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Associations between breast milk feeding, introduction of solid foods, and weight gain in the first 12 months of life

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Abstract

Background and Objectives—Breast milk feeding and solid food introduction can influence infant growth, but are rarely examined together. The objectives were: describe relationships between feeding practices, feeding practices and weight gain, and how the relationship of breast milk feeding and growth may change when breastfed infants start solid foods before 6 months.

Methods—Data was analyzed on 438 infants from the Moms2Moms Study (2011–2012, Ohio), using multivariable linear and logistic regression models to explore each of the relationships.

Results—For each additional month of breast milk feeding, solid food introduction was delayed by 1.32 days (95% CI: 0.11 to 2.53) and average weight gain per month decreased by 5.05 grams (95% CI: 7.39 to 2.17). There was no association between solid food introduction and growth.

Conclusions—Longer breastfeeding duration was associated with slower growth regardless of solid food introduction. Age at solid food introduction was not associated with growth.

Keywords

breast milk feeding; complementary foods; weight; weight-for-age z-score; growth; weight gain

Introduction

The American Academy of Pediatrics (AAP) recommends that infants be exclusively breastfed for the first 6 months of life. Solid foods can be supplemented starting at about 6 months of age, with the continuation of breastfeeding recommended until at least 12

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months.¹ The European Society for Pediatric Gastroenterology and Nutrition holds similar recommendations, stating that exclusive breastfeeding for 6 months with delay of complementary foods until at least 17 weeks is ideal.² For many reasons, these recommendations are not always closely followed by those making feeding practice decisions. A previous study by Grummer-Strawn, et al. found that 70% of infants who started solid foods early (at or before 4 months) were no longer breastfeeding at 6 months. In contrast, only 34% of infants exclusively breastfed at 4 months were no longer breastfeeding at 6 months. This indicates that there is a potential relationship between introduction of solid foods and the timing of breastfeeding discontinuation.³ Many mothers have indicated that their healthcare professional recommended introduction of solids before 6 months, which implies that some primary care providers are not promoting the AAP recommendations.⁴

Infant nutrition is important in development and health throughout life. Exclusively breastfed infants experience slower growth rates from 3 to 12 months compared to infants who are weaned early, but remain at or above reference values.^{5,6} One potential mechanism underlying this may be the leptin in breast milk which may help infants regulate energy intake.⁷ While complementary foods provide dietary benefits such as iron and vitamin D, formula and other solid foods may displace breast milk, and leptin, from the diet.^{6,8} Also, bottle-fed infants may be less able to regulate intake compared to breastfed infants.⁹ Earlier introduction of solid foods has been shown to correspond to higher weights later at 3 years of age.⁸ However, studies examining the relationship between the timing of introduction of solid foods and obesity risk have produced conflicting results. Most have found that age of solid food introduction has a minimal association with growth and weight gain.^{10,11} Few studies consider solid food introduction as an intermediary in the relationship between breastfeeding and weight gain. In addition, many published studies used the previous recommendations from the AAP, which permitted solid food introduction at 4 months.¹ It is likely that early introduction of solid foods can impact infant growth, but the relationship remains unclear. However, breastfeeding for the recommended amount of time results in slower, normal growth rates. Early introduction of solid foods may alter these benefits provided by breastfeeding. As a result, infant feeding practices may have a substantial influence on the prevalence of childhood obesity, which was 16.9% in 2009–2010.¹²

Most studies on the breastfeeding-growth relationship do not take into account the fact that many infants receive a combination of direct and expressed breast milk, and formula feedings during a given unit time, and there is substantial variation in the relative proportions of each across individual infants. Thus, it has been difficult to differentiate within this “mixed fed” group in the past. The purpose of this secondary data analysis from the Moms2Moms Study was to examine these relationships and to identify any alteration in growth when breastfed infants start solid foods earlier than recommended by the AAP, compared to infants who start foods at or after 6 months. An additional goal was to compare results between two different measures of breast milk feeding duration, including one that accounted for a combination of breast milk and formula feeding.

Methods

Study Population and Data Collection

A roster was assembled of all English-speaking women 18 years of age who delivered a singleton, live born infant at >24 weeks' gestation at The Ohio State University Wexner Medical Center (OSUWMC) during five months of 2011 (n=1244). OSUWMC operates a large delivery service for both high- and low-risk obstetric patients in the Columbus, Ohio area. Women whose medical record indicated their intention to exclusively "bottle feed" their infant (n=303), women lacking valid contact information (n=111), prisoners (n=11), and infant deaths (n=6) were excluded. Twelve months after delivery, a questionnaire was mailed to eligible women to assess lactation and infant feeding practices; information on child weight; and demographics. The methods for the Moms2Moms Study have been described previously.¹³

Study Variables

Maternal and child characteristics were gathered from the obstetric record and the questionnaire. Maternal race and ethnicity (non-Hispanic White, non-Hispanic African-American/Black, and Hispanic or other or multiple races; additional categories were offered as response options but were grouped because of small numbers), receipt of Women, Infants, and Children (WIC) benefits during pregnancy or postpartum (yes/no), smoking during pregnancy or postpartum (yes/no), marital status at start of pregnancy (married or living with partner versus single, not living with partner, separated, or divorced), education level (college or post-graduate versus some college or less), maternal employment or school enrollment since the child's birth (>20 hours/week versus 0–20), and sex of the child were measured via the questionnaire. Gestational age at birth in weeks was obtained from the medical record.

The questionnaire also assessed feeding practices, including breast milk feeding practices and duration, formula use, and timing of solid food introduction. Breast milk feeding (i.e. at the breast or expressed milk feeding) duration was measured in months. In addition to unweighted duration, an intensity-weighted breast milk feeding duration variable was created which accounted for feeding of up to two substances (direct or expressed breast milk and formula) in the same unit of time. This was based on the percentage of each feeding substance on a given day. Values could range from 0 (did not participate in that feeding practice on the given day) to 1 (that was the only feeding practice for the given day), or 0.5 if the subject participated in both practices for that day. The daily intensity-weighted breast milk feeding duration variables were summed to indicate the intensity-weighted breast milk feeding duration in the first 12 months postpartum. Age of solid food introduction was calculated in both days and months, and converted to a binary variable dichotomized to those who introduced solids before the AAP recommended 6 months and those who introduced solids at or after 6 months.

The child's birth weight was obtained from the medical record for 98% of the participants, and from the survey if not found in the chart. The mother reported in the survey the child's weight at the most recent doctor's visit, along with the child's age at the time of the visit.

The primary outcome measure was the child's weight-for-age z-score (WFA) at the time the survey was completed. Average weight gain per month since birth, change in WFA z-score from birth to 12 months, and rate of change of WFA z-score from birth to 12 months were also used as outcome measures.

Statistical Analysis

We examined descriptive statistics for the sample demographics, feeding practices, and outcome measures, and then used bivariate linear and logistic regression models to examine associations between breast milk feeding duration and infant growth, breast milk feeding duration and timing of introduction of solid foods, and the timing of introduction of solid foods and infant growth. We also built models adjusted for confounders, including: maternal race/ethnicity, WIC, smoking, maternal relationship status (partnered vs. not), maternal education, employment status (outside home 20 hours or more per week since the child's birth vs. not), and gestational age. These variables were selected because they were found in previous studies to be important confounders, or because they showed a significant correlation with one or more of the feeding practice variables.

The association of breast milk feeding duration and age at solid food introduction was explored using unweighted breast milk feeding duration and the intensity-weighted breast milk feeding duration in months. Multivariable linear regression was used to assess the continuous age at introduction of solid foods, while multivariable logistic regression was used to examine the binary variable for age at introduction of solids. Briefly, the relationship of birth weight with each of the feeding practices was explored. We examined the relationship of breast milk feeding and growth, using the WFA z-score, weight gain per month, WFA z-score change from birth to 12 months, and rate of WFA z-score change from birth to 12 months. We then examined the relationship among age at solid food introduction and each of the weight outcome measurements, including breast milk feeding duration as a confounder in addition to the variables listed previously. Finally, we tested for an interaction between the breast milk feeding and solid food introduction variables by including a product term in the model and a criterion of $p < 0.05$. SAS v. 9.3 was used for all analyses.¹⁴

Results

Of the 813 questionnaires that were mailed, 501 were returned completed. Unintelligible responses ($n=2$), preterm births ($n=60$), and those without feeding data ($n=1$) were excluded from these analyses. The final sample size for these analyses is 438. Children who were younger than 9 months at their most recent weight or with missing or implausible weight values were excluded from models examining the weight outcome ($n=56$), leaving 382 total children included in weight analyses.

Sample Characteristics

The demographics of the study sample are listed in Table 1. Just over three-quarters of the subjects were non-Hispanic White (80.1%), while 10.0% identified as non-Hispanic Black, and 9.8% identified as multi-racial or another race or of Hispanic ethnicity. One-quarter of the participants were WIC recipients, and 7.3% were smokers. Almost three-quarters of the

sample had a college or post-graduate degree (72.1%), and 68.7% started working or attending school for 20 hours or more per week at some point since the child's birth. The majority of mothers (89.9%) were partnered at the start of their pregnancy. The mean gestational age of the infants was 39.0 weeks, with a mean birth weight of 3424 grams. Average breast milk feeding duration was 7.1 months, while average age at first introduction of solid foods was 5.5 months. The mean infant weight at the time of survey completion was 9653 grams, and the mean age at measurement was 11.37 months.

Breast Milk Feeding Duration and Age at Introduction of Solids

Breast milk feeding duration was positively associated with the age at which solid foods were introduced (Table 2). For each additional month of breast milk feeding, solid food introduction was delayed by 1.32 days (95% confidence interval [CI] 0.11–2.53, adjusted model). This relationship was similar when using the intensity-weighted breast milk feeding duration (1.53 days; 95% CI 0.29–2.77, adjusted model). This relationship was also assessed using solid food start as a binary variable (<6 vs. ≥6 months); no association was observed with this more crude measure (data not shown).

Birth Weight and Feeding Practice

Before examining growth in relation to breast milk feeding practice, we assessed the association between birth weight z-score and feeding practices to examine how infant size at birth might influence subsequent practices. Unadjusted models showed a relationship between birth weight and breast milk feeding duration, but the relationship was not significant for any of the feeding practices after adjustment (Table 3).

Breast Milk Feeding Duration, Age at Introduction of Solid Foods, and Weight or Weight Gain

No associations were observed between age at solid foods introduction and growth (Table 3). However, there was a significant negative relationship between breast milk feeding duration and all weight outcomes. The relationship was similar for the unweighted breast milk feeding duration variable and the intensity-weighted breast milk feeding duration variable. For each additional month of breast milk feeding, average weight gain per month decreased by 5.05 grams (95% CI –7.93 to –2.17, adjusted model), while average weight gain per month decreased by 5.42 grams (95% CI –8.39 to –2.46, adjusted model) when using the intensity-weighted breast milk feeding variable. The adjusted models did not differ greatly from the unadjusted.

Interaction of Breast Milk Feeding Duration and Age at Solid Food Introduction

None of the models showed a significant interaction between breast milk feeding and age of solid food introduction (binary variable) for any of the weight outcomes (Table 4). Separate models were assessed using the continuous variable, but again, no interaction was observed (data not shown).

Discussion

In this retrospective cohort study, the beneficial relationship of breast milk feeding and growth was supported. Breast milk feeding for longer durations, per recommendations, was associated with very slightly delayed introduction of solids. Breast milk feeding duration was also negatively associated with weight and weight gain, suggesting that longer breast milk feeding durations result in slower growth. While the majority of studies do not take into account the intensity of breast milk feeding in relation to formula feedings, our use of the intensity-weighted breast milk feeding duration only slightly altered the growth relationship when comparing to the unweighted breast milk feeding duration. Despite the association between breast milk feeding and growth, timing of solid food introduction had no significant relationship with weight or weight gain.

Although the mothers in this study generally indicated that they intended to breastfeed when their child was born, many deviated from the current AAP recommendations for breastfeeding and solid food introduction: 41.2% of mothers breastfed for less than 6 months, 72.6% breastfed for less than 12 months, and 48.1% of mothers started solid foods before 6 months of age (Table 1).¹ Data for this study were collected before the recommendations for solid food introduction changed from 4 months to 6 months, so physicians may have offered guidance to these mothers based upon the earlier recommendations. However, the recommendations for 12 months of breastfeeding duration did not change, so women are in need of more support when it comes to breastfeeding.

It has been suggested that there is an element of reverse causality in the association between breastfeeding and growth. Previous studies indicated that infants of lower weights have greater odds of being weaned and introduced to solid foods early, in order to help them gain weight.^{15,16} We partially examined the potential for this occurrence by assessing the relationship of birth weight and feeding practice. None of the feeding practices showed a significant relationship with birth weight in adjusted models (Table 3). Baker et al. used a similar method to determine the presence of reverse causality, and found similar results, although the association of breastfeeding duration and birth weight was significant.¹⁷

Our results were consistent with others that examined the relationship of solid foods and breastfeeding. Hendricks, et al. examined infant feeding practices and found that breastfeeding for any duration was associated with other positive feeding practices, including delay of solid foods.¹⁸ Scott et al. also found a significant relationship between breastfeeding and introduction of solids; mothers who introduced solid foods at 17 weeks or later had also breastfed for 11 weeks or more.¹⁹ The most likely explanation for this is that mothers who follow recommendations for breastfeeding will be more likely to follow all infant feeding recommendations, including solid food introduction.

Several studies have looked at the relationship of breastfeeding, weight, and obesity at different ages from infancy to childhood and adulthood.^{20–22} Our results are consistent with many of these studies in showing that prolonged breast milk feeding leads to slower growth and less weight gain, and these benefits persist throughout the first year. Breast milk feeding intensity, especially in the second half of infancy, has been found to be predictive of a lower

WFA z-score at 12 months.²³ Most studies, including one by Gopinath et al., show that breastfeeding duration is the major influential factor on weight gain, and also that the relationship with weight is more pronounced in the first 2 years of life than in later childhood and adulthood.²⁴

There are two possible explanations for the negative association of breast milk feeding and weight gain. Breastfeeding for longer durations supplies infants with more leptin, allowing tighter regulation of energy intake.⁷ However, many children in this study were receiving milk that was pumped and stored, and it is unclear whether that milk differs from milk fed at the breast in composition and health outcomes. Another possible mechanism is that breastfeeding allows infants to learn how to control their own energy intake, as compared to bottle feeding, and allows the mother to learn the indications for when the infant has received enough milk, thereby preventing overfeeding. Taveras et al. found that maternal feeding restriction was independently associated with a higher body-mass index (BMI) at 3 years of age.²⁵ However, feeding restriction did not significantly alter the relationship between breastfeeding and growth, suggesting that it plays a minor role in the relationship between breastfeeding and weight gain. Maternal characteristics such as socioeconomic status can also influence feeding practice decisions and thereby influence growth. Mothers of middle and low socioeconomic status are less likely to initiate breastfeeding, and if they do breastfeed they are more likely to discontinue breastfeeding before 4 months of age.²⁶

As stated above, we observed no relationship between the age at solid food introduction and weight and weight gain. These findings are consistent with the literature, although some studies have been contrary. Mehta et al. found in a trial experiment that early introduction of solids (at 3–4 months) did not alter infant growth in the first year of life.²⁷ One systematic review of 23 studies also found no clear association between age of introduction of solid foods and childhood BMI.²⁸ However, they did find very early introduction of solids (before 4 months) had a small relationship with increased BMI. Moss and Yeaton also found a higher prevalence of obesity in children at 2 years and 4 years of age when introduced to solids before 4 months.²⁹ Our results indicate that early introduction of solids does not appear to result in an energy surplus and therefore is not associated with increased weight and weight gain. Instead, as infants grow, solid foods supplement the breast milk in the diet without adding any excess energy. This most likely occurs because the infants are able to self-regulate their energy intake.

Our intention was to examine the relationship of breast milk feeding and weight and weight gain, stratified by either early or timely introduction of solids. However, we found no interaction between breast milk feeding and solid food introduction, determining that the stratified models were unnecessary. Other studies found a relationship with growth and these feeding practices. Huh et al. found that the relationship between age at solid food introduction and weight outcome differed according to breastfeeding status. Timing of solid food introduction was not related to obesity prevalence or anthropometric measures in breastfed infants at 3 years of age, but in formula-fed infants early solid food introduction was related to higher obesity prevalence and WFA z-score.³⁰ Moss and Yeaton found that compared to never breastfed infants, breastfed infants introduced to solids before 4 months of age had a non-significant higher percentage of healthy weight status, suggesting that

breastfeeding offers some protection from obesity when solid foods are introduced early.²⁹ Unlike these studies, we did not examine a comparison between breastfed children and children who were not breastfed or who were formula-fed. A possible explanation is that breast milk feeding for any duration results in tighter regulation of energy intake, so that timing of solid food introduction becomes less influential on growth. As the studies described previously indicate, this relationship may be different for infants who are not breastfed.

Strengths and Limitations

A unique advantage of our sample was the proportion of low-income subjects. We used receipt of WIC during pregnancy or postpartum as an approximation of low income status, and 25.2% of subjects indicated that they were WIC recipients. Therefore, our results are generalizable to various levels of socioeconomic status. Another unique aspect was the intensity-weighted breast milk feeding duration variable. In addition, our population was racially and ethnically diverse, with close to 20% non-white participants. Finally, our outcome measures of weight gain per month, WFA z-score, and related quantities are reliable measures of weight and weight gain for infants in the first year of life. Some limitations of the study include the possibility of recall bias, because mothers were asked about feeding practice decisions that may have been made 6 months prior to the time of survey completion. In addition, it may have been informative to ask specifically about infant cereal introduction, as many mothers do not consider this to be a solid food.

Conclusion

Breast milk feeding was associated with delayed introduction of solids, weight, and weight gain in this cohort. While we observed no relationship between solid food introduction and weight, any breast milk feeding at all may be the important factor in determining the influence of age of solid food introduction on growth. Further studies are needed to examine the possible protective effect of breast milk feeding on weight gain when solids are introduced early. These results are consistent with the reasoning behind breast milk feeding recommendations, indicating that longer breast milk feeding duration is more beneficial. However, our sample did fall short of these recommendations. Other studies may examine barriers to breast milk feeding, or methods to increase its initiation and duration, to ensure that infants receive the maximum benefit of breastfeeding.

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Table 1

Characteristics of Analytical Sample of 438 Mother-Infant Pairs, Moms2Moms Study (Ohio, 2011–2012)

Characteristic	n	%
Maternal Race and Ethnicity		
Non-Hispanic White	351	80.1
Non-Hispanic Black	44	10.0
Other (Hispanic, multi-racial, or another race)	43	9.8
WIC ^a receipt	110	25.2
Smoker (pregnancy or postpartum)	32	7.3
Mother partnered at start of pregnancy	393	89.9
Maternal education level		
Some college or less	122	27.9
College or post-graduate degree	315	72.1
Mother started work or school 20 or more hours per week since child's birth	301	68.7
Infant sex		
Male	229	52.2
Gestational age, mean (SD), weeks	39.0 (1.1)	
Infant age at introduction of solid foods, mean (SD), months	5.5 (1.8)	
Started solid foods <4 months	23	5.3
4 – <6 months	183	42.2
6 months	228	52.5
Breastfeeding duration, mean (SD), months	7.1 (4.5)	
Breastfed for <6 months	176	41.2
Breastfed for <12 months	310	72.6
Infant weight, mean (SD), grams		
At birth	3424 (445)	
At 12 months (actual measurement age 11.37±1.70 months)	9653 (1331)	

^a Abbreviation: WIC, Special Supplemental Nutrition Program for Women, Infants and Children

Missing data: 1 subject for maternal race/ethnicity, 3 subjects for WIC receipt, 2 subjects for smoker, 2 subjects for mother partnered, 2 subjects for maternal education level, 1 subject for mother's work/school, 5 subjects for solid food start, 2 subjects for breastfeeding duration

Linear regression estimates and 95% confidence intervals (CIs) for age at introduction of solid foods in days by breastfeeding duration and intensity, Moms2Moms Study (Ohio, 2011–2012)

Table 2

Feeding Practice	Age at introduction of solid foods (days)	
	β (95% CI)	
	Unadjusted	Adjusted ^a
Breastfeeding duration (months)	1.18 (0.05, 2.31)	1.32 (0.11, 2.53)
Intensity-weighted breastfeeding duration (months)	1.32 (0.16, 2.49)	1.53 (0.29, 2.77)

^a Adjusted for: maternal race/ethnicity, WIC receipt, maternal smoking, maternal partner, maternal education level, maternal work/school, gestational age

Table 3

Linear regression estimates and 95% CIs for infant weight and weight gain from birth to 12 months by age of solid food introduction, breastfeeding duration and intensity, Moms2Moms Study (Ohio, 2011–2012)

Feeding Practice	Birth weight z-score		WFA ^a z-score at 12 months		Average weight gain per month		Change in WFA z-score from birth to 12 months		Rate of change of WFA z-score	
	Birth weight z-score		WFA ^a z-score at 12 months		Average weight gain per month		Change in WFA z-score from birth to 12 months		Rate of change of WFA z-score	
	Unadjusted	Adjusted ^b	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Age at solid food start (months) ^c	0.03 (−0.02, 0.07)	0.03 (−0.01, 0.07)	−0.01 (−0.07, 0.06)	0.01 (−0.06, 0.07)	−1.04 (−8.12, 6.04)	0.74 (−6.37, 7.76)	−0.03 (−0.11, 0.04)	−0.02 (−0.08, 0.05)	−0.00 (−0.01, 0.00)	−0.00 (−0.01, 0.01)
Breastfeeding duration (months)	0.02(0.00, 0.04)	0.02 (−0.00, 0.03)	−0.04 (−0.07, −0.02)	−0.04 (−0.07, −0.02)	−5.50 (−8.16, −2.82)	−5.05 (−7.93, −2.17)	−0.07 (−0.09, −0.04)	−0.06 (−0.09, −0.03)	−0.01 (−0.01, −0.00)	−0.01 (−0.01, −0.00)
Intensity-weighted breastfeeding duration (months)	0.02 (0.01, 0.04)	0.01 (−0.01, 0.03)	−0.04 (−0.07, −0.02)	−0.05 (−0.07, −0.02)	−5.75 (−8.50, −2.99)	−5.42 (−8.39, −2.46)	−0.07 (−0.10, −0.04)	−0.06 (−0.09, −0.03)	−0.01 (−0.01, −0.00)	−0.01 (−0.01, −0.00)

^a Abbreviation for weight-for-age

^b Adjusted for: maternal race/ethnicity, WIC receipt, maternal smoking, maternal partner, maternal education level, maternal work/school, gestational age

^c Adjusted models including this variable were also adjusted for breastfeeding duration

Table 4

Interaction of breastfeeding and age at solid food introduction in relation to weight and weight gain from birth to 12 months, Moms2Moms Study (Ohio, 2011–2012)

Interaction Term	WFA z-score at 12 months ^b	Average weight gain per month	Change in WFA z-score from birth to 12 months	Rate of change of WFA z-score
Breastfeeding duration (months)*age at solid food introduction (days) ^d (n=376)	0.78	0.48	0.11	0.20
Intensity-weighted breastfeeding duration (months)*age at solid food introduction (days)(n=376)	0.65	0.96	0.47	0.66

^d Introduction of solid foods used as binary variable: <180 days or 180 days

^b Adjusted for: maternal race/ethnicity, WIC receipt, maternal smoking, maternal partner, maternal education level, maternal work/school, gestational age