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Maternal Diet During Lactation and Breastfeeding Practices have Synergistic Association with Child Diet at 6 Years

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Abstract

Objective: Children breastfed during infancy consume more fruits and vegetables than formula-fed children. This pattern is likely due, in part, to infant learning from flavors of the mother's diet transmitted through breast milk, but more research is needed to understand associations between early flavor exposures and later dietary patterns. We examined whether breastfeeding and maternal fruit and vegetable consumption during nursing were synergistically associated with higher child fruit and vegetable consumption.

Design: Prospective cohort study of breastfeeding duration, maternal diet postpartum, and child diet. Complete breastfeeding and maternal diet data were available for 1396 mother-child dyads; multiple imputation was used for missing data in other variables. In separate multivariable logistic regression models, we estimated the adjusted odds of high child fruit or vegetable consumption at 12 months or 6 years as a function of breastfeeding duration, maternal fruit or vegetable consumption during nursing, and their interaction.

Setting: The Infant Feeding Practices Study II and Year 6 Follow-Up.

Subjects: Mother-child dyads followed from birth to 6 years from 2005 – 2012 in the U.S.

Results: Longer breastfeeding duration was associated with high child fruit and vegetable consumption at 12 months. At 6 years, the interaction between breastfeeding duration and maternal vegetable consumption was associated with high child vegetable consumption.

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Authorship:

Jacob Beckerman conceptualized and designed the study, performed the statistical analyses, and drafted, reviewed, and revised the manuscript.

Emily Slade oversaw the analysis and reviewed and revised the manuscript.

Alison Ventura conceptualized and designed the study, oversaw the analysis, and reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of Interest: None

Ethical standards:

As a secondary analysis of de-identified data, the present study was deemed exempt from approval by the Harvard University and California Polytechnic State University Institutional Review Boards. Initial data collection procedures were approved by the Research Involving Human Subjects Committee of the US Food and Drug Administration and the US Office of Management and Budget.

Conclusions: Higher maternal vegetable consumption and longer breastfeeding duration were synergistically associated with high child vegetable consumption at 6 years, independent of sociodemographic characteristics and fruit and vegetable availability. Exposures to vegetable flavors through breastmilk may promote later child vegetable consumption.

Keywords

Breastfeeding; Maternal Diet; Vegetables; Child Diet

Introduction

Fruits and vegetables promote healthy body weight and are protective against cardiovascular diseases and some cancers, yet are lacking in child and adult diets.^(1,2) Early childhood is of paramount importance for efforts to improve diet because food preferences are a primary driver of diet^(3–5) and early childhood is a sensitive period for the development of food preferences⁽⁶⁾ that persist into later Life.^(5,7,8)

Breastfeeding, in addition to having direct benefits for maternal and child health,^(9,10) may promote healthy diet in later childhood because it is a key factor in the development of flavor preferences. Infants are exposed to flavors from their mothers' diets through breast milk, and randomized trials have demonstrated that this exposure increases infants' acceptance of those flavors during complementary feeding.^(11,12) This mechanism may explain why, in observational studies of populations around the world, 2- to 13-year-old children breastfed during infancy consume more fruits and vegetables than their formula-fed peers, even after accounting for key sociodemographic confounders (e.g., income, education).^(13–21) Alternatively, the observational nature and narrow focus of confounders included in these studies make it possible that other confounding factors can explain this association. Thus, further research on associations between breastfeeding and later child diet is needed that accounts for a wider array of likely confounders, such as the home food environment⁽²²⁾ and intention to breastfeed.⁽²³⁾ Additionally, this research should evaluate whether associations between breastfeeding and child diet at later ages are consistent with the aforementioned biological mechanism underlying flavor learning.

To this end, we used data from the Infant Feeding Practices Study II (IFPS II), a six-year cohort study of mother-child dyads. We hypothesized that, in accordance with the previously demonstrated effects of breastfeeding and maternal diet on infant food acceptance,^(11,12) the combination of breastfeeding and higher maternal fruit and vegetable consumption during nursing would be associated with high child fruit and vegetable consumption at 12 months and 6 years, even after accounting for likely confounders not considered in previous studies.

Methods

Participants and Recruitment

The IFPS II was a prospective cohort study from 2005 – 2012 with repeated measures of breastfeeding and child diet. Detailed information about participants and methods can be found elsewhere.⁽²⁴⁾ Briefly, pregnant women 18 years old in their third trimester of

pregnancy were recruited from a consumer opinion panel. Of the 4902 recruited, the only women invited to complete the study were those who responded to a birth screener phone call (response rate = 82.9%) and indicated they had singleton births at 35 weeks of gestation with infant birth weight 5 pounds. Infants with medical conditions that could affect feeding were excluded from the study. The cohort was sent questionnaires approximately monthly throughout the infants' first year of life, with response rates ranging from 63% to 83%. While participants were from across the United States, the cohort was not nationally representative; compared to participants in a nationally representative sample of mothers, IFPS II participants were older, had higher educational attainment and income, and were more likely to be white, to breastfeed, and to breastfeed longer.⁽²⁴⁾

The Year 6 Follow-Up Study (Y6FU) was conducted when the children were six years old. Detailed information about participants and methods can be found elsewhere.⁽²⁵⁾ The Y6FU was completed by 1542 of the 1624 mothers successfully contacted (response rate = 52%, cooperation rate = 95%). Compared to non-respondents, Y6FU respondents were older, more likely to be white and married, had higher educational attainment and income, and breastfed their children longer.⁽²⁵⁾

Breastfeeding Duration

Each IFPS II questionnaire asked, "How old was your baby when you completely stopped breastfeeding and pumping milk?" Mothers continuing to breastfeed at the time of the last IFPS II questionnaire they answered reported total breastfeeding duration in the Y6FU.

The first 16 weeks of life are a critical exposure period for flavor learning;^(11,12) we therefore dichotomized breastfeeding duration as <16 weeks or 16 weeks. We fit models with two other categorizations of breastfeeding duration as sensitivity analyses. The first took into account the American Academy of Pediatrics recommendation to breastfeed for at least one year:⁽²⁶⁾ <16 weeks, 16 to <52 weeks (sufficient for flavor learning but less than recommended), and 52 weeks (meeting recommendations). The second considered the potential difference between exclusive formula feeding and any breastfeeding: 0 weeks (exclusive formula feeding), >0 to <16 weeks, and 16 weeks. In these sensitivity analyses, point estimates were similar, but due to smaller group sizes, standard errors were larger than in the models fit with dichotomized breastfeeding duration. Only results with the dichotomized breastfeeding duration variable are presented here.

Maternal Diet

Between the three- and four-month IFPS II questionnaires, 1463 mothers completed the National Cancer Institute's diet history questionnaire (response rate = 82%) (Centers for Disease Control, unpublished results). The questionnaire was modified to capture maternal diet in the past month, thus focusing on diet post-partum.⁽²⁴⁾ A total of 67 mothers were removed from the maternal diet sample due to implausible calorie or carbohydrate intake (N=41) or missing postnatal data (N=26) (Centers for Disease Control, unpublished results).

Maternal daily fruit intake (servings/day) and daily vegetable intake (servings/day) were both centered at their means and included in models as continuous variables. Total caloric

intake was also included in all models, which energy-adjusts the fruit and vegetable intake measurements, thereby improving their validity.⁽²⁷⁾

Child Diet

In each of the IFPS II questionnaires, mothers reported what they fed their infant in the past seven days on a food frequency chart. Child fruit intake and vegetable intake at 12 months of age were used as the first outcomes in this study. Both variables were dichotomized as <1.5 times/day vs. 1.5 times/day, as was done by Rose et al.⁽²⁸⁾ to match the Child and Adult Care Food Program recommendations to serve fruits and vegetables three times per day.

During the Y6FU, mothers reported the frequency that their six-year-old ate fruits (fresh, frozen, or canned, not including juice) and vegetables.⁽¹⁵⁾ Vegetable intake frequency was calculated as the sum of two variables: “Green leafy or lettuce salad, with or without other vegetables,” and “Other vegetables: fresh, frozen, or canned (other than green leafy or lettuce salads, potatoes, or cooked dried beans)” Consistent with previous studies, both fruit and vegetable intake frequency at Y6FU were dichotomized by median split.⁽¹⁵⁾ Henceforth, child fruit and vegetable intake at both ages will be referred to as high consumption versus low consumption.

Covariates

To thoroughly address confounding, we adjusted for a wide range of covariates, including many not considered in previous studies. These variables were selected based on theory and previous research illustrating their associations with child diet as well as maternal diet or breastfeeding duration. Covariates included: 1) *maternal demographics*: age, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic Asian/Pacific Islander, non-Hispanic Other), education (high school, 1 – 3 years college, 4 years college), household income as a percentage of the federal poverty line (<100, 100 - 185, 186 – 349, 350), marital status (married; divorced, widowed, or separated; never married), parity (primiparous vs. multiparous); 2) *child characteristics*: sex, preterm birth (<37 weeks), child age at time of questionnaire completion; 3) *barriers and facilitators to breastfeeding*: prenatal plans for breastfeeding duration (<6 months, 6 – 11 months, 12 months), maternal employment 3 months postpartum, childcare use 3 months postpartum, 4) *the child’s food environment*, introduction to solid fruits or vegetables by the month 4 questionnaire, WIC enrollment in the first year postpartum, SNAP enrollment at Y6FU, fruit and vegetable availability at home as a snack at Y6FU (rarely/sometimes, often, always), fast food for dinner less than once per week at Y6FU; 5) *maternal health*: prepregnancy BMI (underweight or normal weight, overweight, obese), smoking during pregnancy, depression (assessed in the month 2 questionnaire by the Edinburgh Postnatal Depression Scale and dichotomized per guidelines),⁽²⁹⁾ gestational diabetes; and 6) *additional measures of maternal employment, childcare use, and smoking*: maternal employment at month 6, 9, 12, and any time by Y6FU; childcare use at month 6, 9 and 12; and smoking during the first year postpartum and at Y6FU.

Statistical Analysis

We had a final sample of 1396 mother-child dyads with complete data on breastfeeding duration and maternal diet for the current study. The level of missing data in the IFPS II study is commensurate with other mother-child cohorts.^(30–32) We imputed missing data for other variables using multiple imputation by chained equations.^(33,34) The amount of missing data in all variables can be found in Table 1 and Supplemental Table 1. Continuous variables were imputed using predictive mean matching, and categorical variables were imputed using the discriminant function. All reported results are based on 50 imputed datasets. Trace plots were checked for convergence, and the imputation procedure achieved over 98% efficiency for all parameter estimates. In addition to the variables included in our analytic models (both independent and dependent variables), imputation models included infant fruit and vegetable intake reported on the 6-, 7-, 9-, and 10-month questionnaires, as these were strong predictors of infant fruit and vegetable intake at 12 months. Imputation models also included Y6FU measurements of maternal BMI and depression, as they were strong predictors of prepregnancy BMI and depression 2 months postpartum, respectively. We had complete data on breastfeeding duration and maternal diet, so no imputation was required for the main effects or interaction of these key variables. To reduce bias in the estimated regression coefficients, interaction terms were included in the imputation models with the “just another variable” approach.⁽³⁵⁾ The imputation procedure was completed using PROC MI in SAS 9.4. Full multiple imputation results can be found in Supplemental Tables 2 – 5; only results using the multiply-imputed data are presented below. Complete case analysis results can be found in Supplemental Tables 6 – 7.

Descriptive statistics were calculated for each independent variable. We tested for differences in these variables by breastfeeding duration using chi-squared tests and equal variance t-tests. Our a priori hypotheses were that, consistent with experimental research demonstrating the combined effect of breastfeeding and maternal diet on infant acceptance of fruits and vegetables, we would observe a positive interaction between breastfeeding and maternal diet on later child diet. The outcomes in our multivariable analyses are high versus low child fruit or vegetable intake at 12 months or 6 years of age. Logistic regression models were used to assess the association of these outcomes with breastfeeding duration, maternal diet, and their interaction, adjusting for potential confounders. The impact of including each set of covariates on estimates of the main effects and interaction effect of maternal diet and breastfeeding duration are shown in Supplemental Tables 2 – 5. The type I error rate was set at 0.05. Because we considered these analyses exploratory, we did not make family-wise error rate or false discovery rate adjustments. All analyses were performed in SAS version 9.4.

Results

Children were breastfed for an average of 25.1 weeks; 42.4% of mothers breastfed less than 16 weeks even though 86.1% intended to breastfeed at least 24 weeks (Table 1). At 12 months, 64% of children had high fruit consumption (1.5 times/day) and 60% had high vegetable consumption (1.5 times/day) (Table 1). At 6 years, the median fruit intake was once daily and the median vegetable intake was 1.14 times daily. At both 12 months and 6

years, significantly more children breastfed ≥ 16 weeks had high fruit consumption compared to those breastfed <16 weeks; there were no statistically significant differences in child vegetable consumption by breastfeeding duration (Table 1). Breastfeeding duration was also strongly associated with many demographic, maternal health, and environmental variables including education, income, marital status, planned breastfeeding duration, maternal employment, childcare use, prepregnancy BMI, maternal smoking, and multiple measures of the child's food environment (Table 1, Supplemental Table 1).

In fully-adjusted analyses, there was a significant main effect of breastfeeding duration at 12 months; children breastfed ≥ 16 weeks had significantly higher odds of high fruit (AOR = 1.42, 95% CI 1.00 – 2.01) and vegetable (AOR = 1.44, 95% CI 1.01 – 2.04) intake compared to children breastfed <16 weeks (Supplemental Tables 2 - 3). Neither the main effect of maternal diet during nursing nor the interactions between breastfeeding duration and maternal diet were statistically significant at 12 months (Figure 1, Supplemental Tables 2 - 3).

In fully-adjusted analyses of child diet outcomes at 6 years, there were no significant main effects of breastfeeding duration or maternal diet, but there was a statistically significant interaction between breastfeeding duration and maternal vegetable consumption on child vegetable consumption (p for interaction = 0.037; Figure 1, Supplemental Tables 4 – 5). Among children breastfed ≥ 16 weeks, each additional serving of vegetables in the mother's diet during nursing was associated with a 22% higher odds of high child vegetable consumption (AOR = 1.22, 95% CI 1.08 – 1.37) (Figure 1). In contrast, among children breastfed <16 weeks, maternal vegetable consumption during nursing was not significantly associated with child vegetable consumption (AOR = 1.04, 95% CI 0.91 – 1.19). The interaction between breastfeeding duration and maternal fruit consumption during nursing on child fruit consumption was not statistically significant (p = 0.096) (Figure 1).

Discussion

In fully-adjusted analyses, we found that longer breastfeeding duration and higher maternal vegetable consumption while nursing had a synergistic association with child vegetable consumption at 6 years, supporting the hypothesis that exposures to the flavors of vegetables through breast milk during nursing may promote the child's later vegetable consumption. We did not find a significant analogous interaction effect on child fruit consumption at 6 years, or on child fruit or vegetable consumption at 12 months. While previous research has demonstrated the influence of breastfeeding and maternal diet on infant food acceptance^(11,12) and that food preferences established early in life are carried forward into later life,^(5,7,8) this study is among the first to explore whether the combination of breastfeeding and maternal nursing diet is associated with diet in later childhood.

At 12 months of age, we found a significant main effect of breastfeeding duration on child fruit and vegetable consumption, even after controlling for a wide array of confounders. This result may reflect an effect of breastfeeding on food acceptance in early infancy. Many, (36–38) but not all,⁽³⁹⁾ previous studies have found that breastfed infants are more accepting of novel fruits and vegetables than formula-fed infants. While acceptance of initially-

rejected foods can be improved through repeated exposure,⁽⁴⁰⁾ many parents do not continue serving previously-rejected foods,⁽⁴¹⁾ perhaps because they find the recommendation to reintroduce rejected foods 10-15 times to promote acceptance confusing or difficult to implement.^(41,42) As such, foods rejected early in infancy may not be reintroduced sufficiently to become a meaningful part of infants' diets at 12 months of age. In the current study, infants breastfed <16 weeks may have been less accepting of fruits and vegetables, possibly explaining why they were significantly less likely to have high fruit or vegetable consumption at 12 months compared to children breastfed longer.

At 6 years of age, we found a statistically significant interaction indicating that longer breastfeeding duration and higher maternal vegetable consumption had a synergistic association with high child vegetable consumption. Since vegetables are among children's most disliked foods⁽⁴³⁾ and child preferences are a key driver of the foods parents choose for their children,⁽⁵⁾ early life exposures that promote vegetable liking may be particularly important for promoting vegetable consumption. Although the observational nature of the current study limits causal interpretation about how early feeding experiences influence later diet, our findings are consistent with recommendations to expose infants to the flavors of healthy foods through breast milk to create a foundation for a healthy diet.⁽⁴⁰⁾

Unlike child vegetable consumption, we did not find a statistically significant interaction between breastfeeding duration and maternal fruit consumption on child fruit consumption at 6 years of age. Young children may be more accepting of fruits because they have an inborn preference for sweet taste;⁽⁴⁴⁻⁴⁶⁾ familiarity with fruit flavors may therefore be less important for promoting child fruit consumption. However, it may be especially important to establish familiarity with vegetable flavors to help children overcome their inborn dislike for bitter tastes⁽⁴⁴⁻⁴⁶⁾ and consume vegetables. Since children experience heightened neophobia, or the fear of new foods, starting at age 2,⁽⁶⁾ introducing vegetable flavors prior to the onset of neophobia, such as through the combination of breastfeeding and maternal vegetable consumption while nursing, may be an effective strategy for increasing their consumption.^(11,12) In sum, inborn taste preferences and developmental patterns of neophobia may explain why, in the current study, we observed a statistically significant interaction between breastfeeding and maternal diet only for children who had entered their neophobic phase (i.e., only at 6 years of age) and only for vegetables.

Our study has many strengths, including the use of a prospective cohort of mother-child dyads to create models that match the biology of flavor learning during infancy and the social determinants of both breastfeeding and child diet. To model the mechanism of flavor learning through breast milk, we examined the interaction between maternal diet and breastfeeding, and we categorized breastfeeding duration according to infants' critical developmental window for flavor learning.^(11,12) Also, to isolate flavor learning through breast milk, we controlled for the timing of infants' first exposure to solid fruits and vegetables because these exposures serve as opportunities for infants to learn the flavors of these foods, and earlier exposures to vegetables tend to increase infant acceptance of novel vegetables.⁽⁴⁷⁾ To reflect the social determinants of breastfeeding, we included common barriers like employment.⁽⁴⁸⁾ We also adjusted for women's planned breastfeeding duration; when mothers are asked during pregnancy how long they plan to breastfeed, they are able to

factor in a broad array of barriers and facilitators to breastfeeding, which is why others have advocated for adjusting for this variable.⁽²³⁾ Last, unlike previous studies, we adjusted for the child's food environment, an important determinant of child fruit and vegetable consumption.⁽²²⁾

Despite these strengths, the observational nature of this study limits the extent to which causal inference can be drawn from these results. Our results may be biased by uncontrolled or residual confounding, despite our adjustment for many likely confounders. Results may also be biased by measurement error; the food frequency questionnaire used in this study shows high validity,⁽⁴⁹⁾ but non-random and systematic biases in diet measurement have been reported with food frequency questionnaires.⁽⁵⁰⁾ Similarly, reporting error has been documented when parents complete food frequency questionnaires about their children's diets.⁽⁵¹⁾ While others have found child vegetable intake to be strongly associated with child vegetable liking,⁽²¹⁾ child preferences were not measured in the current study and it is therefore not possible to say whether child preferences at 12 months or 6 years are associated with breastfeeding and/or maternal diet during nursing. Future studies should measure child preferences to test the hypothesis that exposures to vegetable flavors in breastmilk during infancy can increase vegetable intake in later childhood by increasing child vegetable liking.

Another limitation to the current study is that there was considerable loss to follow-up over the 6-year study period. Unfortunately, for cohort studies of this duration, substantial dropout is the norm.^(30–32) For example, of 2128 live births in another U.S. cohort, 1279 mother-child dyads provided data for the mid-childhood visit (median 7.7 years).⁽³¹⁾ As such, studies on these cohorts should use rigorous missing data methods, as we have employed here.

While our use of multiple imputation was a strength that few previous studies on this topic have employed, the validity of our findings rests on the assumption of data missing at random. If data are not missing at random, the magnitude of the bias depends on the strength of the association between the missing data mechanism(s) and our variables of interest, independent of the observed population characteristics included in our multiple imputation approach. Because our multiple imputation step included many observed characteristics that have strong associations with our variables of interest, the independent association between unobserved characteristics and our variables of interest is unlikely to be strong. As such, the magnitude of bias is likely small. Nonetheless, our results must be interpreted cautiously and we encourage other investigators to repeat our analyses in different populations.

An additional direction for future studies is to carefully examine different breastfeeding durations. Using three, rather than two, breastfeeding duration categories in the current study produced similar results, but our ability to detect differences between three groups may have been limited by sample size. Of particular interest for future research is examining differences between infants exclusively formula fed and infants breastfed for at least four weeks, as there is experimental evidence that four weeks of exposure to a vegetable flavor through breastmilk can affect infant acceptance of that flavor.⁽¹¹⁾ However, even with a

larger sample, there is strong potential for confounding when comparing these groups, so conclusions must be drawn carefully.

Our findings, which suggest that the combination of breastfeeding and maternal vegetable consumption while nursing may promote later child vegetable consumption, have important implications for improving population health. However, when considering potential changes to practice and policy, it is critical to examine diet and breastfeeding in the larger biological and social contexts that shape the health behaviors of mothers and their children. First, breastfeeding is not the only opportunity for children to learn to like the flavors of healthy foods; flavor learning begins in utero, where fetuses are exposed to flavors from their mothers' diets via the amniotic fluid.^(3,6) Flavor learning continues well after breastfeeding, with parental feeding practices and environmental factors playing a key role in children's ultimate food preferences and diets.⁽⁵²⁾ Achieving improvements in child nutrition, and therefore population health, will likely require efforts across these stages of development. Second, within any given developmental stage, it is crucial to acknowledge the myriad factors that can facilitate or inhibit health-promoting practices. For example, the many well-established health benefits of breastfeeding^(9,26) are disproportionately enjoyed by mothers in this study and others^(10,48) who have high-income, high educational attainment, and who are not in paid employment. In this study, 42.4% of mothers stopped breastfeeding by 16 weeks even though 86.1% intended to breastfeed for at least 24 weeks, highlighting the fact that desire to breastfeed is seldom the limiting factor. As such, population-level benefits of breastfeeding, including its potential role in promoting healthy child diet, may be best realized if clinicians, policymakers, and others go beyond individual-level interventions directed at mothers and address broader contextual barriers to breastfeeding.⁽⁵²⁾ Similarly, the broader context must be considered to effectively promote healthy maternal diet during pregnancy and nursing.

In conclusion, we found that the combination of longer breastfeeding duration and higher maternal vegetable consumption during nursing is associated with child vegetable consumption at six years. These results align with results from randomized trials, which have demonstrated that exposing infants to vegetable flavors through breastmilk can increase infants' acceptance of vegetable flavors in solid foods.^(11,12) Our results also align with observational studies of older children, which have found that breastfeeding in infancy is associated with greater vegetable intake in childhood.^(13–17,19–21) As such, our study adds to the evidence that breastfeeding, and specifically exposure to vegetable flavors through breastmilk, may help to lay a foundation for acceptance of a healthy diet later in childhood.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Kim S, Moore L, Galuska D, et al. (2014) Vital Signs: Fruit and Vegetable Intake Among Children — United States, 2003–2010. *MMWR Morb. Mortal. Wkly. Rep* 63, 671–676. [PubMed: 25102415]
2. Lock K, Pomerleau J, Causer L, et al. (2005) The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet. *Bull World Heal. Organ* 83, 100–108.
3. Birch LL (1999) Development of Food Preferences. *Annu. Rev. Nutr* 19, 41–62. [PubMed: 10448516]
4. Yuan WL, Rigal N, Monnery-Patris S, et al. (2016) Early determinants of food liking among 5y-old children: a longitudinal study from the EDEN mother-child cohort. *Int. J. Behav. Nutr. Phys. Act* 13, 20. [PubMed: 26876058]
5. Russell CG & Worsley A (2013) Why don't they like that? And can I do anything about it? The nature and correlates of parents' attributions and self-efficacy beliefs about preschool children's food preferences. *Appetite* 66, 34–43. [PubMed: 23474088]
6. Ventura AK & Worobey J (2013) Early Influences on the Development of Food Preferences. *Curr. Biol* 23, R401–R408. [PubMed: 23660363]
7. Mennella JA, Reiter AR & Daniels LM (2016) Vegetable and Fruit Acceptance during Infancy: Impact of Ontogeny, Genetics, and Early Experiences. *Adv. Nutr. An Int. Rev. J* 7, 211S–219S.
8. Portella AK, Kajantie E, Hovi P, et al. (2012) Effects of in utero conditions on adult feeding preferences. *J. Dev. Orig. Health Dis* 3, 140–152. [PubMed: 25102005]
9. Victora CG, Bahl R, Barros AJD, et al. (2016) Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *Lancet* 387, 475–490. [PubMed: 26869575]
10. Rollins NC, Bhandari N, Hajeerhoy N, et al. (2016) Why invest, and what it will take to improve breastfeeding practices? *Lancet* 387, 491–504. [PubMed: 26869576]
11. Mennella JA, Daniels LM & Reiter AR (2017) Learning to like vegetables during breastfeeding: a randomized clinical trial of lactating mothers and infants. *Am. J. Clin. Nutr* 106, 67–76. [PubMed: 28515063]
12. Mennella JA, Jagnow CP & Beauchamp GK (2001) Prenatal and postnatal flavor learning by human infants. *Pediatrics* 107, E88. [PubMed: 11389286]
13. Scholtens S, Brunekreef B, Smit HA, et al. (2008) Do Differences in Childhood Diet Explain the Reduced Overweight Risk in Breastfed Children? *Obesity* 16, 2498–2503. [PubMed: 18756263]
14. Soldateli B, Vigo A & Regina Justo Giugliani E (2016) Effect of Pattern and Duration of Breastfeeding on the Consumption of Fruits and Vegetables among Preschool Children. *PLoS One* 11, e0148357. [PubMed: 26844543]
15. Perrine CG, Galuska DA, Thompson FE, et al. (2014) Breastfeeding Duration Is Associated With Child Diet at 6 Years. *Pediatrics* 134, S50–S55. [PubMed: 25183756]
16. De Lauzon-Guillain B, Jones L, Oliveira A, et al. (2013) The influence of early feeding practices on fruit and vegetable intake among preschool children in 4 European birth cohorts. *Am J Clin Nutr* 98, 804–812. [PubMed: 23864537]
17. Okubo H, Miyake Y, Sasaki S, et al. (2017) Feeding practices in early life and later intake of fruit and vegetables among Japanese toddlers: the Osaka Maternal and Child Health Study. *Public Health Nutr.* 19, 650–657.
18. Cooke LJ, Wardle J, Gibson E, et al. (2004) Demographic, familial and trait predictors of fruit and vegetable consumption by pre-school children. *Public Health Nutr.* 7, 295–302. [PubMed: 15003137]
19. Grieger JA, Scott J & Cobiac L (2011) Dietary patterns and breast-feeding in Australian children. *Public Health Nutr.* 14, 1939–1947. [PubMed: 21729461]
20. Burnier D, Dubois L & Girard M (2011) Exclusive breastfeeding duration and later intake of vegetables in preschool children. *Eur. J. Clin. Nutr* 65, 196–202. [PubMed: 20978527]

21. de Wild VW, Jager G, Olsen A, et al. (2018) Breast-feeding duration and child eating characteristics in relation to later vegetable intake in 2–6-year-old children in ten studies throughout Europe. *Public Health Nutr.* 21, 2320–2328. [PubMed: 29631638]
22. Blanchette L & Brug J (2005) Determinants of fruit and vegetable consumption among 6-12-year-old children and effective interventions to increase consumption. *J. Hum. Nutr. Diet* 18, 431–443. [PubMed: 16351702]
23. Amir LH & Donath SM (2012) Maternal diet and breastfeeding: A case for rethinking physiological explanations for breastfeeding determinants. *Early Hum. Dev.* 88, 467–471. [PubMed: 22118871]
24. Fein SB, Labiner-Wolfe J, Shealy KR, et al. (2008) Infant Feeding Practices Study II: Study Methods. *Pediatrics* 122, S28–35. [PubMed: 18829828]
25. Fein SB, Li R, Chen J, et al. (2014) Methods for the Year 6 Follow-Up Study of Children in the Infant Feeding Practices Study II. *Pediatrics* 134, S4–S12. [PubMed: 25183754]
26. Eidelman AI, Schanier RJ, Johnston M, et al. (2012) Breastfeeding and the Use of Human Milk. *Pediatrics* 129, e827–e841. [PubMed: 22371471]
27. Willett W (2013) *Nutritional Epidemiology*. 3rd ed. New York: Oxford University Press.
28. Rose CM, Savage JS & Birch LL (2016) Patterns of early dietary exposures have implications for maternal and child weight outcomes. *Obesity* 24, 430–438. [PubMed: 26717908]
29. Cox JL, Holden JM & Sagovsky R (1987) Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *Br. J. Psychiatry* 150, 782–6. [PubMed: 3651732]
30. Boyd A, Golding J, Macleod J, et al. (2013) Cohort Profile: The 'Children of the 90s'-the index offspring of the Avon Longitudinal Study of Parents and Children. *Int. J. Epidemiol* 42, 111–127. [PubMed: 22507743]
31. Oken E, Baccarelli AA, Gold DR, et al. (2015) Cohort profile: project viva. *Int. J. Epidemiol* 44, 37–48. [PubMed: 24639442]
32. Heude B, Forhan A, Slama R, et al. (2015) Cohort Profile: The EDEN mother-child cohort on the prenatal and early postnatal determinants of child health and development. *Int. J. Epidemiol* 44, 353–363.
33. Raghunathan TE, Lepkowski JM, Van Hoewyk J, et al. (2001) A Multivariate Technique for Multiply Imputing Missing Values Using a Sequence of Regression Models. *Surv. Methodol* 27, 85–96.
34. van Buuren S (2007) Multiple imputation of discrete and continuous data by fully conditional specification. *Stat. Methods Med. Res* 16, 219–242. [PubMed: 17621469]
35. White IR, Royston P & Wood AM (2011) Multiple imputation using chained equations: Issues and guidance for practice. *Stat. Med* 30, 377–99. [PubMed: 21225900]
36. Hausner H, Nicklaus S, Issanchou S, et al. (2010) Breastfeeding facilitates acceptance of a novel dietary flavour compound. *Clin. Nutr* 29, 141–8. [PubMed: 19962799]
37. Maier AS, Chabanet C, Schaal B, et al. (2008) Breastfeeding and experience with variety early in weaning increase infants' acceptance of new foods for up to two months. *Clin. Nutr* 27, 849–857. [PubMed: 18838198]
38. Forestell CA & Mennella JA (2007) Early Determinants of Fruit and Vegetable Acceptance. *Pediatrics* 120, 1247–1254. [PubMed: 18055673]
39. Schwartz C, Chabanet C, Lange C, et al. (2011) The role of taste in food acceptance at the beginning of complementary feeding. *Physiol. Behav* 104, 646–652. [PubMed: 21554893]
40. Anzman-Frasca S, Ventura AK, Ehrenberg S, et al. (2018) Promoting healthy food preferences from the start: a narrative review of food preference learning from the prenatal period through early childhood. *Obes. Rev* 19, 576–604. [PubMed: 29266778]
41. Goodell LS, Johnson SL, Antono AC, et al. (2017) Strategies Low-Income Parents Use to Overcome Their Children's Food Refusal. *Matern. Child Health J* 21, 68–76. [PubMed: 27443653]
42. American Academy of Pediatrics (2018) Infant Food and Feeding. <https://www.aap.org/en-us/advocacy-and-policy/aap-health-initiatives/HALF-Implementation-Guide/Age-Specific-Content/pages/infant-food-and-feeding.aspx> (accessed August 2018).

43. Fildes A, van Jaarsveld CHM, Wardle J, et al. (2014) Parent-Administered Exposure to Increase Children's Vegetable Acceptance: A Randomized Controlled Trial. *J. Acad. Nutr. Diet* 114, 881–888. [PubMed: 24091061]
44. Fildes A, Lopes C, Moreira P, et al. (2015) An exploratory trial of parental advice for increasing vegetable acceptance in infancy. *Br. J. Nutr* 114, 328–336. [PubMed: 26063588]
45. Steiner J (1977) Facial expressions of the neonate infant indicating the hedonics of food related chemical stimuli In *Taste and Development: the genesis of sweet preference*, pp. 173–189 [Weiffenbach J, editor]. Bethesda, MD: US Department of Health, Education, and Welfare, Public Health Service, National Institutes of Health.
46. Steiner JE (1979) Human facial expressions in response to taste and smell stimulation. *Adv. Child Dev. Behav* 13, 257–95. [PubMed: 484324]
47. Lange C, Visalli M, Jacob S, et al. (2013) Maternal feeding practices during the first year and their impact on infants' acceptance of complementary food. *Food Qual. Prefer* 29, 89–98.
48. Thulier D & Mercer J (2009) Variables Associated With Breastfeeding Duration. *J. Obstet. Gynecol. Neonatal Nurs* 38, 259–268.
49. Subar AF, Thompson FE, Kipnis V, et al. (2001) Comparative Validation of the Block, Willett, and National Cancer Institute Food Frequency Questionnaires. *Am. J. Epidemiol* 154, 1089–1099. [PubMed: 11744511]
50. Kipnis V, Midthune D, Freedman LS, et al. (2001) Empirical Evidence of Correlated Biases in Dietary Assessment Instruments and Its Implications. *Am. J. Epidemiol* 153, 394–403. [PubMed: 11207158]
51. Burrows TL, Martin RJ & Collins CE (2010) A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water. *J. Am. Diet. Assoc* 110, 1501–1510. [PubMed: 20869489]
52. Beckerman JP, Alike Q, Lovin E, et al. (2017) The Development and Public Health Implications of Food Preferences in Children. *Front. Nutr* 4, 66. [PubMed: 29326942]

Figure 1. Multivariable-adjusted odds ratio of high child fruit or vegetable consumption associated with a one serving/day increase in maternal fruit or vegetable consumption, respectively, by breastfeeding duration.

All models were adjusted for maternal demographics (age, race/ethnicity, education, household income as a percentage of the federal poverty line, marital status, parity), child characteristics (sex, preterm birth, child age at time of questionnaire completion), barriers and facilitators to breastfeeding (prenatal plans for breastfeeding duration, maternal employment 3 months postpartum, childcare use 3 months postpartum), the child's food environment (WIC enrollment in the first year postpartum, introduction to solid fruits or vegetables by the month 4 questionnaire), maternal health (prepregnancy BMI, smoking during pregnancy, depression, gestational diabetes), and additional measures of maternal employment, childcare use, and smoking (maternal employment at month 6, 9, 12; childcare use at month 6, 9 and 12; and smoking during the first year postpartum). Year 6 models were additionally adjusted for the following variables measured only at Y6FU: fruit and vegetable availability at home as a snack, fast food for dinner less than once per week, SNAP enrollment, maternal employment at Y6FU, and maternal smoking at Y6FU. Full results can be found in Supplemental Tables 4 – 7, model 7.

Table 1.

Mean (S.D.) or percent values for descriptive characteristics of study participants stratified by duration of any breastfeeding.

	Total (N = 1396)		<16 weeks breastfeeding ^a (N = 592)		16 weeks breastfeeding ^a (N = 804)		
	N or Mean	% or SD	N or Mean	% or SD	N or Mean	% or SD	Missing (%) ^b
Maternal Characteristics							
Age (years)***	29.2	5.3	28.5	5.6	29.8	5.0	0.1
Race/ethnicity*							1.7
Asian/Pacific Islander	47	3.4	12	2.1	35	4.4	
Black	64	4.7	35	6.0	29	3.7	
Hispanic	76	5.5	38	6.6	38	4.8	
White	1160	84.6	481	83.1	679	85.6	
Other	25	1.8	13	2.3	12	1.5	
Education***							5.5
High School	242	18.4	141	26.0	101	13.0	
1 – 3 years college	510	38.7	235	43.4	275	35.4	
4 years college	567	43.0	166	30.6	401	51.6	
Income-poverty ratio***							0.0
<100% FPL	206	14.8	123	20.8	83	10.3	
100% - 185% FPL	331	23.7	139	23.5	192	23.9	
>185% - <350% FPL	512	36.7	184	31.1	328	40.8	
350% FPL	347	24.9	146	24.7	201	25.0	
Maternal Diet							
Fruit (servings/day)***	2.2	2.1	2.0	2.1	2.4	2.1	0.0
Vegetables (servings/day)**	3.7	2.5	3.4	2.4	3.9	2.7	0.0
Calories/day*	1926.5	755.3	1879.0	812.4	1961.5	708.8	0.0
Child Characteristics							
Female	724	51.9	309	52.3	415	51.6	0.1
Breastfeeding duration (weeks)***	25.1	20.7	4.3	4.6	40.4	13.2	0.0
12 month child diet							
Fruit >1.5 times/day**	613	63.7	213	58.2	400	67.0	31.0
Vegetables >1.5 times/day	576	60.1	204	56.8	372	62.1	31.4
6 year child diet							
Fruit intake > median***	329	41.9	100	33.1	229	47.3	43.7
Vegetable intake > median	367	46.7	131	43.4	236	48.8	43.7
Barriers and Facilitators to Breastfeeding							

	Total (N = 1396)		<16 weeks breastfeeding ^a (N = 592)		16 weeks breastfeeding ^a (N = 804)		
	N or Mean	% or SD	N or Mean	% or SD	N or Mean	% or SD	Missing (%) ^b
Planned breastfeeding duration (assessed prenatally) ***							18.7
<6 months	158	13.9	119	31.6	39	5.2	
6 – 11 months	461	40.6	177	47.0	284	37.5	
12 months	516	45.5	81	21.5	435	57.4	
Child's Food Environment							
Fruit and vegetables available as a snack at home **							43.7
Always	533	67.8	186	61.8	347	71.6	
Often	193	24.6	83	27.6	110	22.7	
Sometimes/never	60	7.6	32	10.6	28	5.8	
Maternal Health							
Pre-pregnancy BMI **							1.4
<25 (underweight/normal)	704	51.1	272	46.7	432	54.4	
25 - <30 (overweight)	353	25.6	146	25.0	207	26.1	
30 (obese)	320	23.2	165	28.3	155	19.5	

SD = standard deviation

^a – Unadjusted statistical comparisons by breastfeeding duration were made with chi-square or equal variance t-tests.

^b – The percent of the total sample (n = 1396) with missing data for each variable.

* - differs by breastfeeding duration, p <0.05

** - differs by breastfeeding duration, p <0.01

*** - differs by breastfeeding duration, p <0.001