the data to account for that potential threat to validity.

Additionally, while the nurses and dieticians of the WIC program consistently record infant weight and length data and women's measured weights during pregnancy visits, maternal pre-pregnancy weight information is self-reported. Gestational weight gain is then calculated from this self-reported data. A recent systematic review and meta-analysis found that use of self-reported pre-pregnancy weight is a reliable manner of measuring this variable in research (Headen et al. 2017). Additionally, both breastfeeding duration and exclusivity were measured via self-report.

Two factors were unique to this sample that affect generalizability. First, the average duration of breastfeeding was quite low in this sample ($m = 5.58$, $SD = 7.14$), and there were few women who breastfed beyond 12 weeks. The generalizability of findings regarding breastfeeding's impact on child weight are impacted by the low dose of breastfeeding that was received by infants in this dataset. Furthermore, future prospective research could use a more precise measure of breastfeeding than weeks, as was collected in this dataset. A more precise measure would offer a better understanding of dose and effect of breastfeeding on child weight. Second, because this was a statewide sample of WIC participants, the SES is lower than the state and national median. The results of this study may not be applicable to other, less vulnerable populations.

6. Conclusion

In this study, pre-pregnancy weight status and gestational weight gain were significantly associated with early childhood obesity risk among a sample of maternal-child dyads enrolled in the WIC program. In this sample, breastfeeding did not decrease the risk of early childhood obesity. These results provide a renewed call to primary care providers and pregnancy care providers to focus on evidence-based preventive health behaviors that will promote women's weight management throughout the childbearing years.

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