Sociodemographic Differences and Infant Dietary Patterns

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KEY WORDS

infant, dietary patterns, feeding, nutrition, growth, epidemiology

ABBREVIATIONS

AAP—American Academy of Pediatrics
CDC—Centers for Disease Control and Prevention
CI—confidence interval
IFPS II—Infant Feeding Practices Study II
WHO—World Health Organization
WIC—Special Supplemental Nutrition Program for Women, Infants, and Children

Dr Wen initiated and developed the research question, led the analytic plan, conducted all data analyses, and drafted the manuscript; Drs Kong and Eiden contributed to the development of research question and the analytic plan, interpreted the results, and made major contributions to revising the manuscript; Ms Sharma and Dr Xie contributed to the development of research question, result interpretation, and revision of the manuscript; and all authors approved the final manuscript as submitted.

www.pediatrics.org/cgi/doi/10.1542/peds.2014-1045

doi:10.1542/peds.2014-1045

Accepted for publication Aug 11, 2014

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: This work was supported by a seed funding (awarded to Dr Wen) from the Department of Pediatrics, State University of New York at Buffalo.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

WHAT'S KNOWN ON THIS SUBJECT: Despite breastfeeding recommendations by the World Health Organization and the American Academy of Pediatrics, there is less agreement on appropriate use of infant solid foods. There are currently no well-established dietary guidelines for US infants that are similar to the Dietary Guidelines for Americans (aged >2 years).

WHAT THIS STUDY ADDS: Distinct dietary patterns exist among US infants and have differential influences on growth. Use of "Infant guideline solids" (vegetables, fruits, baby cereal, and meat) with prolonged breastfeeding is a promising healthy dietary pattern for infants after age 6 months.

abstract

OBJECTIVES: To identify dietary patterns in US infants at age 6 and 12 months, sociodemographic differences in these patterns, and their associations with infant growth from age 6 to 12 months.

METHODS: We analyzed a subsample (760 boys and 795 girls) of the Infant Feeding Practices Study II (2005–2007). Mothers reported their infants' intakes of 18 types of foods in the past 7 days, which were used to derive dietary patterns at ages 6 and 12 months by principal component analysis.

RESULTS: Similar dietary patterns were identified at ages 6 and 12 months. At 12 months, infants of mothers who had low education or non-Hispanic African American mothers (vs non-Hispanic white) had a higher score on "High sugar/fat/protein" dietary pattern. Both "High sugar/fat/protein" and "High dairy/regular cereal" patterns at 6 months were associated with a smaller increase in length-for-age *z* score (adjusted β per 1 unit dietary pattern score, −1.36 [95% confidence interval (CI), −2.35 to −0.37] and −0.30 [−0.54 to −0.06], respectively), while with greater increase in BMI *z* score (1.00 [0.11 to 1.89] and 0.32 [0.10 to 0.53], respectively) from age 6 to 12 months. The "Formula" pattern was associated with greater increase in BMI *z* score (0.25 [0.09 to 0.40]). The "Infant guideline solids" pattern (vegetables, fruits, baby cereal, and meat) was not associated with change in length-for-age or BMI *z* score.

CONCLUSIONS: Distinct dietary patterns exist among US infants, vary by maternal race/ethnicity and education, and have differential influences on infant growth. Use of "Infant guideline solids" with prolonged breastfeeding is a promising healthy diet for infants after age 6 months. *Pediatrics* 2014;134:e1387–e1398

Infancy is a critical period for learning about foods including milk and solids.[1] Most infants experience a rapid transition from a diet of predominantly milk (breast milk and/or formula) to a mixed diet from various food groups consumed by other family members.[2,3] The World Health Organization (WHO) and the American Academy of Pediatrics (AAP) recommend exclusive breastfeeding for 6 months with continuation of breastfeeding for 12 months or longer,[4,5] but there is less agreement on the appropriate use (ie, introduction timing and types) of solid foods.[6–8] As a result, there are currently no well-established dietary guidelines for infants and toddlers that are similar to the Dietary Guidelines for Americans, which apply only to individuals older than age 2 years.[9] Age-specific dietary guidelines are needed for infants and toddlers, because they have different nutrient needs from older children and adults.[10]

However, more research is needed to better understand the effects of foods on the health and development of infants and toddlers to develop evidenced-based dietary guidelines for them. It is difficult to study the health effect of individual solid foods on infants because solid foods consumed by infants are often inter-correlated with each other and with the type of milk consumed by the infants.[11] For example, fruits are usually eaten together with vegetables, and baby cereal with formula. This methodological challenge may be partially solved by dietary pattern analysis, a relatively new tool in nutrition research that examines one's whole diet rather than individual foods.[12,13] To date, only 3 studies examined dietary patterns among infants and toddlers. They were conducted in the United Kingdom (Southampton Women's Survey),[14] Australia (NORISH and South Australian Infants Dietary Intake Study),[15] and France (Etude des Déterminants pré et post natals précoces du dévelopement et de la santé de l'Enfant).[16] These non-US studies reported that distinct dietary patterns already existed among infants and toddlers, suggesting disparities in eating behaviors begin at a very young age. It is very likely that infant dietary patterns from other countries cannot be generalized to US infants, given the considerable differences in culture, food availability, and parental feeding practices. Little is known on the role of infant dietary patterns in child growth and development. In the UK study mentioned previously, infants who had a high score on the "infant guidelines" dietary pattern (fruit, vegetables, and home-prepared foods) at 6 months gained body weight more rapidly from age 6 to 12 months, whereas infants who had high consumption of "adult foods" (bread, savory snacks, biscuits, and chips) gained weight less rapidly.[17] In the same cohort, a higher score of "infant guidelines" dietary pattern at age 12 months was associated with higher lean mass index and IQ at age 4 years, but not with BMI or fat mass index at age 4 years.[18,19] The Australian study found that "core foods" (fruit, grains, vegetables, cheese, and nuts/seeds) and "basic combination" (white bread, milk, spreads, juice, and ice cream) pattern scores at age 14 months were not associated with BMI *z* score at age 14 or 24 months.[15]

To the best of our knowledge, there is no known published study on dietary patterns among US infants. Given the importance of this area of research, we therefore conducted a secondary data analysis on infant dietary patterns in the Infant Feeding Practices Study II.[20] We aimed to (1) identify infant dietary patterns among US infants, (2) explore sociodemographic differences in these dietary patterns, and (3) examine the associations between dietary patterns and infant growth. Accordingly, we hypothesized that (1) several distinct dietary patterns, such as breastfeeding, formula, healthy solids, and unhealthy solids, were prevalent among US infants, (2) these dietary patterns varied by maternal education, race/ethnicity, and household income, and (3) formula and unhealthy solids (energy dense) patterns were associated with fast growth in infant adiposity.

METHODS

Sample and Subjects

We analyzed data from a subsample of the Infant Feeding Practices Study II (IFPS II), a US longitudinal pre-birth cohort study conducted from 2005 to 2007. The IFPS II was conducted by the US Food and Drug Administration in collaboration with the Centers for Disease Control and Prevention (CDC). Details on the study design have been published elsewhere.[20] Briefly, this longitudinal study followed pregnant women from late pregnancy through their infant's first year of life.

The original full study sample consisted of 4902 pregnant women and 3033 full-term newborns (gestational age $\geq$37 complete weeks); 2095 of mother-child dyads were followed at age 6 months and 1807 were followed at age 12 months.[20] For the purpose of this analysis, we only considered the 3030 newborns who had completed data on gender. The descriptive analysis (Aim 1) on dietary patterns included 1555 infants who had age 6 month diet information and 1445 infants who had age 12 month diet information. The exploratory analysis (Aim 2) of sociodemographic and other correlates of diet patterns included 1378 infants at age 6 months and 1275 infants at age 12 months. The final growth analysis (Aim 3) of the associations between dietary patterns and infant growth outcomes only included the 530 infants who had complete data on infant growth outcomes at both age 6 and 12 months. We recognized the considerable differences in sample size across analytic Aims 1 to 3. We chose to use these overlapping but different subsamples because (1) a larger, more representative sample is usually preferred in principle component analysis, which could identify more robust and complete infant dietary patterns in the Aim 1 analysis, (2) the smaller samples for Aim 2 and Aim 3 were used because of practical survey issues such as missing data and attrition, and (3) for Aim 3, we further required complete growth data at both age 6 and 12 months to assess the change in growth measures, which was essential for causal interpretation. Fig 1 shows the analytic sample flow. Sample characteristics with regard to sociodemographic variables and birth outcomes are displayed in Table 1. Overall, the distributions of these characteristics were fairly similar across the original full 6-month follow-up and 12-month follow-up samples. However, compared with all newborns in the original full sample, the infants who had both 6-month and 12-month follow-ups had higher birth weight and household income, and their mothers were more likely to be white, highly educated, and married.

The CDC approved this analytic plan and provided access to the de-identified and public-use data of IFPS II. This secondary data analysis was exempted from ethical approval by the Social and Behavioral Sciences Institutional Review Board, State University of New York at Buffalo.

Measures

Infant Diet

In the monthly surveys at 3, 4, 5, 6, 7, 8, 9, 10.5, and 12 months of infant ages, mothers reported their full-term infant's intake of 18 types of foods in the past 7 days. These foods included breast milk, formula, cow's milk, other milk (eg, soy milk, rice milk, goat milk), other dairy foods (eg, yogurt, cheese, ice cream, pudding), other soy foods (eg, tofu, frozen soy desserts), 100% fruit or 100% vegetable juice, sweet drinks (eg, juice drinks, soft drinks, soda, sweet tea, Kool-Aid), baby cereal, other cereals and starches (eg, breakfast cereals, teething biscuits, crackers, breads, pasta, rice), fruit, vegetables, French fries, meat/chicken/combination dinners, fish or shellfish, peanut butter/other peanut foods/nuts, eggs, and sweet foods (eg, candy, cookies, cake). Infant food intake was reported as the number of feedings per day or per week. For consistency, we converted the number of feedings per day into that of per week by multiplying by 7. The weekly intake of these 18 types of foods at age 6 and 12 months was used to derive infant dietary patterns. We chose age 6 and 12 months because (1) they are the cut-off points used in current WHO and AAP feeding guidelines: exclusive breastfeeding for at least 6 months, adding nutritious solids after age 6 months; breastfeeding for at least 12 months, transition from baby food to table food after age 12 months[4,5,21,22]; and (2) 2 well-child visits are also usually scheduled at age 6 and 12 months for infant growth check-up.[23] By focusing on dietary transition at age 6 and 12 months, our findings on dietary patterns can inform the discussion on infant diet and growth between the pediatrician and parents or other caregivers at these 2 critical well-child visits. In addition, we examined infant dietary patterns at age 9 months (Aim 1) and their correlates (Aim 2) in the supplemental analysis, given its importance in well-child visits. IFPS-II did not collect any information on infant growth measures between 7-month and 12-month visits, which prevented us from including 9 months in our Aim 3 analysis on the association between dietary patterns and infant growth.

Correlates of Dietary Patterns

Based on previous literature,[14–16] we considered some important household, maternal, and child characteristics as potential correlates of dietary patterns. These characteristics included household income; maternal age, race/ethnicity, education level, marital status, employment, parity, pre-pregnancy BMI (normal/underweight [BMI <25], overweight [BMI 25–29.9], and obese [BMI 30+]), gestational diabetes, gestational weight gain

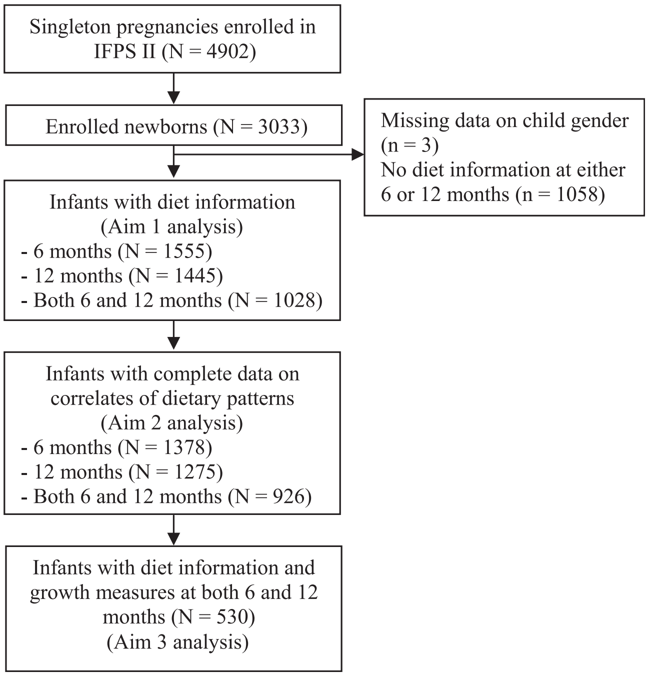

FIGURE 1
Flowchart of the analytic samples, Infant Feeding Practices Study II, 2005–2007.

TABLE 1 Child, Maternal, and Household Characteristics of the Original Full and Follow-Up Samples

	All IFPS II Newborns (N = 3030)		Infants at 6-mo Follow-up (n = 1555)[a]		Infants at 12-mo Follow-up (n = 1445)[a]		Infants at Both 6-mo and 12-mo Follow-up (n = 530)[b]		6-mo Versus All P value	12-mo Versus All P value	6-mo and 12-mo Versus All P value
	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)			
Child											
Female gender	1529 (50.5)	—	795 (51.1)	—	734 (50.8)	—	267 (50.4)	—	0.671	0.835	0.971
Birth weight, g	—	3453 (467)	—	3468 (462)	—	3480 (467)	—	3504 (474)	0.295	0.070	0.021
Gestational age, wk	—	39.3 (1.3)	—	39.3 (1.3)	—	39.3 (1.2)	—	39.3 (1.2)	0.936	0.782	0.840
Method of birth	—	—	—	—	—	—	—	—	0.494	0.197	0.159
Vaginal, non-induced	1156 (38.2)	—	612 (39.4)	—	578 (40.0)	—	211 (39.8)	—	—	—	—
Vaginal, induced	1017 (33.6)	—	496 (31.9)	—	449 (31.1)	—	155 (29.3)	—	—	—	—
Planned cesarean section	489 (16.1)	—	269 (17.3)	—	256 (17.7)	—	101 (19.1)	—	—	—	—
Emergency cesarean section	361 (11.9)	—	176 (11.3)	—	161 (11.1)	—	63 (11.9)	—	—	—	—
Enrolled in WIC program	589 (19.4)	—	394 (25.3)	—	313 (21.7)	—	95 (17.9)	—	0.058	0.010	<0.001
Household											
Income, USD	—	—	—	—	—	—	—	—	0.001	0.002	<0.001
<$25 000	659 (21.8)	—	271 (17.4)	—	259 (17.9)	—	76 (14.3)	—	—	—	—
$25 000 to $39 999	707 (23.3)	—	352 (22.6)	—	320 (22.2)	—	100 (18.9)	—	—	—	—
$40 000 to $59 999	710 (23.4)	—	374 (24.1)	—	338 (23.4)	—	139 (26.2)	—	—	—	—
$60 000+	954 (31.5)	—	558 (35.9)	—	528 (36.5)	—	215 (40.6)	—	—	—	—
Mother											
Age, y	—	28.8 (5.5)	—	29.6 (5.2)	—	29.7 (5.3)	—	30.3 (5.0)	<0.001	<0.001	<0.001
18 to 24	702 (23.2)	—	264 (17.0)	—	228 (15.8)	—	59 (11.1)	—	<0.001	<0.0001	<0.001
25 to 29	1019 (33.6)	—	519 (33.4)	—	500 (34.6)	—	186 (35.1)	—	—	—	—
30 to 34	833 (27.5)	—	501 (32.2)	—	444 (30.7)	—	178 (33.6)	—	—	—	—
35+	471 (15.5)	—	270 (17.4)	—	273 (18.9)		107 (20.2)	—	—	—	—
Race/ethnicity	—	—	—	—	—	—	—	—	<0.001	0.013	<0.001
White, non-Hispanic	2484 (82.0)	—	1346 (86.6)	—	1246 (86.2)	—	483 (91.1)	—	—	—	—
African American, non-Hispanic	143 (4.7)	—	36 (2.3)	—	43 (3.0)	—	6 (1.1)	—	—	—	—
Hispanic	183 (6.0)	—	66 (4.2)	—	71 (4.9)	—	18 (3.4)	—	—	—	—
Asian/Pacific Islander	78 (2.6)	—	48 (3.1)	—	32 (2.2)	—	15 (2.8)	—	—	—	—
Others	57 (1.9)	—	24 (1.5)	—	22 (1.5)		8 (1.5)	—	—	—	—
Educational level	—	—	—	—	—	—	—	—	<0.001	<0.001	<0.001
High school or lower	584 (19.3)	—	245 (15.8)	—	232 (16.1)	—	66 (12.5)	—	—	—	—
1 to 3 y of college	1119 (36.9)	—	536 (34.5)	—	494 (34.2)	—	163 (30.8)	—	—	—	—
College graduate	802 (26.5)	—	506 (32.5)	—	476 (32.9)	—	217 (40.9)	—	—	—	—
Post-graduate	276 (9.1)	—	193 (12.4)	—	176 (12.2)	—	84 (15.9)	—	—	—	—
Married	2213 (73.0)	—	1254 (80.6)	—	1164 (80.6)	—	456 (86.0)	—	<0.001	<0.001	<0.001
Employed	1998 (65.9)		1007 (64.8)	—	948 (65.6)	—	354 (66.8)	—	0.366	0.727	0.799
Parity	—	—	—	—	—	—	—	—	0.988	0.555	0.003
Nulliparous	861 (28.4)	—	450 (28.9)	—	415 (28.7)	—	194 (36.6)	—	—	—	—
1 previous birth	1194 (39.4)	—	617 (39.7)	—	596 (41.3)	—	200 (37.7)	—	—	—	—
2+ previous births	879 (29.0)	—	458 (29.5)	—	403 (27.9)	—	136 (25.7)	—	—	—	—
Pre-pregnancy BMI, kg/m^2	—	26.5 (6.7)	—	26.4 (6.6)	—	26.8 (6.9)	—	26.3 (6.7)	0.648	0.321	0.497
Normal/underweight (<25)	1497 (49.4)	—	786 (50.6)	—	699 (48.4)	—	271 (51.1)	—	0.724	0.466	0.748
Overweight (25–29.9)	779 (25.7)	—	403 (25.9)	—	374 (25.9)	—	145 (27.4)	—	—	—	—
Obese (≥30)	716 (23.6)	—	353 (22.7)	—	355 (24.6)	—	114 (21.5)	—	—	—	—

TABLE 1 Continued

	All IFPS II Newborns (N = 3030)		Infants at 6-mo Follow-up (n = 1555)[a]		Infants at 12-mo Follow-up (n = 1445)[a]		Infants at Both 6-mo and 12-mo Follow-up (n = 530)[b]		6-mo Versus All P value	12-mo Versus All P value	6-mo and 12-mo Versus All P value
	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)	n (%)[c]	Mean (SD)			
Gestational diabetes	186 (6.1)	—	97 (6.2)	—	93 (6.4)	—	39 (7.4)	—	0.895	0.701	0.287
GWG	—	14.2 (6.5)	—	14.2 (6.2)	—	14. (6.3)	—	14.3 (6.0)	0.772	0.543	0.563
Low	568 (18.8)	—	294 (18.9)	—	261 (18.1)	—	93 (17.6)	—	0.967	0.615	0.136
Normal	858 (28.3)	—	453 (29.1)	—	432 (29.9)	—	180 (34.0)	—	—	—	—
Excessive	1453 (48.0)	—	754 (48.5)	—	696 (48.2)	—	257 (48.5)	—	—	—	—

GWG, gestational weight gain; —, indicates not applicable.
[a] With complete data on infant diet.
[b] With complete data on infant diet and growth measures.
[c] The sum of some categories were less than the total owing to missing data.

(low, normal, and excessive)[24]; and child gender, birth weight, gestational age, method of birth, and enrollment in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) at age 6 and 12 months. Mothers reported the information on these correlates at prenatal survey, birth screeners (phone interview), or neonatal surveys.

Infant Growth Outcomes

Mothers reported their infant's weight, length, and age at their most recent doctor's visit at the 3-month (mean age at the most recent visit, 2.28 [SD, 0.48] months), 5-month (4.21 [SD, 0.43] months), 7-month (6.34 [SD, 0.48] months), and 12-month (12.02 [SD, 0.61] months) surveys. For the purpose of this analysis, we only included infant growth data at 7-month and 12-month surveys. Because the infants' actual age at the most recent doctor's visit reported at the 7-month survey was closer to 6 months, we renamed these measures as 6-month growth measures. We calculated infant BMI as weight in kilograms/length in meters,[2] and used it as an indirect measure for infant adiposity. For both age 6 and 12 months, we calculated gender- and age-specific length-for-age z score and BMI z score by gender and age for children using WHO Child Growth Standards.[25] To quantify the longitudinal change in infant growth measures, we further calculated the differences in their z scores from age 6 to 12 months (eg, length-for-age z score at age 12 months minus length-for-age z score at age 6 months), which were used as our key growth outcomes in the following analyses.

Although the literature is inconclusive, we operationally defined optimal infant growth as length-for-age z score and BMI z score being ~0 (equivalent to population average) based on WHO Child Growth Standards.[25] WHO Child Growth Standards are believed to reflect the optimal or ideal child growth, as they were derived from an international, longitudinal sample of healthy, breastfed infants and young children raised in environments (eg, no maternal smoking) that do not constrain growth.[25,26] In developed societies such as the United States, infancy fast adiposity growth measured by the gain in BMI z score or weight-for-length z score is unfavorable because it is a strong risk factor for later obesity and cardio-metabolic disorders, especially in an obesogenic environment.[27,28]

Statistical Analyses

Despite the well-documented evidence for the obesogenic effect of formula (vs breastfeeding), little is known about the role of different solids in infant growth. Because this was the very first study on dietary patterns in US infants, we decided to apply an exploratory rather than confirmatory approach, which could offer more flexibility for generating hypotheses for future replication and confirmation. Specifically, based on infants' intake of 18 types of foods, we derived infant dietary patterns at the ages of 6, 9, and 12 months using principle component analysis (FACTOR PROCEDURE in SAS; SAS Institute, Inc, Cary, NC).[29] We applied orthogonal transformation (Varimax) to rotate the original derived components, which could lead to uncorrelated components with a greater interpretability.[30] We only retained the derived components with an eigenvalue $>$1.00 and also containing 2 or more original foods with loading factor $\geq$0.4. An infant's individual factor score for each dietary pattern (component) was constructed by summing his or her intakes of the component food items weighted by factor loadings. A higher factor score indicated higher adherence to the corresponding dietary pattern. These factor scores (continuous variables) were then used for the following analyses on their correlates and associations with infant growth.

For each dietary pattern (dependent variable), we fit a multivariable linear regression model to examine sociodemographic and other correlates. Because most of these correlates were suggested by the literature and have individual predefined hypotheses (rather than 1 universal null hypothesis), we chose not to adjust *P* values for multiple comparisons in the same multivariable linear regression model.[31,32] Guided by a hierarch approach, we fit 3 multivariable linear regression models to examine the associations between each of dietary patterns (predictor) at 6 months and each of infant growth variables (outcome). The key growth outcomes included differences in length-for-age *z* score and BMI *z* score from age 6 to 12 months. In the Model 1 (basic model) we adjusted for the *z* score of the corresponding growth measure at age 6 months to yield "conditional growth" from age 6 to 12 months. The use of conditional growth could measure the deviation in an infant's subsequent growth from its expected level, given his or her baseline growth status.[33] In the Model 2 (other-dietary-patterns-adjusted model) we additionally adjusted for the other 3 dietary patterns at age 6 months. In the Model 3 (confounders-adjusted model) we further adjusted for the significant correlates of dietary patterns. We completed all data analyses in SAS version 9.3. The significant level α was set as 0.05.

RESULTS

Sample Characteristics

Table 1 shows child, household, and maternal characteristics of the original full sample ($N = 3030$) and the 2 analytic samples followed at age 6 months ($n = 1555$), 12 months ($n = 1445$), and both 6 and 12 months ($n = 530$), respectively.

Dietary Patterns

Based on the infants' intake of 18 types of foods, we derived 4 dietary patterns with an eigenvalue >1.00 and also 2 or more original foods with loading factor ≥0.4 at age 6 months, which could explain 50.0% of the total variance (Table 2). Based on the included foods in each pattern, they were named as "High sugar/fat/protein," "Infant guideline solids," "Formula," and "High dairy/regular cereal." Although breast milk was not literally reflected by any of these 4 patterns at age 6 months, it was highly inversely correlated with the "Formula" pattern (loading factor = −0.93). We also derived 4 dietary patterns at age 12 months, which explained 40.1% of the total variance (Table 3). They were named as "High sugar/fat/protein," "Infant guideline solids," "Formula/baby cereal," and "High dairy." The included food types were similar to those at age 6 months except that "baby cereal non-baby cereals/starches" replaced "baby cereal" to be in "Infant guideline solids." "Baby cereal" was combined with "Formula" as the "Formula/baby cereal" pattern. Similarly, breast milk was not literally reflected by any of these 4 patterns at age 12 months, but it was inversely correlated with the "Formula/baby cereal" pattern (loading factor = −0.93) and the "High dairy" pattern (loading factor = −0.40). Overall, the dietary patterns at age 9 months

TABLE 2 Infant Food Intake and Dietary Patterns at Age 6 Months ($N = 1555$)

	Weekly Eater, *n* (%)	Mean Intake (SD), Serving/Week	Factor Loading on Dietary Pattern[a]			
			1 - High Sugar/Fat/Protein	2 - Infant Guideline Solids	3 - Formula	4 - High Dairy/Regular Cereal
Food group						
Breast milk	828 (53.3)	3.25 (3.42)	—	—	−0.93	—
Formula	996 (64.1)	2.80 (2.71)	—	—	0.95	—
Cow's milk	16 (1.0)	0.02 (0.28)	—	—	—	0.49
Other milk (eg, soy, rice, goat)	6 (0.4)	0.01 (0.21)	—	—	—	—
Other dairy foods	104 (6.7)	0.04 (0.18)	—	—	—	0.48
Other soy foods	3 (0.2)	0.004 (0.13)	—	—	—	—
100% fruit/vegetable juice	383 (24.6)	0.23 (0.56)	—	—	—	0.60
Sweet drinks	38 (2.4)	0.03 (0.24)	0.78	—	—	—
Baby cereal	1293 (83.2)	1.28 (1.12)	—	0.57	—	—
Non-baby cereals/starches	258 (16.6)	0.14 (0.41)	—	—	—	0.60
Fruit	1033 (66.4)	0.88 (0.96)	—	0.83	—	—
Vegetables	1090 (70.1)	0.88 (0.89)	—	0.86	—	—
French fries	28 (1.8)	0.007 (0.07)	0.67	—	—	—
Meat/chicken	232 (14.9)	0.14 (0.40)	—	0.40	—	—
Fish/shellfish	2 (0.1)	0.001 (0.03)	0.85	—	—	—
Nut foods	7 (0.5)	0.002 (0.04)	0.88	—	—	—
Eggs	26 (1.7)	0.01 (0.10)	0.48	—	—	—
Sweet foods	32 (2.1)	0.01 (0.07)	0.71	—	—	—
Eigenvalue	—	—	3.41	2.10	1.82	1.67
Variance explained	—	—	18.9%	11.7%	10.1%	9.3%

[a] Only show loading factors 0.4 or greater.

—, indicates not applicable or factor loading <0.4.

were similar to those at age 6 and 12 months (Supplemental Table 7), except that nut foods and eggs were included in the "High dairy/protein" patterns rather than the "High sugar/fat" pattern.

Significant Correlates of Dietary Patterns

Table 4 shows significant correlates of 6-month dietary patterns. Supplemental Table 8 shows significant correlates of 9-month dietary patterns. Table 5 shows significant correlates of 12-month dietary patterns. At age 12 months, a high score on "High sugar/fat/protein" pattern was correlated with low household income, maternal non-Hispanic African American race/ethnicity, and low education. In contrast, a high score on "Infant guideline solids" pattern was correlated with high household income, maternal non-Hispanic white race/ethnicity, and high education. A high score on "Formula/baby cereal" pattern was correlated with emergency cesarean section, infant's enrollment in WIC program, maternal older age, Asian/Pacific Islander race/ethnicity, first childbirth, and low gestational weight gain. A high score on "High dairy" pattern was correlated with lower birth weight, methods of births other than vaginal–non-induced, maternal non-Hispanic white race/ethnicity, low education, being employed, and obesity.

Dietary Patterns and Infant Growth

Table 6 shows the estimated associations between 6-month dietary patterns and change in infant growth outcomes from age 6 to 12 months from multivariable linear regression models. Both "High sugar/fat/protein" and "High dairy/regular cereal" dietary patterns at age 6 months were associated unfavorable infant growth patterns (ie, being shorter and fatter). Specifically, they were associated with smaller increase in length-for-age z score (adjusted β per 1 unit dietary pattern score, −1.36 [95% CI, −2.35 to −0.37] and −0.30 [−0.54 to −0.06], respectively), while greater increase in BMI z score (1.00 [0.11 to 1.89] and 0.32 [0.10 to 0.53], respectively) from age 6 to 12 months, after adjusting for the corresponding growth measure at age 6 months, other dietary patterns, and potential confounders. The "Formula" dietary pattern at age 6 months was associated with greater increase in BMI z score (0.25 [0.09 to 0.40]) from age 6 to 12 months (fatter); but it was not associated with change in length-for-age z score (0.01 [−0.16 to 0.18]) from age 6 to 12 months (normal linear growth). The "Infant guideline solids" pattern was not associated with change in length-for-age z score (0.12 [−0.05 to 0.29]) (normal linear growth) or BMI z score (0.06 [−0.09 to 0.22]) (normal body mass growth) from age 6 to 12 months.

DISCUSSION

In this national and prospective sample, we identified 4 dietary patterns at age 6 and 12 months from the 18 original types of foods commonly consumed by US infants. As we expected, 1 pattern was milk-based ("Formula," or not breastfeeding), 2 contained unhealthy solids ("High sugar/fat/protein," "High

TABLE 3 Infant Food Intake and Dietary Patterns at Age 12 Months (N = 1445)

	Weekly Eater, *n* (%)	Mean Intake (SD), Serving/Week	Factor Loading on Dietary Pattern[a]			
			1 - High Sugar/Fat/Protein	2 - Infant Guideline Solids	3 - Formula/Baby Cereal	4 - High Dairy
Food group						
Breast milk	374 (25.9)	0.97 (1.96)	—	—	−0.40	−0.75
Formula	486 (33.6)	0.96 (1.66)	—	—	0.79	—
Cow's milk	1191 (82.4)	2.31 (1.70)	—	—	—	0.76
Other milk (eg, soy, rice, goat)	97 (6.7)	0.12 (0.58)	—	—	—	—
Other dairy foods	1224 (84.7)	1.04 (0.83)	—	0.42	—	—
Other soy foods	66 (4.6)	0.03 (0.21)	—	—	—	—
100% fruit/vegetable juice	1095 (75.8)	0.94 (0.89)	—	—	—	−0.42
Sweet drinks	223 (15.4)	0.11 (0.38)	0.58	—	—	—
Baby cereal	662 (45.8)	0.53 (0.86)	—	—	0.60	—
Non-baby cereals/starches	1376 (95.2)	1.87 (1.14)	—	0.49	—	—
Fruit	1424 (98.6)	1.81 (0.86)	—	0.82	—	—
Vegetables	1426 (98.7)	1.72 (0.79)	—	0.83	—	—
French fries	651 (45.1)	0.11 (0.19)	0.58	—	—	—
Meat/chicken	1358 (94.0)	1.22 (0.78)	—	0.54	—	—
Fish/shellfish	287 (19.9)	0.05 (0.13)	—	—	—	—
Nut foods	404 (28.0)	0.13 (0.33)	0.49	—	—	—
Eggs	910 (63.0)	0.27 (0.37)	0.59	—	—	—
Sweet foods	817 (56.5)	0.25 (0.37)	0.56	—	—	—
Eigenvalue	—	—	2.04	2.19	1.46	1.55
Variance explained	—	—	11.3%	12.1%	8.1%	8.6%

[a] Only show loading factors with absolute values 0.4 or greater.
—, indicates not applicable or factor loading <0.4.

TABLE 4 Significant Correlates of Infant Dietary Patterns at Age 6 Months (*N* = 1378)

Correlate	Difference in the Score of Dietary Pattern at Age 6 Months (95% CI)[a]			
	1 - High Sugar/Fat/Protein	2 - Infant Guideline Solids[b]	3 - Formula	4 - High Dairy/Regular Cereal
Child				
Female gender	—	−0.14 (−0.24 to −0.04)	—	−0.12 (−0.21 to −0.03)
Birth weight, g	—	—	−0.20 (−0.30 to −0.10)	—
Gestational age, wk	—	—	—	—
Method of birth				
Vaginal, non-induced	—	Reference	Reference	—
Vaginal, induced	—	0.14 (0.02 to 0.26)	0.13 (0.01 to 0.24)	—
Planned cesarean section	—	−0.02 (−0.17 to 0.12)	0.19 (0.05 to 0.33)	—
Emergency cesarean section	—	0.22 (0.05 to 0.40)	0.25 (0.07 to 0.42)	—
Enrolled in WIC program	—	—	0.51 (0.37 to 0.66)	—
Household				
Income, USD	—	—	—	—
<$25 000	—	Reference	Reference	Reference
$25 000 to $39 999	—	0.06 (−0.11 to 0.23)	0.16 (−0.01 to 0.33)	−0.20 (−0.35 to −0.05)
$40 000 to $59 999	—	0.15 (−0.02 to 0.32)	0.19 (0.01 to 0.36)	−0.29 (−0.45 to −0.14)
$60 000+	—	0.21 (0.05 to 0.38)	0.38 (0.21 to 0.56)	−0.26 (−0.41 to −0.11)
Mother				
Age, y				
18 to 24	Reference	—	—	—
25 to 29	−0.04 (−0.10 to 0.02)	—	—	—
30 to 34	−0.06 (−0.12 to 0.00)	—	—	—
35+	−0.05 (−0.11 to 0.02)	—	—	—
Race/ethnicity				
White, non-Hispanic	Reference	Reference	—	Reference
African American, non-Hispanic	0.08 (−0.04 to 0.20)	0.01 (−0.33 to 0.34)	—	0.31 (0.01 to 0.61)
Hispanic	0.09 (0.00 to 0.18)	0.11 (−0.14 to 0.37)	—	−0.05 (−0.28 to 0.18)
Asian/Pacific Islander	0.05 (−0.05 to 0.15)	−0.32 (−0.61 to −0.03)	—	−0.15 (−0.42 to 0.11)
Others	−0.07 (−0.22 to 0.08)	−0.47 (−0.90 to −0.04)	—	0.05 (−0.34 to 0.43)
Educational level				
High school or lower	—	Reference	Reference	Reference
1 to 3 y of college	—	−0.15 (−0.31 to 0.00)	−0.13 (−0.28 to 0.02)	−0.15 (−0.29 to −0.01)
College graduate	—	−0.19 (−0.36 to −0.03)	−0.20 (−0.37 to −0.04)	−0.31 (−0.45 to −0.16)
Post-graduate	—	−0.33 (−0.53 to −0.12)	−0.33 (−0.54 to −0.13)	−0.23 (−0.42 to −0.05)
Unmarried	0.07 (0.02 to 0.12)	—	0.28 (0.13 to 0.43)	—
Employed	—	0.16 (0.05 to 0.27)	0.17 (0.06 to 0.28)	—
Parity				
Nulliparous	—	—	Reference	—
1 previous birth	—	—	−0.03 (−0.16 to 0.10)	—
2+ previous births	—	—	−0.21 (−0.36 to −0.07)	—
Pre-pregnancy BMI, kg/m^2				
Normal/underweight (<25)	—	—	Reference	—
Overweight (25–29.9)	—	—	−0.16 (−0.30 to −0.01)	—
Obese (≥30)	—	—	−0.07 (−0.20 to 0.07)	—

[a] Estimates from multivariable linear regression model; significant if 95% CI does not cross 0.00.
[b] Including fruits, vegetables, baby cereal, and meats.
—, indicates not in the final regression model due to non-significant association.

dairy"), and the other contained healthy solids ("Infant guideline solids"). Consistent with our previous knowledge, these dietary patterns varied substantially by maternal education and race/ethnicity. As we hypothesized, "High sugar/fat/protein," "High dairy/regular," and "Formula" were associated with fast gain in infant adiposity reflected by BMI *z* score. An unexpected finding was that "High sugar/fat/protein" and "High dairy/regular" were associated with slower growth in infant length.

In line with the literature, we found evidence on sociodemographic disparities in infant dietary patterns.[14,16] Maternal education seems to be an important correlate for infant dietary patterns, as mothers who had a low education level tended to feed their infant with "High sugar/fat/protein" diet at age 12 months. In previous studies, mothers who had low education level tended to feed their infant with "adult" diet (bread, savory snacks, biscuits, and chips)[14] or "basic combination" diet (white bread, milk, spreads, juice, and ice-cream),[15] which were also unhealthy or age-inappropriate dietary patterns. Mothers of low education level might lack the needed nutrition knowledge for their infant, which could cause them to practice unhealthy infant feeding,

TABLE 5 Significant Correlates of Infant Dietary Patterns at Age 12 Months (*N* = 1275)

Correlate	Difference in the Score of Dietary Pattern at Age 12 Months (95% CI)[a]			
	1 - High Sugar/Fat/Protein	2 - Infant Guideline Solids[b]	3 - Formula/Baby Cereal	4 - High Dairy
Child				
Birth weight, g	—	—	—	−0.10 (−0.30 to 0.00)
Method of birth				
Vaginal, non-induced	Reference	—	Reference	Reference
Vaginal, induced	0.14 (0.03 to 0.26)	—	0.05 (−0.07 to 0.18)	0.22 (0.10 to 0.35)
Planned cesarean section	−0.03 (−0.17 to 0.10)	—	0.03 (−0.11 to 0.18)	0.21 (0.06 to 0.36)
Emergency cesarean section	−0.03 (−0.20 to 0.13)	—	0.32 (0.13 to 0.50)	0.25 (0.07 to 0.44)
Enrolled in WIC program	—	—	0.24 (0.12 to 0.37)	—
Household				
Income, USD				
<$25 000	Reference	Reference	—	—
$25 000 to $39 999	−0.33 (−0.49 to −0.18)	0.00 (−0.17 to 0.18)	—	—
$40 000 to $59 999	−0.35 (−0.51 to −0.19)	0.22 (0.04 to 0.39)	—	—
$60 000+	−0.43 (−0.58 to −0.27)	0.17 (0.00 to 0.34)	—	—
Mother				
Age, y				
18 to 24	—	—	Reference	—
25 to 29	—	—	−0.07 (−0.23 to 0.10)	—
30 to 34	—	—	0.22 (0.04 to 0.39)	—
35+	—	—	0.40 (0.21 to 0.60)	—
Race/ethnicity				
White, non-Hispanic	Reference	Reference	Reference	Reference
African American, non-Hispanic	0.41 (0.13 to 0.70)	−0.19 (−0.50 to 0.12)	0.15 (−0.15 to 0.45)	−0.10 (−0.41 to 0.22)
Hispanic	0.12 (-0.11 to 0.35)	−0.26 (−0.50 to −0.01)	0.12 (−0.12 to 0.36)	0.14 (−0.11 to 0.40)
Asian/Pacific Islander	0.17 (−0.15 to 0.49)	−0.51 (−0.85 to −0.16)	0.38 (0.05 to 0.71)	−0.46 (−0.81 to −0.10)
Others	−0.02 (−0.41 to 0.38)	0.60 (0.17 to 1.03)	0.21 (−0.21 to 0.62)	−0.44 (−0.88 to 0.00)
Educational level				
High school or lower	Reference	Reference	—	Reference
1 to 3 y of college	−0.20 (−0.35 to −0.06)	0.15 (0.00 to 0.31)	—	−0.21 (−0.37 to −0.05)
College graduate	−0.34 (−0.49 to −0.19)	0.25 (0.08 to 0.41)	—	−0.33 (−0.49 to −0.17)
Post-graduate	−0.42 (−0.62 to −0.23)	0.39 (0.18 to 0.60)	—	−0.54 (−0.74 to −0.33)
Employed	—	—	—	0.23 (0.12 to 0.35)
Parity				
Nulliparous	—	—	Reference	—
1 previous birth	—	—	−0.26 (−0.39 to −0.13)	—
2+ previous births	—	—	−0.47 (−0.61 to −0.33)	—
Pre-pregnancy BMI, kg/m^2				
Normal/underweight (<25)	—	—	—	Reference
Overweight (25–29.9)	—	—	—	0.03 (−0.10 to 0.16)
Obese (≥30)	—	—	—	0.14 (0.01 to 0.28)
GWG				
Low	—	—	Reference	—
Normal	—	—	−0.15 (−0.30 to −0.01)	—
Excessive	—	—	−0.12 (−0.26 to 0.02)	—

[a] Estimates from multivariable linear regression model; significant if 95% CI does not cross 0.00.
[b] Including fruits, vegetables, dairy, regular cereal, and meats.
"—" indicates not in the final regression model due to non-significant association.

which emulates their own poor personal dietary choices.[14,34] Additionally, our analysis also showed that non-Hispanic African American women tended to feed their infant with unfavorable diet (ie, "High dairy/regular cereal" at age 6 months and "High sugar/fat/protein" at age 12 months). Most foods in these 2 dietary patterns, such as cow's milk and other dairy foods, non-baby cereals, sweet drinks, French fries, and sweet foods, are discouraged by the AAP guidelines to be offered to infants.[22,35] Infant formula is on the list of WIC-eligible food and is free to low-income households.[36] This might explain our observation that enrollment in the WIC program was associated with high consumption of "Formula" pattern at age 6 months and "Formula/baby cereal" pattern at age 12 months. After adjusting for WIC enrollment and other sociodemographics, we found that infants from low-income households were more likely to be fed "High sugar/fat/protein" diet, possibly because of the relatively low price of these foods and family dietary habit.

In addition, we observed notable differences in the correlates of dietary

TABLE 6 Associations Between Dietary Patterns at Age 6 Months and Change in Infant Growth Outcomes From Age 6 to 12 Months (N = 530)

Dietary pattern at age 6 mo	Change in Length-For-Age Z Score From 6 to 12 Months (95% CI)[a]			Change in BMI Z Score From 6 to 12 Months (95% CI)[a]		
	β in basic model[b]	β in other-dietary-pattern-adjusted model[c]	β in confounders-adjusted model[d]	β in basic model[b]	β in other-dietary-pattern-adjusted model[c]	β in confounders-adjusted model[d]
1 - High sugar/fat/protein	−1.04 (−1.96 to −0.13)	−1.38 (−2.36 to −0.41)	−1.36 (−2.35 to −0.37)	0.70 (−0.14 to 1.53)	1.13 (0.25 to 2.01)	1.00 (0.11 to 1.89)
2 - Infant guideline solids[e]	0.13 (−0.03 to 0.30)	0.10 (−0.07 to 0.27)	0.12 (−0.05 to 0.29)	0.05 (−0.10 to 0.21)	0.09 (−0.06 to 0.24)	0.06 (−0.09 to 0.22)
3 - Formula	−0.02 (−0.19 to 0.15)	−0.01 (−0.18 to 0.16)	0.01 (−0.16 to 0.18)	0.29 (0.13 to 0.44)	0.28 (0.13 to 0.43)	0.25 (0.09 to 0.40)
4 - High dairy/regular cereal	−0.19 (−0.41 to 0.03)	−0.30 (−0.53 to −0.06)	−0.30 (−0.54 to −0.06)	0.24 (0.04 to 0.44)	0.34 (0.13 to 0.55)	0.32 (0.10 to 0.53)

[a] Estimates from multivariable linear regression models; significant if 95% CI does not cross 0.00.

[b] Adjusted for corresponding growth measure at 6 months.

[c] Adjusted for corresponding growth measure at 6 months and the other 3 dietary patterns.

[d] Adjusted for corresponding growth measure at 6 months; the other 3 dietary patterns; household income; maternal age, race/ethnicity, education level, pre-pregnancy BMI, gestational diabetes, gestational weight gain; and child gender and gestational age.

[e] Including fruits, vegetables, baby cereal, and meats.

patterns between age 6 and 12 months. These differences may be explained by the fact that the optimal diet during infancy should be age-tailored to fit the infant's growth and nutritional need, status of teeth growth, ability of chewing and other eating skills, and allergic sensitivity. For example, higher maternal education was associated with lower score on "Infant guideline solids" at age 6 months, but with higher score on the same dietary pattern at age 12 months. This seemingly paradoxical phenomenon might be explained by that although solid foods of this pattern are relatively healthy, they should be used in moderation during mid-infancy so that they will not compete with or replace breastfeeding at age 6 months when breast milk is still the preferred food for infants.[37] Educated mothers may prefer breast milk over these "healthy" solid foods at age 6 months, but gradually increase them with age to a high level at age 12 months.

Infant diet plays an important role in infant growth. As expected, we found that "High sugar/fat/protein" and "High dairy/regular cereal" diet patterns were associated with greater increase in weight-for-length z score, an indirect measure for adiposity. This may be attributable to the excessive caloric intake from these high-energy-density foods.[38] High protein intake by infants could lead to accelerated growth and increased adipose tissue ("the early protein hypothesis"), possibly by stimulating secretion of insulin-like growth factor 1 and cell proliferation.[39] Rapid infant weight gain, especially fat mass gain, is a major concern, as it is associated with obesity later in life.[27,28,40] Interestingly, both "High sugar/fat/protein" and "High dairy/regular cereal" diet patterns were associated with slower length (linear) growth. These associations might just be attributable to random error or residual confounding such as genetics, shared family habits (eg, poor diet, poor sleep), and/or poor home environment limiting infant movements (eg, small home space, poor house structure).[41] They might also be attributable to 1 of the intrinsic limitations of the principle component analysis (ie, it sometimes generates a biologically implausible conclusion). If not, they might be explained by the real biological effects (eg, calcium, vitamin D, growth hormone) of some special nutritional composition of these 2 dietary patterns on infant length growth. "High sugar/fat/protein" foods are often palatable and could easily dominate the infant's diet by competing with other more nutritious foods rich in calcium and vitamin D (essential for bone growth) and consequently inhibit infant length growth. For example, research has shown that high sugar intake is associated with insufficient intake of calcium and iron among young children.[42,43] "High dairy/regular cereal" diet at age 6 months is considered as age-inappropriate foods by the AAP.[44] The high protein content in cow's milk can irritate the lining of the digestive system of an infant, which can result in malabsorption of micronutrients such as calcium. Another possible explanation is that short stature or slow length growth itself could alter feeding behavior; some mothers may offer energy-dense foods in an effort to make their infant grow faster. But this reverse causality was less likely in our prospective analysis in which a dietary pattern at age 6 months was the exposure and change in length-for-age z score from age 6 to 12 months was the outcome.

In line with previous research,[45] we found the "Formula" dietary pattern was associated with greater adiposity accumulation during late infancy, indicated by greater increase in BMI z scores from age 6 to 12 months. This may be attributable to low self-regulation of food intake and over-consumption of energy in formula-fed infants.[46,47]

We found the "Infant guideline solids" pattern was not associated with length-for-age or BMI *z* score from age 6 to 12 months in our sample, suggesting that it could promote normal linear and body mass growth in infancy that met WHO Child Growth Standards. The UK study reported that infants who had high consumption of "infant feeding guidelines" foods (fruit, vegetables, and home-prepared foods) at age 6 months gained weight more rapidly from age 6 to 12 months,[17] but in a later study they found that "infant guidelines" dietary pattern at age 12 months was associated with higher lean mass index, but not with BMI or fat mass index at age 4 years.[18] Taken together, it seems that "Infant guideline solids" dietary pattern is beneficial to infant growth by selectively promoting lean mass growth without increasing the risk for obesity.

This analysis had several limitations. First, although the IFPS II sample was national, it might not represent the total US population, because the sample was not randomly obtained, rather it was based on customer opinion panel.[20] Secondly, the IFPS II only collected the information on the frequency of 18 common food groups, not specific foods consumed or portion size.[20] Thirdly, maternal reports of infant diet and clinically measured growth outcomes were subject to recall bias.[48] Fourthly, there was considerable attrition and missing data at age 6 and 12 months, which could threaten the generalizability of our findings. Particularly, our analytic sample for the final growth analysis over-represented non–low-income households and white and more educated mothers. Fifthly, the principle component analysis was performed in an overlapping but different (larger) subsample than the final growth analysis. Although this approach was needed to generate more robust dietary patterns, it was subject to mismatch of main dietary patterns between the 2 subsamples. Sixthly, we did not include maternal diet in the analysis owing to its large amount of missing data (>50%) by study design.[20] Lastly, our analysis did not adjust for paternal genetic contribution (eg, weight and height) to infant growth.

CONCLUSIONS

In summary, distinct dietary patterns could be identified among US infants as early as age 6 months. These patterns varied considerably by sociodemographics, especially by maternal education and race/ethnicity. Although existing evidence is insufficient for us to make a solid recommendation on the optimal dietary pattern(s) for US infants, a combination of prolonged breastfeeding and gradual introduction of "Infant guideline solids" (vegetables, fruits, baby cereal, and meat) can be a promising candidate of healthy dietary pattern for infants after 6 months of age based on our analysis and others. Our advice to parents is to introduce "Infant guideline solids" gradually after age 6 months so that these solids will not completely replace breastfeeding (which should be continued until at least age 12 months). For example, at each meal the mother can try to breastfeed the infant first and then use these guideline solids if the infant is still hungry.

ACKNOWLEDGMENTS

The authors appreciate Dr Leonard H. Epstein for providing critical comments on data analysis and the manuscript. The authors thank the CDC staff for providing access to raw data and guidance of data use. The IFPS II study was conducted by the US Food and Drug Administration and the CDC.

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Pediatrics; originally published online October 13, 2014;
DOI: 10.1542/peds.2014-1045

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