SUPPLEMENT ARTICLE

Association of Breastfeeding Intensity and Bottle-Emptying Behaviors at Early Infancy With Infants' Risk for Excess Weight at Late Infancy

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ABSTRACT

OBJECTIVE. Our goal was to test the hypothesis that infants who were breastfed more intensively during early infancy (≤6 months) will be less likely to have excess weight during late infancy (>6 months) and to examine the independent impact of infant-initiated bottle emptying and mothers' encouragement of bottle emptying on infants' risk for excess weight.

METHOD. The sample consisted of 1896 mothers who participated in postpartum surveys of the Infant Feeding Practice Study II and who provided at least 1 weight measurement of their infants during the second half of infancy. We used multiple logistic regression models to assess the association between infants' risks for excess weight during the second half of infancy and 3 self-reported feeding practices during the first half of infancy after adjusting for a series of sociodemographic characteristics. The early feeding practices examined included the percentage of all milk feedings in which infants consumed breast milk (breastfeeding intensity), the frequency of bottle feedings in which infants initiated bottle emptying, and the frequency of bottle feedings in which mothers encouraged bottle emptying.

RESULTS. Infants fed with low (<20% of milk feeds being breast milk) and medium (20%–80%) breastfeeding intensity in the first half of infancy were at least 2 times more likely to have excess weight during the second half of infancy than those breastfed at high intensity (>80%). Infants who often emptied bottles in early infancy were 69% more likely than those who rarely emptied bottles to have excess weight during late infancy. However, mothers' encouragement of bottle emptying was negatively associated with their infants' risk for excess weight during the second half of infancy.

CONCLUSIONS. Infants' risk for excess weight during late infancy was negatively associated with breastfeeding intensity but positively associated with infant-initiated bottle emptying during early infancy. These findings not only provide evidence for the potential risk of not breastfeeding or breastfeeding at a low intensity in development of childhood obesity, but they also suggest that infant-initiated bottle emptying may be an independent risk factor as well. *Pediatrics* 2008;122:S77–S84

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Key Words
breastfeeding, bottle feeding, obesity, etiology, infant

Abbreviations
IFPS—Infant Feeding Practice Study
CI—confidence interval

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THE ESTIMATED PERCENTAGE of 6- to 11-year-old US children considered to be obese more than quadrupled since the 1960s to ~19% during 1999–2004.[1] The increase in childhood obesity was also observed among preschoolers and infants, with ~4- and 5-percentage-point increases among 6- to 23-month-olds and 2- to 5-year-olds, respectively, from the late 1970s to 2000.[2] Along with the rise in pediatric obesity, there has been an increase in the prevalence of obesity-related health conditions in youth, such as elevated serum lipid and insulin concentrations, asthma, type 2 diabetes, and hypertension, that once were considered to be adult problems.[3–6] In addition, children who are obese have been shown to be more likely to develop psychosocial problems.[7] Given the numerous health risks associated with children being obese, the prevention and treatment of childhood obesity is becoming one of the most important public health challenges.[8]

Many studies have shown that infants who are ever breastfed are at less risk for later childhood obesity than infants who are never breastfed.[9–12] Others have shown that increased breastfeeding duration is associated with lower rates of childhood obesity.[13–16] For example, Harder et al[16] reported that for each month of breastfeeding of infants up to 9 months of age, the odds of infants later being obese decreased by 4%. Although several studies have also indicated that exclusive breastfeeding has a stronger negative correlation with a child's risk of becoming obese than

nonexclusive breastfeeding, very few studies have attempted to quantify the relation between breast milk consumption and childhood obesity.[12,16] One of the main challenges for researchers when attempting to quantify the dose-response relation is that the quantity of breast milk consumed by infants is difficult, if not impossible, to measure. A cross-sectional survey using maternal recall is the most common method used in population studies to estimate initiation and duration of breastfeeding, but it may not be a valid method for estimating the duration of breastfeeding when mothers are asked to recall the duration >3 years after breastfeeding and are not able to provide satisfactory information on exclusivity of breastfeeding.[17]

The earlier onset of childhood obesity emphasizes the need to determine what impact breastfeeding has on infants' risk for excess weight during infancy given that rapid growth during this time period has been associated with later childhood obesity.[18–22] In this longitudinal prospective study, we defined weight-for-age *z* scores of >1 as excess weight for infants and tested 3 hypotheses related to the associations between infant feeding practices during early infancy (≤6 months) and excess weight during late infancy (>6 months): (1) infants who are breastfed more intensely will be less likely to have excess weight than those who are breastfed less intensely; (2) infants who often empty bottles will be more likely to have excess weight than those who rarely empty bottles, regardless of the bottle's contents; and (3) encouragement of bottle emptying by mothers will increase the risk that infants will have excess weight during late infancy.

METHODS

Sample

To test our hypotheses, we analyzed data from the second Infant Feeding Practice Study (IFPS II), a US national mail study of infant feeding practices conducted collaboratively by the US Food and Drug Administration and the Centers for Disease Control and Prevention. The IFPS II sample was drawn from a consumer opinion panel of ~500 000 households, and the study gathered information from mothers aged ≥18 years. Questionnaires were sent once prenatally and 10 times over a 1-year period postpartum. Only mothers of healthy newborns born at a gestational age of ≥35 weeks and birth weight of ≥5 lb were included in the postpartum surveys. Approximately 2000 mothers were followed longitudinally with 10 questionnaires mailed ~1, 2, 3, 4, 5, 6, 7, 9, $10^{1/2}$, and 12 months after their child's birth. For this study, we analyzed data from 1896 mothers who provided at least 1 weight of their infants measured during the second half of infancy. The details of the overall IFPS II design and the study's response rates are presented elsewhere in this supplement.[23]

Outcome Measure

At the 3-, 5-, 7-, and 12-month surveys, the mothers were asked to provide their infant's weight and length as measured at their most recent doctor's visit and their infant's age at the time of measurement. Because we realized that the reported ages for weight and length measurement at the most recent doctor's visit were not necessarily the same and there were certain concerns regarding the reported length, we did not use weight for length as our outcome measure in this study. Instead, we used weight for age, with the last reported weight as our outcome measure, providing that the age at that weight measurement was >6 months. To standardize the infants' weight according to their age, we estimated the weight-for-age *z* score by using the Centers for Disease Control and Prevention's reference (www.cdc.gov/nchs/about/major/nhanes/growthcharts/datafiles.htm) and excluded *z* scores greater than 5 or less than −5 for their biologically implausibility. We dichotomized the *z* scores as ≤1 or >1, indicating either normal or excess weight, respectively, during late infancy.

Main Exposure

At each of 10 postpartum surveys, the mothers were asked to estimate the average number of feedings of formula and various types of milk including breast milk, cow's milk, and other milk (such as soy milk, rice milk, goat milk) that their infant had received per day during the preceding 7 days. From this information, we calculated "breastfeeding intensity," which we defined as the percentage of milk feedings in which the infant received breast milk, that is, [number of breast milk feedings/(breast milk + formula + cow's milk + other milk feedings)] × 100%. The mean breastfeeding intensity over the first half of infancy was then calculated among the infants whose mothers answered at least 3 of the first 6 postpartum surveys. To be consistent with previous literature,[24] we considered mean breastfeeding intensity to be "high" if >80% of milk feedings were of breast milk, "medium" if 20%–80% were of breast milk, and "low" if <20% were of breast milk. This measure of breastfeeding intensity also tends to reflect breastfeeding duration, because infants whose mothers stop breastfeeding before 6 months will generally have lower breastfeeding intensity over the first half of infancy than infants who were breastfed through 6 months.

At the 2-, 3-, 4-, 5-, and 6-month surveys, the mothers were asked to answer the following 4 questions relating to bottle emptying on a 5-point Likert scale ("never," "rarely," "sometimes," "most of the time," or "always"):

1. "How often does your baby drink all of his or her bottle of formula?"
2. "How often does your baby drink all of his or her cup or bottle of pumped milk?"
3. "How often is your baby encouraged to finish a bottle if he or she stops drinking before the formula is all gone?"
4. "How often is your baby encouraged to finish a cup or bottle if he or she stops drinking before the pumped breast milk is all gone?"

Because we wanted to test the independent association between infant-initiated bottle emptying and excess

weight regardless of the bottle's contents, we first took the average Likert score on questions 1 and 2 for all mothers who responded to these questions in at least 3 of the month 2 through 6 surveys. We then categorized this overall infant-initiated bottle emptying (empty_baby) into 5 levels as "never" (empty_baby = 1), "rarely" ($1 <$ empty_baby ≤ 2), "sometimes" ($2 <$ empty_baby < 4), "most of time" ($4 \leq$ empty_baby < 5), and "always" (empty_baby = 5). Similarly, mothers' encouraging bottle emptying (empty_mom) was based on the responses to questions 3 and 4 and categorized as mothers "never," "rarely," "sometimes," "most of time," and "always" encouraging bottle emptying during the first half of infancy.

Other Measures

To control for confounding effects in our multivariate analyses, we adjusted for a series of sociodemographic characteristics, maternal health, and other infant feeding practices as listed in Table 1. Because we speculated that the age of the infants when introduced to solid food and feedings of sweet drinks might also be associated with excess weight, we included age of the infants when the mothers reported first feeding them solid food and the mean number of feedings of sweet drinks that the infants received per day over the first half of infancy in our multiple logistic regression analysis. The solid foods were primarily listed as food groups such as infant cereal, fruit, vegetables, and meat or chicken; the sweet-drinks question asked about servings of juice drinks, soft drinks, sodas, sweet tea, Kool-Aid, etc. The mothers' prepregnancy BMIs were computed by using the equation BMI = weight/height squared (kg/m^2).

Statistical Analysis

We first examined the bivariate association between each of the 3 infant feeding variables of primary interest and the infant's excess weight. To reduce the risk of losing power with small cells for the extreme values, we used terciles to divide bottle-empting variables into 3 equal parts (low tercile = "rarely"; midtercile = "sometimes"; and high tercile = "often") and then examined their association with excess weight during late infancy. We used the Student's t test to examine the mean difference for continuous variables between infants who had excess weight and those who did not have excess weight during the second half of infancy, and we used the χ^2 test to determine if differences in the proportions within the 2 outcome groups were statistically significant for categorical variables.

To examine the association between feeding practices during early infancy and risk for excess weight during late infancy, we applied multiple logistic regression models in which we assessed the independent impact of each feeding practice of primary interest after controlling for other feeding practices and confounding factors. Of the 1896 infants whose weight was measured during the second half of their infancy, we eliminated 22 infants with impossible age reversals (ie, the reported age at the subsequent weight measurement was younger than that reported at the previous weight measurement), 38 infants with missing data on breastfeeding intensity, 149 infants who were exclusively breastfed at the breast and, thus, never used a bottle, 242 infants with missing data on bottle-emptying behaviors, and 258 infants with missing data on other covariates in the model. These eliminations left us with 1187 infants in the final multiple logistic regression analysis.

RESULTS

Among the 1896 mothers who provided at least 1 weight measurement for their infants during the second half of infancy, 86% were white, 4% were black, 5% were Hispanic, and 4% were another race/ethnicity; their average age was 29.6 years (SD: 5.3 years); 46% had a college degree; and 83% were married.

The proportion of infants with excess weight (weight-for-age z score > 1) ranged from 24.8% at the 3-month survey to 11.5% at the 12-month survey. Of the 1896 infants whose weight was measured during the second half of infancy, 246 (13%) were categorized as having excess weight (Table 2). For 25% of these infants, the last reported weight was measured at 6 to 11 months, for 74% it was measured at 11 to 13 months, and for 1% it was measured at 13 to 15 months of age (data not shown).

Table 3 describes the distribution of the feeding practices of primary interest during the first half of infancy among 1896 infants who had their last weight measured during the second half of infancy. Despite recommendations by the American Academy of Pediatrics that mothers should breastfeed exclusively during the first 6 months of life,[25] only 26% of the mothers in our study reported doing so, with >50% of the infants being breastfed at low or medium intensity. Although 58.3% of the mothers reported that their infants always or most of the time emptied their bottles of formula or pumped milk, only 15.6% reported encouraging their infants to do so. The correlation coefficient between infant-initiated bottle emptying and mothers' encouragement of bottle emptying was only 0.16.

Results of our bivariate analyses (Table 1) showed that infants who received breast milk in <20% of all milk feedings during their first 6 months of life were more likely to have excess weight in late infancy than those who received breast milk in >80% of all milk feedings. The bottle emptying initiated by infants was associated with an increased risk for excess weight in late infancy, whereas mothers' encouragement of bottle emptying was associated with a decreased risk.

Results of our multiple logistic regression analysis (Table 4) showed that infants with low or medium breastfeeding intensity during the first half of infancy were at least 2 times more likely to have excess weight during the second half of infancy than those with high breastfeeding intensity and that infants who often emptied their bottle were 69% more likely to have excess weight during late infancy than those who rarely did so; it was surprising, however, that we found an inverse relation between mothers' encouragement of bottle empting and infants' risk for excess weight. The Hosmer-

TABLE 1 **Bivariate Analysis of the Association Between Each Variable and Infants' Risk of Having Excess Weight After 6 Months of Age**

Variables	Last Weight Measured for Infants Aged >6 mo		
	Excess Weight: Weight-for-Age *z* Score > 1 (*n* = 246)	No Excess Weight: Weight-for-Age *z* Score ≤ 1 (*n* = 1650)	*P*
Feeding practice of primary interest over the first half of Infancy			
Breastfeeding intensity (*N* = 1858), %			<.01
Low (<20%)	46.9	34.2	
Medium (20%–80%)	22.4	18.1	
High (>80%)	30.7	47.7	
Frequency of infant-initiated bottle emptying (*N* = 1461), %			.01
Rarely (low tercile)	30.69	40.91	
Sometimes (midtercile)	30.69	28.67	
Often (high tercile)	38.61	30.42	
Frequency of mothers' encouragement of bottle emptying (*N* = 1460), %			.09
Rarely (low tercile)	39.60	31.96	
Sometimes (midtercile)	33.17	35.61	
Often (high tercile)	27.23	32.43	
Confounding variables			
Infant gender (*N* = 1896), %			.07
Boy	43.9	50.1	
Girl	56.1	49.9	
Gestational age at birth, mean (SD), wk (*N* = 1896)	39.5 (1.3)	39.4 (1.2)	.53
Birth weight, mean (SD), kg (*N* = 1896)	3.7 (0.5)	3.4 (0.5)	<.01
Age at the first introduction of solid food, mean (SD), wk (*N* = 1895)	19.1 (7.2)	20.8 (7.3)	<.01
No. of sweet drinks per day over the first half of infancy, mean (SD), *n*/d (*N* = 1896)	0.03 (0.14)	0.02 (0.14)	.28
Maternal age, mean (SD), y (*N* = 1895)	29.3 (5.4)	29.7 (5.3)	.24
Parity (*N* = 1863), %			.65
1	27.7	29.1	
>1	72.3	70.9	
Maternal education (*N* = 1794), %			<.01
High school graduate or less	23.5	17.0	
Some college	42.0	35.2	
College graduate	34.5	47.8	
Race/ethnicity (*N* = 1773), %			<.01
Non-Hispanic white	83.6	91.6	
Non-Hispanic black	6.9	3.5	
Hispanic	9.5	4.9	
Income as a percentage of federal poverty index (*N* = 1896), mean (SD)	274.4 (197.1)	275.5 (196.2)	.93
Prepregnancy BMI, mean (SD), kg/m^2 (*N* = 1871)	27.9 (8.4)	26.5 (6.4)	<.01
No. of cigarettes mothers smoked at 3 mo postpartum, mean (SD) (*N* = 1715)	1.45 (3.9)	1.04 (3.6)	.12

P values were obtained by Student's *t* tests for the continuous variables and by χ^2 tests for the categorical variables.

Lemeshow goodness-of-fit statistic shows that the *P* value computed from the χ^2 distribution is .97, indicating that the multiple logistic regression model fits the data very well.

DISCUSSION

In this study, we confirmed our hypotheses that infants who were breastfed less intensively during early infancy had increased odds of having excess weight in late infancy. Regardless of bottle contents, infants who often emptied their bottles in early infancy also had increased odds of having excess weight in late infancy, relative to those who rarely emptied their bottles. However, we also unexpectedly found that maternal encouragement of bottle emptying was negatively associated with infants' risk for excess weight.

Previous studies have suggested 2 main possible mechanisms for why breastfeeding may protect against childhood obesity. First, the properties of breast milk and/or metabolic programming attributable to infant feeding mode may reduce the risk of becoming obese. Two hormones related to the etiology of childhood obe-

TABLE 2 **Mean Age, Weight, and Weight-for-Age *z* Score According to Survey Month and Summary of Last Weight Measured**

	Survey Month When Infants' Weight Measured at a Doctor's Office Was Reported				Last Weight Measured for Infants Aged >6 mo
	3	5	7	12	
Sample size, *n*	2126	1898	1661	1512	1896
Age at weight measurement, mean (SD), mo	2.33 (0.58)	4.21 (0.61)	6.38 (0.66)	11.97 (0.91)	10.87 (2.31)
Weight, mean (SD), kg	5.54 (0.88)	6.77 (1.07)	7.84 (1.14)	9.58 (11.37)	9.28 (1.40)
Weight-for-age *z* score, mean (SD)	0.34 (1.13)	0.26 (1.29)	0.07 (1.40)	−0.38 (1.48)	−0.25(1.16)
Biologically implausible *z* score					
Less than −5	4	10	8	9	0
More than 5	1	2	5	2	0
Dichotomized *z*-score distribution, %					
>1	24.8	23.6	19.7	11.5	13.0
≤1	75.2	76.4	80.3	88.5	87.0

sity are leptin and adiponectin, which are found in breast milk but not in infant formulas.[26,27] Leptin may help regulate appetite and energy metabolism, and adiponectin may cause weight loss by raising metabolic rates without affecting appetite.[28] The ratio of leptin concentration to fat mass has been found to be the lowest among children who consumed the most human milk in early life.[29] It was also found that formula-fed infants have higher plasma insulin levels than breastfed infants, and elevated plasma insulin levels were associated with greater subsequent weight gain among Pima Indian children.[30,31] Because of the unique properties of breast milk, the links between breastfeeding and later childhood obesity are biologically plausible. A second possible mechanism that could explain why breastfeeding may reduce the risk of developing childhood obesity pertains to infants' learned self-regulation of energy intake. In theory, breastfed infants may be better able to control the amount of milk they consume in response to their internal satiety cues than bottle-fed infants, who might be encouraged to finish a bottle even if they are already full. One piece of evidence for infant control of breast milk intake is a negative correlation found between the energy density of breast milk (determined primarily by fat content) and the amount of milk consumed by exclusively breastfed infants.[32,33] This correlation presumably reflects the ability of breastfed infants to self-regulate their milk consumption to match their energy needs.[34]

TABLE 3 **Distribution of Feeding Practices of Primary Interest Reported by the Mothers During Their Infants' First 6 Months**

Feeding-Practice Variables	*n*	%
Breastfeeding intensity (percentage of breast milk feeds among all milk feeds) (*N* = 1858)		
Low (<20%)	666	35.9
Medium (20%–80%)	346	18.6
High (>80%)	846	45.5
Infant initiated bottle emptying (*N* = 1461)		
Never	3	0.21
Rarely	28	1.92
Sometimes	578	39.56
Most of the time	793	54.28
Always	59	4.04
Maternal encouragement of infant bottle emptying (*N* = 1460)		
Never	117	8.01
Rarely	305	20.89
Sometimes	810	55.48
Most of the time	204	13.97
Always	24	1.64

The results of this study are consistent with previous studies that showed the benefits of breastfeeding in reducing the risk of developing obesity among infants[34–37] and shed some additional light on the potential mechanisms behind the association. Although the inverse dose-response relation that we found between breastfeeding intensity and excess weight supports the plausible biological roles of breastfeeding against childhood obesity, the association we found between infant-initiated bottle emptying and excess weight suggests that low self-regulation among bottle-fed infants, perhaps as a result of their inability to respond to internal satiety cues, may also explain why breastfeeding protects against childhood obesity.

One of the advantages of breastfeeding is that it allows infants to control the amount of milk they consume.[32–34] In breastfeeding, the milk fat content toward the end of the feeding episode (ie, "hind milk") is much higher than at the start of the episode ("fore milk"), which might signal to the infant that the feeding episode is coming to an end. In contrast, formula-fed infants are obviously not exposed to such "physiologic signaling" because the bottle content remains constant throughout the feeding episode. A corollary of this is that among bottle-fed infants, it is the caretaker and not the infant who controls the child's caloric intake. In addition, bottle-fed infants spend less effort drinking the milk from the bottle, because they do not need to suck nonnutritively at the breast until the milk ejection reflex occurs, which may also lead to their low self-regulation with a tendency of overeating. Results of a previous study showing that the sucking pressure changed from nonnutritive sucking to nutritive sucking in the opposite direction between breastfeeding and bottle feeding further indicates that bottle feeding is a completely different feeding method regardless of attempts to make it more

TABLE 4 **Multiple Logistic Regression Results for the Association of Excess Weight in the Second Half of Infancy With Breastfeeding Intensity and Bottle-Emptying Behaviors in the First Half of Infancy ($N = 1187$)**

Risk Factors	Adjusted Odds Ratio (95% CI)[a]
Feeding practices of primary interest over the first half of infancy	
Breastfeeding intensity	
Low (<20%)	2.32 (1.40–3.84)
Medium (20%–80%)	2.11 (1.24–3.60)
High (>80%)	Referent
Frequency of infant-initiated bottle emptying	
Rarely (low tercile)	Referent
Sometimes (midtercile)	1.28 (0.80–2.03)
Often (high tercile)	1.69 (1.09–2.63)
Frequency of maternal encouragement of infant bottle emptying	
Rarely (low tercile)	Referent
Sometimes (midtercile)	0.56 (0.37–0.87)
Often (high tercile)	0.49 (0.31–0.77)
Confounding variables	
Infant gender (boy = 0 vs girl = 1)	1.73 (1.19–2.51)
Gestational age at birth (weeks)	0.85 (0.73–0.99)
Age when the last weight was measured (weeks)	0.97 (0.95–0.98)
Birth weight (kg)	4.37 (2.81–6.79)
Age when solid food was first indicated (weeks)	0.99 (0.96–1.02)
Mean No. of sweet drinks over the first half of infancy (feedings per day)	1.98 (0.59–6.65)
Maternal age (years)	1.01 (0.97–1.05)
Parity (primiparous = 0 vs multiparous = 1)	1.16 (0.75–1.80)
Maternal education	
High school graduate or less	1.31 (0.75–2.29)
Some college	1.20 (0.77–1.86)
College graduate	Referent
Race/ethnicity	
Non-Hispanic white	Referent
Non-Hispanic black	3.26 (1.60–6.65)
Hispanic	2.68 (1.35–5.32)
Income as a percentage of federal poverty level	1.00 (1.00–1.00)
Maternal BMI before pregnancy	1.02 (0.99–1.04)
Maternal smoking at 3 mo postpartum (cigarettes per day)	1.03 (0.98–1.07)

[a] The adjusted odds ratio for each feeding practice was obtained by controlling for other feeding practices as well as all the confounding variables listed.

closely resemble breastfeeding.[38] Given the association between feeding mode (breast versus bottle) and infants' self-learned ability to control their feeding and the association we found in this study between infant-initiated bottle emptying and risk of having excess weight, one can reasonably surmise that early breastfeeding interventions might improve infants' self-regulation of their energy intake and consequently help to prevent later childhood obesity. If infants cannot be breastfed for some reasons, mothers need to be aware of the relation between infant-initiated bottle emptying and infants' risk of having excess weight, and heath care professionals need to develop a strategy to help mothers either better recognize the satiety cue of infants or ensure that the serving size of each bottle feeding does not exceed the infants' nutritional needs.

Our finding that mothers' encouragement of bottle emptying was negatively associated with infants' risk for excess weight was counter to our original hypothesis. One possible explanation for this finding is that mothers who perceived (perhaps correctly) that their infants were small for their age and not consuming enough were more likely to encourage bottle emptying. The fact that the proportion of mothers who often encouraged bottle emptying was the highest among those whose infants rarely initiated bottle empty (data not shown) also indicates this possible reverse causality. In any case, this negative association warrants additional longitudinal analyses that were beyond the scope of this study.

Results of previous studies have suggested that the protective effect of breastfeeding against obesity during early childhood may persist into the teenage years and adulthood. For example, in a meta-analysis in which a conventional term of "obesity" was used to summarize the data from 28 studies, Owen et al[12] found that the unadjusted odds ratio for obesity among those who were breastfed compared with those who were not was 0.50 among infants (95% confidence interval [CI]: 0.26–0.94), 0.90 among young children (95% CI: 0.87–0.92), 0.66 among older children (95% CI: 0.60–072), and 0.80 among adults (95% CI: 0.71–0.91). Because the largest effect size of breastfeeding was observed among infants, early interventions during the infancy period might be critical for preventing later obesity.

There are several limitations of this study. First, because black and Hispanic mothers were underrepresented in the study population, our results may not be applicable to the entire US population. Second, because both infants' weight measurements and bottle-empting behaviors were reported by the mothers, reporting errors may have occurred, particularly if the mothers were not present at the weight measurement or if someone else bottle fed their infant. However, because there was no time overlap between feeding practice collected during the infants' first 6 months (exposure) and infants' last weight measured after 6 months (outcome), it is unlikely that the misclassification of exposure and outcome data were dependent on one another. For nondifferential misclassification such as this, the reporting errors would bias the results toward the null value.[39] Third, our data on bottle emptying did not capture how much is in a typical bottle of formula or pumped milk. Thus, we cannot rule out the possibility that the association between infant-initiated bottle emptying and excess weight is at least partially mediated by the amount of milk consumed from the bottle. Fourth, the analytical population for our final analysis was 258 cases less than the initial population because of missing data on covariates. However, because our sensitivity analysis, based on the full sample without controlling for these covariates in the models, indicated similar results, our findings on the association of excess weight with breastfeeding intensity and bottle-emptying behaviors seem robust. Last but not least, we excluded 149 infants who were exclusively breastfed but never fed pumped milk because they

had no "bottle-emptying behaviors" for us to analyze; as a result, the true association between breastfeeding intensity and excess weight may have been even stronger than we estimated. The strengths of the study include minimizing reporting bias on feeding practices by using a short-term retrospective recall for the previous 7 days of almost every month postpartum. Also, the sample was national and relatively large.

CONCLUSIONS

We found that infants' risk for excess weight during late infancy was negatively associated with breastfeeding intensity but positively associated with infant-initiated bottle emptying during early infancy. These findings not only provide evidence for the potential risk of not breastfeeding or breastfeeding at a low intensity in development of childhood obesity, but they also suggest that infant-initiated bottle emptying may be an independent risk factor as well. Because the prevalence of childhood obesity has increased dramatically in the United States, both increasing breastfeeding intensity and limiting infant-initiated bottle emptying should be part of strategies to prevent childhood obesity.

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