Original Article
PEDIATRIC OBESITY

Obesity

INSIGHT Responsive Parenting Intervention is Associated with Healthier Patterns of Dietary Exposures in Infants

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Objective: To determine whether a responsive parenting (RP) intervention affects infant dietary patterns.

Methods: Primiparous mother-newborn dyads (n = 291) were randomized to the Intervention Nurses Start Infants Growing on Healthy Trajectories (INSIGHT) RP intervention or control. Curricula were delivered at nurse home visits at ages 3, 16, 28, and 40 weeks. RP group feeding guidance advised responsive feeding, delayed introduction of solids, repeated exposure to novel foods, and age-appropriate portion sizes. Latent class analysis identified patterns of dietary exposure at 9 months. Class membership at 9 months was used to predict BMI percentile at 2 years.

Results: Five dietary patterns were identified: "Breastfed, Fruits and Vegetables," "Breastfed, Low Variety," "Formula, Fruits and Vegetables," "Formula, Low Variety," and "Formula, High Energy Density." Over 60% of infants had patterns low in fruits and vegetables or high in energy-dense foods. RP group infants were less likely than control to be in the "Formula, Low Variety" class (OR = 0.40, 95% CI 0.23–0.71) or "Formula, High Energy Density" class (OR = 0.28, 95% CI 0.12–0.61) relative to the "Formula, Fruits and Vegetables" class. Dietary pattern at 9 months was significantly associated with BMI percentile at 2 years.

Conclusions: While a majority of infants consumed diets low in fruits and vegetables, the INSIGHT RP intervention was associated with healthier dietary patterns.

Obesity (2017) **25**, 185-191. doi:10.1002/oby.21705

Introduction

Composition of the infant diet changes substantially in the first year after birth (1). Initially, infants consume only breastmilk and/or infant formula. Later in the first year, a variety of dietary patterns begins to emerge as infants are introduced to complementary foods (1,2). Caregiver decisions on what, when, and how to feed infants during this transition period influence food preferences, eating behaviors (3), and dietary patterns later in childhood (4,5), making infancy a critical time for promoting healthy dietary patterns. Descriptive data on infant dietary intake from the Feeding Infants and Toddlers Study show that patterns of dietary intake vary widely across children and over time (2). However, less is known about how infants' emerging dietary patterns are related to obesity risk and whether early intervention with parents can modify infant diet.

The Intervention Nurses Start Infants Growing on Healthy Trajectories (INSIGHT) is a randomized controlled trial to evaluate a responsive parenting (RP) intervention designed for the primary prevention of obesity (6). Mothers in the intervention received guidance on RP, which is defined as developmentally appropriate, prompt, and contingent on their infant's needs, in the areas of feeding, sleep, emotion regulation, and active social play. We previously reported that infants randomized to the INSIGHT RP intervention had slower weight gain during the first 6 months after birth, a lower mean weight-for-length percentile at 1 year of age, and a reduced prevalence of overweight at 1 year (7). The purpose of this analysis was to determine whether the INSIGHT RP intervention was associated with healthier patterns of dietary intake in later infancy (age 9 months) when infants are consuming both complementary foods and breastmilk and/or formula and whether these dietary patterns were associated with later weight status.

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Funding agencies: This research was supported by NIH grant R01DK088244. Additional support was received from the Children's Miracle Network at Penn State Children's Hospital. USDA Grant #2011-67001-30117 supported graduate students. REDCap support was received from The Penn State Clinical & Translational Research Institute, Pennsylvania State University CTSA, NIH/NCATS Grant Number UL1 TR000127.

Disclosure: The authors declared no conflict of interest.

Author contributions: EEH assisted in data management, performed the data analyses, and drafted the manuscript. IMP and LLB co-led the conception and design of the study and participated in critical revision of the manuscript. JSS contributed to the design of the study, intervention curriculum development, and data analyses and participated in critical revision of the manuscript. All authors approved the final manuscript.

Clinical trial registration: ClinicalTrials.gov identifier NCT01167270.

Received: 15 June 2016; **Accepted:** 19 September 2016; **Published online 23 December 2016. doi:10.1002/oby.21705**

In a recent study, Rose et al. (8) used latent class analysis (LCA), a person-centered approach, to explore infant dietary patterns. In contrast to variable-centered approaches, which focus on relationships between variables across individuals, person-centered approaches like LCA focus on distinct patterns of variables within individuals (9), allowing subgroups of individuals with different combinations of common characteristics to be identified. Using this approach, five subtypes of infants were identified based on dietary patterns characterized by different combinations of milk feeding (breastfed, formula-fed, or mixed) and complementary foods. Results revealed that infants whose diets were characterized as Mixed High Energy Density were more likely to be overweight at 1 year than those in the other classes (e.g., "Breastfed Fruits and Vegetables," "Breastfed Low Variety," "Formula-Fed Fruits and Vegetables," "Formula-Fed Low Variety") (8). The objectives of this analysis were to use the same LCA approach to (1) identify patterns of milk and complementary feeding among 9-month-old infants participating in the INSIGHT study, (2) explore the effect of maternal and infant characteristics on dietary pattern class membership, (3) determine whether dietary pattern class membership differed between RP and control groups, and (4) assess the relationship between dietary pattern class membership at 9 months and body mass index (BMI) at 2 years.

Methods

Study design

Primiparous mothers and their healthy, term, singleton newborns were recruited from a maternity ward in central Pennsylvania. At 10 to 14 days postpartum, mother–infant dyads were randomized ($n = 291$) to a RP intervention or child safety control intervention. Participants who completed the first study visit at 3 to 4 weeks after birth ($n = 279$) are considered the final study cohort for all analyses as specified in the study protocol (6). At 3, 16, 28, and 40 weeks after birth, nurses visited participants' homes to deliver the intervention curricula. The RP curriculum focused on four infant behavioral states: drowsy, sleeping, fussy, and alert (6). Specific messages on feeding taught parents to recognize hunger and satiety cues, to offer age-appropriate foods and portion sizes, to use food for hunger only and not as a reward or punishment or to soothe a distressed but not hungry child, and to use repeated exposure to promote acceptance of foods, the importance of modeling healthy eating behaviors, shared feeding responsibility, and establishment of routines and limits. The control group received age-appropriate child safety information. Safety messages related to feeding focused on food safety and choking prevention. Additional details on eligibility, screening, and curriculum have been previously published (6). This study was approved by the Human Subjects Protection Office of the Penn State College of Medicine and was registered at ClinicalTrials.gov before the first participant's enrollment.

Measures

Data were collected and managed using Research Electronic Data Capture (10). Demographic predictors, including education, income, and marital status, were collected from participants at enrollment. Maternal age, prepregnancy BMI, and gestational weight gain and infant sex, birth weight, and gestational age were extracted from medical records. Childcare use and maternal employment status were collected from mothers during interviews with research staff.

Infant dietary intake was assessed using a food frequency questionnaire (FFQ) at age 9 months (11). Mothers were asked to indicate how often their child consumed 121 food and beverage items in the previous week, as well as the number of feedings per day of breastmilk and formula. Variables for LCA were created by dichotomizing intake of each food group using the method of Rose et al. (8). Infants were classified as predominantly breastfed at 9 months if $\geq$80% of total milk feeds consisted of breastmilk (1). Likewise, predominantly formula-fed at 9 months was defined as $\geq$80% of total milk feeds from formula. Other food and beverage groups were dichotomized based on meeting or not meeting the recommended servings per day of each food for 8- to 11-month-old infants in childcare, using the Child and Adult Care Food Program (CACFP) recommendations (12).

Child weight and height were measured by a nurse blinded to study group at a 2-year clinic visit. Weight was measured in duplicate to the nearest 0.1 kg using an electronic scale (Seca 354, Hanover, MD). Height was measured in duplicate to the 1 cm using a portable stadiometer (Shorr Productions, Olney, MD). Age- and gender-specific BMI percentiles and *z*-scores were calculated using CDC standards (13). BMI percentile is a recommended and widely used indicator of adiposity in children $\geq$2 years of age, with overweight and obesity defined as BMI in 85th to 94th percentile and $\geq$95th percentile, respectively (14).

Statistical analysis

LCA was used to identify discrete, mutually exclusive latent classes based on the infant FFQ data. LCA was performed using PROC LCA (15); this SAS procedure and its user's guide are available at http://methodology.psu.edu. Models with one through seven latent classes were compared with identify the best fitting model using fit criteria including the G^2 fit statistic, Akaike's Information Criterion, and Bayesian Information Criterion, and bootstrap likelihood ratio test (16). To test for both main effects of covariates and interactions with study group, covariates were entered one at a time into an LCA model along with a dummy coded variable for study group and an interaction with study group. To aid in interpretability, effects of covariates were also tested by assigning participants to the class corresponding to their maximum posterior probability in the initial LCA model without covariates, and then testing for differences between classes using ANOVA with Tukey's *post hoc* test for continuous variables or Fisher's exact test for categorical variables. Covariates that were significant individually were entered into a final LCA model along with study group assignment, and the overall effect of study group on class membership was determined from the log-likelihood test in the LCA model. Participants were assigned to classes using the final model with covariates using the classify-analyze approach described by Bray et al. (17).

Finally, dietary class membership at 9 months was used to predict BMI at age 2 years, using a generalized linear model. All analyses were performed in SAS 9.4 (SAS Institute, Cary, NC), and significance was accepted at $P \leq 0.05$ and adjusted for multiple comparisons where appropriate.

Results

Participant characteristics

Participants were predominantly white, non-Hispanic, and married and were on average well educated and higher income (Table 1). There were no differences between the RP and control groups in any of the demographic variables examined, nor was there a significant difference in attrition by study group. Approximately a third of

TABLE 1 Demographic characteristics of infants included in LCA analysis

	Responsive parenting ($n = 129$)	Control ($n = 130$)
Maternal characteristics		
Age (yr)	29.1 (4.5)	28.8 (4.8)
Married (%)	76.0	79.2
Income (%)		
<\$10,000	3.9	2.3
\$10,000-24,999	6.2	6.9
\$25,000-49,999	3.1	16.9
\$50,000-74,999	34.1	19.2
\$75,000-99,999	24.8	16.9
≥\$100,000	24.0	31.5
Don't know/refuse to answer	3.9	6.2
Education (%)		
High school or less	7.8	10.8
Some college	26.4	24.6
College graduate	36.4	39.2
Postgraduate	29.5	25.4
Race (%)		
Black	5.4	4.6
White	89.2	92.3
Native Hawaiian or Pacific Islander	0.8	0
Asian	3.1	3.1
Other	1.6	0
Hispanic (%)	7.0	6.2
Prepregnancy BMI	25.6 (5.0)	25.3 (5.7)
Gestational weight gain (kg)	15.4 (6.3)	15.1 (6.0)
Returned to work by 3 mo (%)	53.1	59.9
Infant characteristics		
Infant sex (% male)	53.5	49.2
Birth weight-for-gestational age z-score	−0.04 (0.88)	0.08 (0.87)
In childcare at 20 wk (%)	60.5	66.2

Values are mean (SD) or %.

the total sample was predominantly breastfed and nearly two thirds were predominantly formula-fed at 9 months (Table 2). These percentages did not differ by study group, nor did the percentage of participants meeting or not meeting the CACFP recommendations for each complementary food.

Latent class analysis of infant dietary patterns

A model with five classes was selected to describe infant dietary patterns at 9 months based on a combination of Akaike's Information Criterion (952 for one class, 703 for two, 646 for three, 608 for four, 594 for five, 593 for six, and 602 for seven), Bayesian Information Criterion (998 for one class, 799 for two, 792 for three, 804 for four, 840 for five, 888 for six, and 947 for seven), bootstrap likelihood ratio test (one vs. two, two vs. three, three vs. four, four vs. five classes, all $P < 0.05$; five vs. six classes, $P > 0.05$), and an inspection of the parameters. The five class model identified classes that were similar to those identified by Rose et al. (8) in the patterns of items endorsed. The average posterior probabilities for the five classes ranged from 0.85 to 0.99.

Table 2 shows the item response probabilities of endorsing each food group for each of the five latent classes. Item response probabilities closer to 1 indicate that infants in that latent class are more likely to consume the item, while probabilities closer to 0 indicate that they are less likely to consume the item. The five classes were labeled based on the combination of milk feeding and solid foods endorsed at 9 months. The first class, "Breastfed, Fruits and Vegetables (BFV)" (24.0% of all participants), was characterized by a high probability of being predominantly breastfed at 9 months, a high probability of consuming fruits and vegetables (FV), and a low probability of consuming fruit juice and high-energy-density (ED) foods like sweet drinks, sweet foods, and French fries. The second class, "Breastfed, Low Variety (BLV)" (10.0% of participants), also had a high probability of being predominantly breastfed at 9 months but a lower probability of consuming FV and other age-appropriate complementary foods than the BFV class. The third class, "Formula, Fruits and Vegetables" (FFV) (15.5% of participants), had a high probability of being predominantly formula-fed at 9 months and consuming FV and a low probability of consuming fruit juice and sweet drinks. The fourth and largest class, "Formula, Low Variety (FLV)" (40.2% of participants), also had a high probability of being predominantly formula-fed at 9 months but had a lower probability of consuming age-appropriate complementary foods and a higher probability of consuming fruit juice than the FFV class. The fifth class, "Formula, High Energy Density (FHED)" (10.3% of participants), was characterized by a high probability of being formula-fed at 9 months and consuming FV, but also a higher probability than the other classes of consuming fruit juice, sweet drinks, sweet foods, and French fries.

Effects of covariates on latent class membership

Effects of covariates (maternal age, income, marital status, education, prepregnancy BMI, gestational weight gain, employment, childcare, infant sex, and birth weight) on class membership probability are shown in Table 3, and for ease of interpretability, differences in means or percentages by class are shown in Table 4. There were no significant interactions between study group and any of the covariates investigated, so the analyses presented include only main effects. Odds ratios (OR) were calculated using BFV as a reference for all other classes, as this pattern is most consistent with current infant feeding guidance. Mothers who were older, higher income, married, and more highly educated were less likely to be classified as FLV and FHED, while mothers with a higher prepregnancy BMI were more likely to belong to these classes. Mothers who had returned to work by 3 months were more likely to belong to the FLV class. There were no significant effects of gestational weight gain, infant sex, infant birth weight-for-gestational age z-score, or use of childcare at 20 weeks on class membership probability.

Effects of RP intervention on latent class membership

When covariates that had significant independent effects on class membership were included together in a single LCA model, maternal age and income were no longer significant and were dropped from the model. In the final model including study group, marital

TABLE 2 Item response probabilities for five latent classes of dietary exposure, based on FFQ data at 9 months

FFQ item	Total sample (%)	BFV[a]	BLV	FFV	FLV	FHED
Breastmilk (≥80%)[b,c]	33.0	0.96	0.98	0.00	0.00	0.00
Formula (≥80%)[c]	58.9	0.00	0.00	0.78	0.94	0.87
Cow's milk (>0 × per day)	2.0	0.00	0.00	0.00	0.00	0.19
Other dairy (≥1 × per day)	35.7	0.55	0.20	0.44	0.20	0.57
Infant cereal (≥3 × per day)	7.8	0.07	0.00	0.25	0.02	0.12
Starches (≥1 × per day)	23.5	0.35	0.08	0.59	0.03	0.38
Vegetables (≥1.5 × per day)	76.5	1.00	0.53	0.98	0.57	0.88
Fruits (≥1.5 × per day)	72.6	1.00	0.01	0.86	0.63	0.95
Meat (≥1 × per day)	12.9	0.22	0.04	0.27	0.01	0.24
Juice (>0 × per day)	38.4	0.16	0.32	0.01	0.52	0.98
Sweet drinks (>0 × per day)	6.3	0.03	0.00	0.00	0.03	0.41
Sweet foods (>0 × per day)	28.2	0.21	0.04	0.38	0.23	0.74
French fries (>0 × per day)	18.0	0.12	0.08	0.28	0.10	0.56

[a]Dietary latent classes: BFV, breastfed, fruits and vegetables; BLV, breastfed, low variety; FFV, formula, fruits and vegetables; FLV, formula, low variety, FHED, formula, high energy density.
[b]The higher frequency category used in the latent class model is listed next to each FFQ item.
[c]As a percentage of total milk (breast and formula) feedings at 9 months.

status, education, prepregnancy BMI, and return to work by 3 months, there was a significant effect of intervention group on class membership ($P = 0.04$). RP group infants were less likely than control to be in the FLV class (OR = 0.40, 95% CI 0.23–0.71) or FHED class (OR = 0.28, 95% CI 0.12–0.61) relative to the FFV class. No differences in class membership by intervention group were noted for the BFV and BLV classes. The percentages of each study group in each dietary latent class are shown in Figure 1.

Latent class membership and BMI at 2 years

Latent class membership at 9 months predicted BMI percentile ($P = 0.0003$) and *z*-score ($P = 0.0004$) at 2 years (Table 5). Infants in the BLV class had significantly higher BMIs than infants in the BFV and FFV classes, and infants in the FHED class had significantly greater BMI than infants in the FFV class. A contrast analysis revealed that infants who had either breast- or formula-based patterns high in FV and low in high-ED foods (BFV and FFV) had significantly lower BMI percentiles and *z*-scores than other patterns ($P < 0.0001$).

Discussion

Among a relatively homogenous, predominantly white, and higher income sample, ~60% of 9-month-olds were consuming

TABLE 3 Independent effects of covariates on latent class membership probability

Covariate	*P*	BFV[a]	BLV	FFV	FLV	FHED
Maternal characteristics						
Age (yr)	0.001	1	0.97 (0.90-1.04)	0.99 (0.93-1.05)	**0.93 (0.88-0.97)**	**0.83 (0.77-0.90)**
Income[b]	0.007	1	0.88 (0.61-1.27)	0.87 (0.59-1.21)	**0.75 (0.58-0.97)**	**0.52 (0.36-0.75)**
Marital status (y/n)	<0.0001	1	0.46 (0.11-1.86)	1.43 (0.24-8.49)	**0.19 (0.07-0.54)**	**0.07 (0.02-0.25)**
Education[c]	<0.0001	1	0.94 (0.54-1.63)	1.17 (0.70-1.97)	**0.45 (0.30-0.68)**	**0.41 (0.23-0.73)**
Prepregnancy BMI	0.02	1	0.95 (0.88-1.03)	0.99 (0.93-1.06)	**1.05 (1.00-1.10)**	**1.09 (1.02-1.15)**
Gestational weight gain (kg)	NS	1	1.03 (0.97-1.09)	1.00 (0.95-1.05)	1.03 (0.97-1.09)	1.04 (0.99-1.08)
Returned to work by 3 mo (y/n)	0.07	1	0.96 (0.37-2.50)	2.32 (0.93-5.77)	**2.27 (1.15-4.49)**	1.73 (0.59-5.07)
Infant characteristics						
Infant sex	NS	1	0.84 (0.33-2.17)	1.04 (0.41-2.63)	1.18 (0.60-2.29)	0.95 (0.33-2.68)
Birth weight-for-gestational age	NS	1	0.85 (0.55-1.30)	0.94 (0.64-1.40)	0.98 (0.73-1.30)	1.11 (0.70-1.75)
Childcare (y/n) at 20 wk	NS	1	0.95 (0.37-2.42)	2.39 (0.92-6.18)	1.88 (0.96-3.71)	1.81 (0.59-5.50

Values are OR (95% CI). Bolded values are significant, $P < 0.05$.
[a]Dietary latent classes: BFV, breastfed, fruits and vegetables; BLV, breastfed, low variety; FFV, formula, fruits and vegetables; FLV, formula, low variety, FHED, formula, high energy density.
[b]<$10,000, $10,000-24,999, $25,000-49,999, $50,000-74,999, $75,000-99,999, or ≥$100,000.
[c]High school or less, some college, college graduate, or postgraduate.

TABLE 4 Demographic characteristics of five dietary latent classes

Variable	P^a	BFV[b] (n = 60)	BLV (n = 25)	FFV (n = 46)	FLV (n = 105)	FHED (n = 23)
Maternal characteristics						
Age (yr)[c]	0.002	30.3[A] (4.7)	29.5[ABC](4.1)	29.8[AB] (3.7)	28.2[BC] (4.9)	26.4[C] (4.4)
Income (%)	0.02					
<\$10,000		1.7	4.0	2.2	3.8	3.8
\$10,000-24,999		6.7	4.0	0.0	7.6	17.4
\$25,000-49,999		3.3	4.0	8.7	12.4	26.1
\$50,000-74,999		25.0	28.0	37.0	22.9	26.1
\$75,000-99,999		21.7	28.0	10.9	26.7	4.4
≥\$100,000		40.0	32.0	32.6	20.0	17.4
Don't know/refuse to answer		1.7	0.0	8.7	6.7	4.4
Married (%)	<0.0001	91.7	84.0	89.1	68.6	52.2
Education	<0.0001					
High school or less		5.0	12.0	6.5	10.5	17.4
Some college		13.3	4.0	15.2	40.0	34.8
College graduate		46.7	48.0	37.0	32.4	30.4
Postgraduate		35.0	36.0	41.3	17.1	17.4
Prepregnancy BMI	0.06	24.7 (4.7)	23.5 (3.1)	25.3 (4.9)	26.0 (5.8)	27.4 (6.8)
Gestational weight gain (kg)	NS	14.2 (6.4)	15.6 (4.9)	14.7 (5.8)	15.8 (6.4)	16.0 (6.9)
Returned to work by 3 mo (%)	0.08	43.3	44.0	63.0	62.9	59.1
Infant characteristics						
Infant sex (% female)	NS	48.3	44.0	43.5	52.4	47.8
Birth weight-for-gestational age z-score	NS	0.03 (0.93)	−0.09 (0.76)	−0.02 (0.82)	0.04 (0.94)	0.10 (0.72)
Childcare at 20 wk (%)	NS	51.7	52.0	68.9	69.9	61.9

Values are mean (SD) or %.
[a]Significant effect of dietary latent class using ANOVA or Fisher's exact test.
[b]Dietary latent classes: BFV, breastfed, fruits and vegetables; BLV, breastfed, low variety; FFV, formula, fruits and vegetables; FLV, formula, low variety; FHED, formula, high energy density.
[c]Values that do not share a common uppercase superscript letter are significantly different from one another.

developmentally inappropriate diets, i.e., low in age-appropriate complementary foods (e.g., fruits, vegetables, meat, cereals, dairy products other than milk) and/or high in ED foods and fruit juice. However, participation in the INSIGHT RP intervention was associated with more healthful dietary patterns. The significant effect of the RP intervention on dietary class membership was primarily attributable to a higher proportion of RP infants who were in the FFV and correspondingly lower proportions in the FLV and FHE classes relative to control. Infants consuming the most developmentally appropriate dietary patterns—BFV and FFV, both characterized by higher intake of FV and low intake of juice and high-ED foods—had the lowest BMI at 2 years. These data are consistent with the hypothesis that effects of RP on dietary intake may be contributing to the positive effects of the RP intervention on weight (7). Future analyses will examine the mediating effects of feeding and diet, as well as other behavioral targets of the intervention (i.e., sleep, self-regulation), on child weight.

In toddlers and older children, nonresponsive feeding practices, such as pressure to eat and restriction, have been linked to low FV intake (18,19) and higher intake of high-ED foods (20), while RP practices such as parental modeling and covert control have been associated with greater FV intake (19,21) and lower intake of high-ED foods

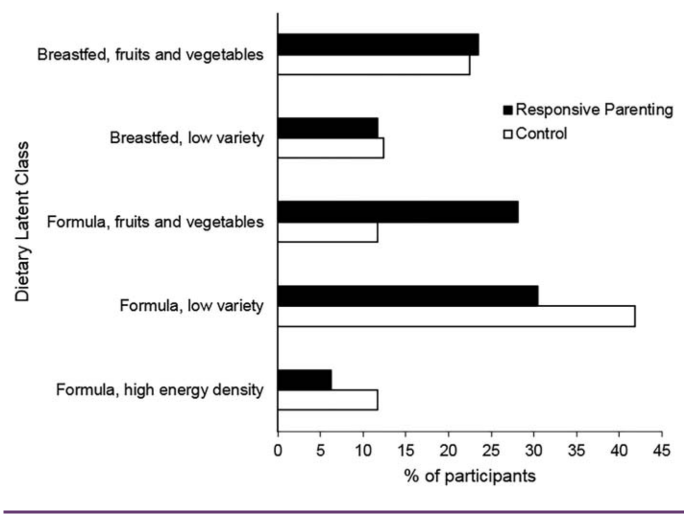

Figure 1 Percentage of participants in the INSIGHT responsive parenting (RP) intervention or control in each dietary class.

TABLE 5 Dietary latent class at 9 months predicts weight outcomes at 2 years

Variable	P^a	BFV[b] ($n = 65$)	BLV ($n = 22$)	FFV ($n = 38$)	FLV ($n = 85$)	FHED ($n = 33$)
BMI percentile	0.0001	45.5^{AB} (30.7)	68.5^{C} (26.5)	35.8^{A} (25.3)	51.3^{BC} (28.5)	60.0^{BC} (26.7)
BMI *z*-score	0.0006	-0.15^{AB} (1.10)	0.56^{C} (0.90)	-0.42^{A} (0.84)	0.04^{ABC} (0.94)	0.34^{BC} (0.87)

Values are mean (SD). Values that do not share a common uppercase superscript letter are significantly different from one another ($P < 0.05$).
[a]Significant effect of dietary latent class using ANOVA.
[b]Dietary latent classes: BFV, breastfed, fruits and vegetables; BLV, breastfed, low variety; FFV, formula, fruits and vegetables; FLV, formula, low variety; FHED, formula, high energy density.

(18,21). Our study adds to this literature by demonstrating that teaching RP may promote more healthful dietary patterns, particularly among formula-fed infants.

In this study, infants with dietary patterns low in developmentally appropriate complementary foods (BLV, FLV) or high in fruit juice and high-ED foods (FHED) had higher BMI at 2 years compared with infants with dietary patterns that were more consistent with infant feeding guidance (BFV and FFV). Consumption of fruit juice (22), sugar-sweetened beverages (23,24), and other high-ED foods (24) in infancy has been associated with increased risk for obesity. Low intake of appropriate complementary foods later in infancy may also be problematic. Limited intake of solids in later infancy may be indicative of excess intake of formula or cow's milk, which has been associated with greater overall energy intake and greater weight in early childhood (25). Exposure to a variety of flavors and textures during this period is also important for the development of food preferences and eating behaviors (3). Repeated exposure to vegetable flavors has been shown to increase consumption of novel foods (26,27), and delayed introduction to lumpy textured foods has been associated with reduced FV intake and feeding difficulties later in childhood (28), which could impact obesity risk.

We recruited both breastfeeding and formula-feeding mother–infant dyads to determine whether an RP intervention, previously shown in a pilot intervention to impact weight gain among breastfeeding infants (29), would also be effective for formula-fed infants. Though we have previously reported that the RP intervention was equally effective for breastfed and formula-fed infants in reducing rapid weight gain (7), the LCA findings indicate that the INSIGHT RP intervention was associated with healthier dietary intake for predominantly formula-fed but not breastfed infants. One potential explanation for this finding is that approximately two thirds of infants who were predominantly breastfed at 9 months were also exposed to diets that were high in FV and low in high-ED foods in both the control and RP groups, suggesting that breastfed infants in our study were already at lower risk for poor diet quality compared with formula-fed infants, which is consistent with previous literature (30,31). In addition, RP messaging on complementary feeding may simply have been more beneficial to parents who predominantly formula-fed their infants. Previous research has suggested that formula-fed infants consume fewer FV in infancy (32) and childhood (33,34), perhaps because breastfed infants are exposed to a variety of flavors in breastmilk and thereby more rapidly accept novel vegetables during weaning (27). To address this, one component of the RP intervention included guidance on repeated exposure to novel foods, particularly vegetables, which has been shown to increase liking and intake of these foods (27). Although the INSIGHT RP intervention increased the proportion of infants consuming the FFV pattern, a substantial number of RP infants were still consuming diets low in FV (BLV, FLV) or consuming FHED, suggesting that additional intervention may be needed to promote healthy infant dietary patterns.

Infants of mothers who were unmarried, lower income, lower education, or had higher BMI were more likely to be consuming formula-based diets that were either low in FV or high in ED foods. This finding is consistent with previous literature reporting positive associations between higher infant dietary quality and maternal age (35,36), education (8,35-37), income (37), and marital status (36) and negative associations with maternal BMI (35). These sociodemographic risk factors have also been linked to nonresponsive feeding practices (36,38,39). Early intervention to promote RP among families with higher sociodemographic risk may improve dietary intake among at-risk infants and help to moderate risk for obesity.

One limitation of this analysis is that the LCA model accounted for breast/formula feeding and dietary intake at 9 months only. We chose to focus on this time point due to the heterogeneity of dietary intake among infants at this age (1), when some infants are transitioning to a more adult-type diet while others are still consuming a limited variety of pureed foods. However, earlier dietary exposures may have also influenced both dietary patterns at 9 months and later weight status at 2 years. While the majority of infants in the breastfed classes at 9 months were predominantly breastfed since birth, prior breastfeeding status was more variable among infants who had formula-based patterns at 9 months. A more robust analysis of infant dietary patterns would account for changes in intake across time; however, our study was not powered for this type of analysis. Additionally, our infant dietary intake data were reported by mothers via FFQ and may thus be subject to error. However, FFQs have been used in this age group in a number of studies (1,40), and dietary patterns derived from our data were associated with infant weight status, providing some external validity for the dietary patterns identified by LCA. Finally, our sample was relatively demographically homogenous. Although we did observe significant relationships between demographic characteristics and dietary class membership, these differences may have been less pronounced than among a more diverse sample.

In summary, this analysis identified five distinct patterns of dietary exposure in 9-month-old infants. Children of mothers who received a RP intervention were less likely to have formula-based dietary patterns with low intake of appropriate complementary foods or high intake of fruit juice and high-ED foods. Furthermore, dietary patterns at 9 months were predictive of BMI at 2 years. These findings suggest that an early RP intervention may promote healthier patterns of dietary intake, at least among formula-fed infants, which may contribute to positive effects of RP on infant growth. However, a substantial number of infants in the RP intervention group had dietary patterns inconsistent with current infant feeding guidance, suggesting that further development of RP interventions to improve dietary intake in infancy is needed.O

Acknowledgments

The authors acknowledge Michele Marini, MS, Stephanie Anzman-Frasca, PhD, Jessica Beiler, MPH, Jennifer Stokes, RN, Patricia Carper, RN, Amy Shelly, LPN, Gabrielle Murray, RN, Heather Stokes, Nicole Verdiglione, Susan Rzucidlo, MSN, RN, Lindsey Hess, MS, Chelsea Rose, PhD, Katherine Balantekin, PhD, RD, and Julia Bleser, MS, for their assistance with this project.

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