Original Research

Any Infant Formula Amount, but Not Infant Formula Type, Is Associated with Less Healthful Subsequent Beverage Intake among Special Supplemental Nutrition Program for Women, Infants, and Children–Participating Children

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A B S T R A C T

Background: The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) provides nutrition assistance to low-income households, including infant formula for infants not fully breastfeeding. Issuance of lactose-reduced infant formula made with corn syrup solids (CSSF) is associated with elevated risk of obesity in early life, but associations between formula type and dietary intake have not been examined.

Objectives: To evaluate associations between infant formula (amount and type) issued by WIC with subsequent child diet at ages 12–59 mo.

Methods: Dietary data from 2014, 2017, and 2020 Los Angeles County WIC Survey respondents ($n = 1339$ children, 12–59 mo of age) were merged with WIC administrative data on infant feeding (amount and type of infant formula at ages 0–12 mo). Intake frequencies were available for sweetened beverages, sweets, juice, fast food, water, fruit, vegetables, and milk. Infant feeding was categorized by amount of WIC-issued formula (descending: fully formula fed, mostly formula fed, mostly breastfed, fully breastfed) and issuance of a CSSF (any, none). Associations between infant feeding (infant formula amount and type) and child diet were evaluated in multivariable generalized estimating equation negative binomial regression models, stratified by child age (12 to <24 mo, 24 to <60 mo).

Results: Any infant formula issuance in the first year of life was adversely associated with subsequent dietary intake. This included 21%–23% higher 100% juice intake at 24 to <60 mo and 11%–13% (at 24 to <60 mo) or 20%–22% (at 12 to <24 mo) lower water intake. CSSF receipt compared with only other infant formula was not consistently associated with subsequent child diet.

Conclusions: Any infant formula amount, but not CSSF receipt compared with other formula types, was associated with less healthful beverage intake patterns among WIC-participating children. WIC nutrition education may have a stronger impact if tailored based on infant feeding practices.

Keywords: infant formula, child diet, WIC, juice, water, lactose-reduced infant formula made with corn syrup solids

Introduction

Poor diet quality is pervasive among children in the United States, including those under 5 y [1]. Minor improvements in child diet quality were observed between 1999 and 2016 [2]. Average child fruit and vegetable intake is low compared with dietary recommendations [1,3], and insufficient intakes of healthy foods are more pronounced among children living in low-income households [4]. Diet quality tracks from infancy into early childhood [5] and adulthood [6], and low diet quality in early childhood can contribute to adverse growth outcomes, including elevated obesity risk [7]. Childhood diet contributes to risk of subclinical cardiovascular disease among children [8] and contributes to obesity [9] and cardiovascular disease risk into

adulthood [10]. Identifying infant dietary factors that contribute to adverse dietary behavior patterns is therefore critical for the primary prevention of chronic disease attributable to diet [11, 12].

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is a nutrition assistance program administered by the United States Department of Agriculture, providing food benefits redeemable for healthy foods, nutrition education, breastfeeding support, and referrals to health and social services to pregnant and postpartum females and their children up to age 5 y who live in low-income households [13]. For infants, infant formula is provided to complement the maternally reported amount of breastfeeding to ensure adequate nutrition [14]. The WIC program serves half of infants born in the United States [15], with over half of participants receiving infant formula from WIC by age 2 mo [16]. Associations between the amount of infant formula provided by WIC and subsequent elevated obesity risk relative to breastfeeding have been reported [17,18]. A recent analysis among WIC-participating children in Southern California who were fed formula in infancy identified a significant association between a specific type of infant formula issued by WIC, lactose-reduced infant formula made with corn syrup solids (CSSF), and 7%–10% higher obesity risk relative to other types of infant formula [19].

Associations between the amount of infant formula issued by WIC and child diet have been previously reported in a national sample of WIC-participating infants, in which receiving more infant formula from WIC was associated with earlier introduction of any solid foods and 100% juice and greater energy intake from 13 to 36 mo of age [20]. Given this association between infant formula amount and diet, and previously reported associations between both infant formula amount [18] and infant formula type [19] issued by WIC with childhood obesity, it is necessary to understand how both amount and type of infant formula contribute to subsequent diet among WIC-participating children. This study was conducted with the aim of identifying whether dietary differences are observed among WIC-participating children by the amount and type of infant formula received from the WIC program. It was hypothesized that receipt of greater amounts of formula and any receipt of a CSSF would be associated with more adverse dietary indicators.

Methods

Setting and sample

This study includes respondents to the triennial Los Angeles (LA) County WIC Survey, a telephone survey conducted among WIC-participating families in LA County, CA. This study includes data from WIC-participating children served by a single large local-agency WIC program, born in January 2013 or later, and who were between 12 and 59 mo of age during LA County WIC Surveys in 2014, 2017, and 2020 ($n = 1760$) [21]. Survey items included in the present study were static across 2014, 2017, and 2020 surveys, though changes were made to questions about child development, adverse childhood experiences, and the COVID-19 pandemic. Respondents received United States $10 incentives for survey completion, which took ~30 min. Response

rates for the 2014, 2017, and 2020 surveys were 50%, 52%, and 53%, respectively. The California Health and Human Services Agency Committee for the Protection of Human Subjects provided Institutional Review Board approval for this study, and oral informed consent was obtained from all study participants.

Survey respondents provided data on a broad range of topics from child diet, household composition, food security, and detailed demographics. Survey data were matched using unique participant identifiers to WIC administrative data. WIC administrative data are collected during initial program eligibility certification and annual recertification and include address of residence, characteristics of participating children (e.g., race, sex, age), their mothers (e.g., education, language preference), and their households (e.g., size, income). WIC administrative data also include information on the food packages issued to participants each month during a certification period. Of the children who met eligibility criteria outlined previously ($n = 1760$), children were excluded for incomplete administrative data on WIC infant food package ($n = 219$) or missing survey data for outcomes or covariates ($n = 202$). The study sample was restricted to the children with a survey collected at ≥ 12 mo of age, full survey data, full infant package information on the amount and type of infant formula issued by WIC from 0 to 12 mo of age, and a valid address of residence to allow determination of the census tract of residence ($n = 1339$).

Childhood diet

LA County WIC Surveys conducted in 2014, 2017, and 2020 included a battery of questions about child food and beverage intake reported by parents of WIC-participating children. These items were previously found to be reliable across multiple assessments (intraclass correlation coefficients for each item ranging from 0.48 to 0.87) and valid (moderate correlation for each item, except regular soda, with 24-h dietary recall intake amounts) [22]. Items assessed include the frequency (on an average day) with which the child in the study consumed items that the WIC program recommends limiting intake of, including specific sugar-sweetened beverages (SSBs: sweetened milk, sweetened <100% juice drinks, i.e., fruit-flavored SSBs), other sweetened beverages (including beverages like Gatorade or Red Bull), regular soda and diet soda, sweets ("such as sweetened cereals, fruit bars, pop-tarts, donuts, cookies and candies"), and items that WIC encourages including water, fruit, vegetables, and milk. Survey respondents were directed to report servings of beverages with "a 12-ounce can, a bottle or a glass" to be considered a single serving. A separate item evaluated the frequency of fast food intake (4 or more times/wk, 1–3 times/wk, <1 time/wk but ≥ 1 time/mo, <1 time/mo, or never). Outcomes for this study included the frequency of total SSBs, soda, diet soda, fruit-flavored SSBs, sweetened milk, sweets, juice, fast food, water, fruit, vegetables, and milk.

Infant feeding

The amount and type of infant formula issued by WIC from 0 to 12 mo of age were used to characterize infant feeding practices, and amount and type of infant formula issued were the primary exposures of interest in this study. The WIC program provides formula to participating infants to complement maternally reported breastfeeding and ensure the nutritional needs of

participating infants are met. WIC issues infants 1 of 4 infant packages each month: a fully breastfeeding package (0 mL of infant formula), a mostly breastfeeding package (≤5323 mL of infant formula monthly), a some breastfeeding package (6624–11,918 mL of infant formula monthly), and a no breast-feeding package (9927–13,071 mL of infant formula monthly) [14]. These data have previously been validated as a proxy for infant feeding practices [23]. Infant feeding from 0 to 12 mo of age was characterized as a breastfeeding score, capturing the inverse of the total amount of formula issued by WIC by adding 3, 2, 1, and 0 points for each month of fully breastfeeding, mostly breastfeeding, some breastfeeding, and no breastfeeding infant package issuance, respectively. For children issued only 12 mo of an infant food package from WIC, the breastfeeding score was multiplied by 13/12. The breastfeeding score was then used to categorize infant feeding into 4 categories: fully formula feeding (0 points), mostly formula feeding (1–18 points), mostly breastfeeding (19–38 points), and fully breastfeeding (39 points), as has been done in prior studies [18,20,24]. Any exposure to a CSSF was assessed dichotomously (0 mo, ≥1 mo of CSSF).

Covariates

Covariates included child age at survey completion (continuous, in years on the date of the survey; a second dichotomous age variable for stratification of the analysis was created with categories of 12 to <24 mo, 24 to <60 mo), sex, and race/ethnicity (Asian, Black, English-speaking Hispanic, Spanish-speaking Hispanic, White, Other); maternal educational attainment (less than high school completion, completed high school, greater than high school completion) and age (<30 y, 30 to <40 y, and ≥40 y); household duration of WIC participation (years), presence of another WIC-participating child (yes, no), Supplemental Nutrition Assistance Program participation (yes, no), food insecurity (food insecure, not food insecure), and income below the federal poverty level (yes, no); and neighborhood contextual factors including the healthy food outlet density (outlets/mile^2), unhealthy food outlet density, and percentile of the Child Opportunity Index [25] in the census tract of residence. Healthy and unhealthy food outlets were defined to align with the modified retail food environment index [26,27], and separate densities were used as these have been independently associated with child growth and obesity in the WIC participant population of LA County [28,29]. Infant feeding practices are socially patterned [30,31]. Prior research has identified relationships between household sociodemographic characteristics and contextual factors [32] and between contextual factors and dietary outcomes [33,34]. Neighborhood contextual factors were therefore included in these analyses because of their potential to confound associations between infant feeding and dietary outcomes.

Statistical analysis

Child, maternal, and household characteristics of participants included in this study were summarized with frequencies and percentages or means and standard deviations for categorical and continuous variables in categories jointly defined by infant feeding category and any issuance of a CSSF, respectively. Testing for differences in distributions of variables (covariates and outcomes) between these groups was performed with chi-square tests and analysis of variance F tests for categorical and continuous variables, respectively. To determine the association between the amount of infant formula issued by WIC and subsequent child diet, generalized estimating equation negative binomial regression models were used for average daily (or weekly) servings of each dietary indicator, stratified by child age (12 to <24 mo, 24 to <60 mo). No regression models were performed for soda, diet soda, and sweetened milk as these outcomes had too few children with any intake in the infant feeding categories defined jointly by formula amount and type. These models included terms for infant feeding category (fully formula fed, mostly formula fed, mostly breastfed, and fully breastfed) and any issuance of a CSSF (yes, no) and were adjusted for child age and race; maternal educational attainment and age; and the density of health and unhealthy food outlets in the census tract of residence. A separate series of generalized estimating equation negative binomial regression models were used determine whether infant formula type, specifically any issuance of a CSSF by WIC, was associated with subsequent diet. These models were also stratified by child age (12 to <24 mo, 24 to <60 mo) and identically parameterized to the previously described models with the addition of a 2-way interaction between infant feeding category (fully formula fed, mostly formula fed, mostly breastfed, fully breastfed) with any issuance of a CSSF (yes, no) to allow the estimation of the association between any CSSF and dietary outcomes in each category of infant feeding. All associations are presented as incidence rate ratios (IRRs) and 95% confidence intervals (CIs). All analyses were conducted using SAS 9.4 (SAS Institute Inc.), and no correction was made for multiple comparisons [35–37]. P values of <0.05 were considered statistically significant.

Results

Of the 1339 children included in this analysis, nearly one-quarter (23.7%) were fully breastfed and received the fully breastfeeding infant package each month from 0 to 12 mo of age (Table 1). English- and Spanish-speaking Hispanic children represented over 70% of every infant feeding group, and race/ethnicity differed across groups (P < 0.0001). Children living in a home with multiple WIC-participating children represented a minority of children in all groups, and the smallest proportion was observed among fully breastfed children (13.2%). Living in a home with multiple WIC-participating children differed significantly between groups (P = 0.03). Maternal educational attainment was higher for infants in groups who received a CSSF or were fully breastfed, and maternal educational attainment differed significantly between groups (P = 0.001).

Differences in average intake frequency for assessed foods and beverages were observed between joint categories for infant formula amount and formula type (Table 2). Among children 12 to <24 mo of age, significant differences were observed in the frequency of sweets intake and the frequency of fast food intake (both P = 0.03). Among children 24 to <60 mo, significant differences between groups were observed for intake frequencies for total SSBs (P = 0.03), diet soda (P = 0.005), sweets (P = 0.01), juice (P = 0.02), and water (P = 0.04). Intake frequencies also varied between younger and older children. Children aged

TABLE 1
Characteristics of WIC-participating children in Los Angeles County by infant formula amount and receipt of any CSSF ($n = 1339$)

	Fully formula fed		Mostly formula fed		Mostly breastfed		Fully breastfed	P
	Any CSSF	No CSSF	Any CSSF	No CSSF	Any CSSF	No CSSF	($n = 318$)	
	($n = 80$)	($n = 167$)	($n = 164$)	($n = 312$)	($n = 53$)	($n = 245$)		
Child characteristics:								
Age (y), mean ± SD	3.1 ± 1.1	3.1 ± 1.1	3.0 ± 1.1	3.1 ± 1.1	2.9 ± 1.1	3.2 ± 1.0	3.0 ± 1.1	0.73
Male, %	48.8	52.7	48.2	51.6	66.0	51.0	43.4	0.06
Race/ethnicity, %								<0.0001
Asian	2.5	7.8	4.3	4.5	3.8	6.9	4.7	
Black	15.0	9.6	6.7	2.2	3.8	4.1	5.7	
Hispanic-EN	47.5	40.7	47.0	39.1	37.7	27.8	33.6	
Hispanic-SP	33.8	33.5	37.8	49.7	49.1	58.0	49.4	
White	1.3	7.8	3.0	2.9	5.7	2.9	5.3	
Other	0.0	0.6	1.2	1.6	0.0	0.4	1.3	
Household/parent characteristics:								
WIC duration (y), mean ± SD	6.1 ± 4.2	6.5 ± 4.8	5.8 ± 4.4	6.8 ± 4.5	7.0 ± 5.4	7.0 ± 4.5	6.6 ± 4.4	0.15
Multiple WIC-participating children in home, %	22.5	22.2	24.4	22.4	17.0	19.2	13.2	0.03
SNAP, %	40.0	47.9	46.3	49.0	47.2	46.5	46.2	0.89
Food insecure, %	22.5	26.3	31.1	28.8	41.5	30.2	26.7	0.27
Income <100% FPL, %	83.8	79.6	75.0	79.8	75.5	77.1	75.5	0.59
Maternal education, %								0.0001
<HS completion	15.0	35.3	29.9	39.7	26.4	44.5	34.6	
HS completion	40.0	31.7	32.3	28.8	22.6	25.7	25.8	
>HS completion	45.0	32.9	37.8	31.4	50.9	29.8	39.6	
Maternal age (y), %								0.09
<30	36.3	38.9	35.4	33.7	28.3	22.9	27.4	
30 to <40	47.5	46.1	47.0	49.0	50.9	56.3	54.4	
≥40	16.3	15.0	17.7	17.3	20.8	20.8	18.2	
Neighborhood characteristics:								
Healthy outlet density (10 outlets/mile^2), mean ± SD	2.4 ± 3.5	3.3 ± 4.2	3.2 ± 4.5	3.5 ± 5.7	3.5 ± 4.8	4.4 ± 6.5	3.7 ± 4.9	0.08
Unhealthy outlet density (10 outlets/mile^2), mean ± SD	9.5 ± 13.4	13.1 ± 17.4	11.7 ± 19.5	13.1 ± 19.0	11.8 ± 17.4	15.8 ± 23.6	15.3 ± 22.2	0.10
Child opportunity index mean ± SD	47.5 ± 29.0	42.0 ± 26.5	45.1 ± 26.9	41.0 ± 27.0	40.1 ± 27.6	42.7 ± 27.6	43.5 ± 27.7	0.46

Abbreviations: CSSF, lactose-reduced infant formula made with corn syrup solids; EN, English-speaking; FPL, federal poverty level; HS, high school; SNAP, Supplemental Nutrition Assistance Program; SP, Spanish-speaking; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

TABLE 2
Mean frequency of intake for foods and beverages by amount and type of infant formula received from WIC among WIC-participating children in Los Angeles County, CA, United States, 2014–2020 ($n = 1339$)

Dietary frequency, mean ± SD	Fully formula fed		Mostly formula fed		Mostly breastfed		Fully breastfed	P
	Any CSSF	No CSSF	Any CSSF	No CSSF	Any CSSF	No CSSF		
	Children 12 to <24 mo							
	$n = 14$	$n = 34$	$n = 41$	$n = 65$	$n = 16$	$n = 45$	$n = 79$	
Items WIC recommends limiting:								
Total SSB (daily)	0.3 ± 0.5	0.5 ± 1.1	0.7 ± 0.8	0.9 ± 1.6	0.9 ± 1.3	0.7 ± 1.1	0.7 ± 1.4	0.55
Soda (daily)	0.0 ± 0.0	0.1 ± 0.2	0.0 ± 0.2	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.1	0.1 ± 0.3	0.71
Diet soda (daily)	0.0 ± 0.0	0.0 ± 0.2	0.0 ± 0.0	0.0 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.1	0.73
Fruit-flavored SSB (daily)	0.2 ± 0.4	0.3 ± 0.6	0.4 ± 0.7	0.4 ± 0.7	0.4 ± 0.7	0.5 ± 0.8	0.3 ± 0.6	0.74
Sweetened milk (daily)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.3	0.2 ± 0.6	0.4 ± 0.7	0.1 ± 0.3	0.1 ± 0.4	0.17
Sweets (daily)	0.6 ± 0.8	0.6 ± 0.8	0.9 ± 0.7	0.6 ± 0.7	0.9 ± 0.9	1.0 ± 1.1	0.6 ± 0.7	0.03
Juice (daily)	1.1 ± 1.0	1.3 ± 1.2	1.3 ± 1.0	1.3 ± 1.0	1.3 ± 1.0	1.3 ± 1.1	1.2 ± 1.1	0.94
Fast food (weekly)	1.9 ± 1.3	1.4 ± 1.3	1.9 ± 1.3	1.5 ± 1.3	2.1 ± 0.9	2.2 ± 1.0	1.6 ± 1.2	0.03
Items WIC encourages:								
Water (daily)	3.4 ± 1.7	3.7 ± 2.2	4.4 ± 2.2	4.2 ± 2.5	4.0 ± 2.5	3.9 ± 1.6	4.7 ± 2.6	0.19
Fruit (daily)	3.0 ± 1.5	3.1 ± 1.4	3.2 ± 1.7	2.8 ± 1.0	2.4 ± 1.1	2.9 ± 1.3	3.1 ± 1.2	0.33
Vegetables (daily)	1.9 ± 1.1	2.4 ± 1.2	2.3 ± 1.9	2.4 ± 1.3	2.3 ± 1.7	2.4 ± 1.1	2.7 ± 1.4	0.50
Milk (daily)	2.9 ± 1.3	3.4 ± 1.8	3.2 ± 1.3	3.3 ± 1.4	2.8 ± 1.8	3.4 ± 1.5	2.6 ± 2.1	0.10
	Children 24 to <60 mo							
	$n = 66$	$n = 133$	$n = 123$	$n = 247$	$n = 37$	$n = 200$	$n = 239$	
Items WIC recommends limiting:								
Total SSB (daily)	1.0 ± 1.6	1.1 ± 1.3	1.1 ± 1.4	1.4 ± 1.6	0.8 ± 1.2	1.2 ± 1.7	1.0 ± 1.3	0.03
Soda (daily)	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.2	0.11
Diet soda (daily)	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.1	0.0 ± 0.1	0.005
Fruit-flavored SSB (daily)	0.5 ± 0.8	0.5 ± 0.8	0.5 ± 1.0	0.6 ± 0.9	0.3 ± 0.6	0.6 ± 1.0	0.4 ± 0.7	0.42
Sweetened milk (daily)	0.2 ± 0.5	0.1 ± 0.4	0.2 ± 0.5	0.3 ± 0.6	0.1 ± 0.5	0.2 ± 0.5	0.1 ± 0.4	0.18
Sweets (daily)	0.7 ± 0.7	0.9 ± 0.8	1.2 ± 1.3	0.9 ± 0.7	0.9 ± 0.7	0.9 ± 0.7	0.9 ± 0.7	0.01
Juice (daily)	1.1 ± 1.0	1.4 ± 1.2	1.3 ± 1.1	1.4 ± 1.2	1.1 ± 0.9	1.4 ± 1.2	1.1 ± 0.9	0.02
Fast food (weekly)	2.3 ± 1.0	2.3 ± 0.9	2.4 ± 0.8	2.4 ± 0.8	2.2 ± 0.8	2.4 ± 0.9	2.2 ± 0.9	0.33
Items WIC encourages:								
Water (daily)	4.3 ± 2.6	4.4 ± 2.2	4.3 ± 2.1	4.4 ± 2.1	4.7 ± 2.2	4.5 ± 2.2	5.0 ± 2.5	0.04
Fruit (daily)	2.7 ± 1.2	2.7 ± 1.2	2.7 ± 1.3	2.8 ± 1.1	2.9 ± 1.0	2.9 ± 1.3	2.8 ± 1.1	0.87
Vegetables (daily)	1.9 ± 0.9	2.0 ± 1.1	1.8 ± 1.1	2.0 ± 1.1	2.1 ± 1.1	2.1 ± 1.1	2.1 ± 1.0	0.61
Milk (daily)	2.0 ± 1.0	2.2 ± 1.2	2.1 ± 1.3	2.1 ± 1.0	1.9 ± 1.0	2.2 ± 1.5	2.2 ± 1.2	0.74

Abbreviations: CSSF, lactose-reduced infant formula made with corn syrup solids; SSB, sugar-sweetened beverage; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

12 to <24 mo generally consumed items WIC recommends limiting, in addition to water, less frequently than children aged 24 to <60 mo. Children aged 12 to <24 mo consumed fruit, vegetables, and milk more frequently than children aged 24 to <60 mo.

Significant differences in average intake frequency persisted between categories of infant feeding type in multivariable regression models (Table 3). For children 12 to <24 mo of age, the rate of sweets and fast food intake were 59% higher (IRR: 1.59; 95% CI: 1.08, 2.32) and 34% higher (IRR: 1.34; 95% CI: 1.10, 1.62) among children who were mostly breastfed than among children who were fully breastfed, respectively. The rate of water intake was 22% lower among children who were fully formula fed (IRR: 0.78; 95% CI: 0.63, 0.97) and 20% lower among children who were mostly breastfed (IRR: 0.80; 95% CI: 0.68, 0.94) than among children who were fully breastfed. The rate of milk intake was 31% higher among children who were mostly formula fed (IRR: 1.31; 95% CI: 1.08, 1.59) and 30% higher among children who were mostly breastfed (IRR: 1.30; 95% CI: 1.06, 1.61) than among children who were fully breastfed.

For children 24 to <60 mo of age, the rate of total SSB intake was 28% higher among children who were mostly formula fed (IRR: 1.28; 95% CI: 1.03, 1.59) than among children who were full breastfed. Rates of sweets intake was 16% lower among children who were fully formula fed (IRR: 0.84; 95% CI: 0.70, <1.00) than among children who were fully breastfed. The rate of juice intake was 21% higher among children who were fully formula fed (IRR: 1.21; 95% CI: 1.03, 1.42), 23% higher among children who were mostly formula fed (IRR: 1.23; 95% CI: 1.07, 1.42), and 23% higher among children who were mostly breastfed than among children who were fully breastfed. The rate of water intake was 11% lower among children who were fully formula fed (IRR: 0.89; 95% CI: 0.81, 0.99) and 13% lower among children who were mostly formula fed (IRR: 0.87; 95% CI: 0.80, 0.95) than among children who were fully breastfed.

Among the infant feeding categories for the amount of formula received from WIC, few significant differences were identified between CSSF recipients and nonrecipients (Table 4). Among children who were fully formula fed, CSSF recipients consumed 28% fewer servings per day of juice (IRR: 0.72; 95% CI: 0.56, 0.94) than nonrecipients at 24 to <60 mo of age, but

TABLE 3

Associations between amount of formula received between 0 and 12 mo of age with subsequent child diet among WIC-participating children in Los Angeles County, CA, United States, 2014–2020 ($n = 1339$)[1].

	Amount of formula			
	Fully formula fed	Mostly formula fed	Mostly breastfed	Fully breastfed
	Children 12 to <24 mo			
Items WIC recommends limiting:				
Total SSB (daily)	0.77 (0.38, 1.56)	1.22 (0.73, 2.06)	1.08 (0.63, 1.87)	1.00 (ref)
Fruit-flavored SSB (daily)	1.01 (0.48, 2.13)	1.38 (0.76, 2.50)	1.53 (0.82, 2.86)	1.00 (ref)
Sweets (daily)	1.00 (0.63, 1.57)	1.14 (0.81, 1.60)	1.59 (1.08, 2.32)	1.00 (ref)
Juice (daily)	1.14 (0.81, 1.60)	1.10 (0.85, 1.43)	1.16 (0.87, 1.55)	1.00 (ref)
Fast food (weekly)	1.00 (0.74, 1.34)	1.02 (0.81, 1.28)	1.34 (1.10, 1.62)	1.00 (ref)
Items WIC encourages:				
Water (daily)	0.78 (0.63, 0.97)	0.91 (0.77, 1.08)	0.80 (0.68, 0.94)	1.00 (ref)
Fruit (daily)	0.99 (0.84, 1.16)	0.97 (0.86, 1.09)	0.91 (0.78, 1.06)	1.00 (ref)
Vegetables (daily)	0.84 (0.70, 1.01)	0.93 (0.80, 1.09)	0.90 (0.76, 1.08)	1.00 (ref)
Milk (daily)	1.24 (0.99, 1.54)	1.31 (1.08, 1.59)	1.30 (1.06, 1.61)	1.00 (ref)
	Children 24 to <60 mo			
Items WIC recommends limiting:				
Total SSB (daily)	1.03 (0.80, 1.32)	1.28 (1.03, 1.59)	1.14 (0.89, 1.44)	1.00 (ref)
Fruit-flavored SSB (daily)	1.11 (0.81, 1.52)	1.21 (0.92, 1.58)	1.16 (0.86, 1.56)	1.00 (ref)
Sweets (daily)	0.84 (0.70, <1.00)	1.04 (0.92, 1.19)	1.02 (0.89, 1.17)	1.00 (ref)
Juice (daily)	1.21 (1.03, 1.42)	1.23 (1.07, 1.42)	1.23 (1.07, 1.43)	1.00 (ref)
Fast food (weekly)	1.01 (0.94, 1.09)	1.04 (0.98, 1.11)	1.04 (0.97, 1.12)	1.00 (ref)
Items WIC encourages:				
Water (daily)	0.89 (0.81, 0.99)	0.87 (0.80, 0.95)	0.92 (0.84, 1.00)	1.00 (ref)
Fruit (daily)	0.97 (0.89, 1.05)	0.98 (0.91, 1.05)	1.02 (0.95, 1.10)	1.00 (ref)
Vegetables (daily)	0.97 (0.87, 1.07)	0.98 (0.89, 1.07)	1.01 (0.92, 1.11)	1.00 (ref)
Milk (daily)	1.00 (0.90, 1.12)	1.00 (0.91, 1.10)	1.00 (0.90, 1.12)	1.00 (ref)

Abbreviations: CSSF, lactose-reduced infant formula made with corn syrup solids; ref, reference; SSB, sugar-sweetened beverage; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

[1] All associations are incidence rate ratio (95% confidence interval) for amount of infant formula received compared with fully breastfeeding. The generalized estimating equation negative binomial regression models for average daily (or weekly) servings of each dietary indicator included terms for infant feeding category (fully formula fed, mostly formula fed, mostly breastfed, and fully breastfed) and any receipt of a CSSF (yes, no). The models were adjusted for child age and race; maternal educational attainment and age; and the density of health and unhealthy food outlets in the census tract of residence.

this was not observed among children who were mostly formula fed or mostly breastfed. Among children who were mostly formula fed, CSSF recipients consumed 43% more servings per day of sweets (IRR: 1.43; 95% CI: 1.02, 2.01) than nonrecipients at 12 to <24 mo of age, but this was not observed among children who were fully formula fed or mostly breastfed.

Discussion

This study identified significant associations between any receipt of infant formula from WIC in the first year of life and child diet from 12 to <60 mo among WIC-participating children. Children ages 12 to <24 mo consumed water and items WIC recommends limiting less frequently than children aged 24 to <60 mo. Children aged 12 to <24 mo consumed items WIC encourages (fruit, vegetables, and milk) more frequently than children aged 24 to <60 mo. At ages 12 to <24 mo, formula receipt was associated with 20%–22% lower frequency of water intake (fully formula fed or mostly breastfed), 30%–31% higher frequency of milk intake (mostly formula fed and mostly breastfed), and 59% and 34% higher frequency of sweets and fast food intake (mostly breastfed) than those in children who were fully breastfed. At 12 to <24 mo of age and among those who were mostly formula fed as infants, CSSF recipients had 43%

higher frequency of sweets intake than no CSSF recipients. At 24 to <60 mo, any formula receipt was associated with 21%–23% higher frequency of juice intake, 11%–13% lower frequency of water intake (fully formula fed or mostly formula fed), 16% lower frequency of sweets intake (fully formula fed), and 28% higher daily frequency of total SSB intake (mostly formula fed) than those in fully breastfed children. At 24 to <60 mo of age, among children who were fully formula fed as infants, CSSF recipients had 28% lower frequency of juice intake than no CSSF recipients. No consistent associations were observed between any CSSF receipt compared with no CSSF receipt and subsequent indicators of child diet across categories of the amount of infant formula received from WIC.

The associations identified in the present study between any intake of infant formula with subsequent dietary indicators for the frequency of juice (at 24 to <60 mo of age) and water intake (at both 12 to <24 and 24 to <60 mo of age) align with prior findings. Children who participated in the national WIC Infant and Toddler Feeding Practices Study (ITFPS)-2 who received infant formula from WIC were found to have juice introduced earlier during complementary feeding, aligning with the present study's finding of higher juice intake among formula recipients [20]. The association between any formula receipt and higher intake of juice also aligns with the Infant Feeding Practices Study (IFPS)-II follow-up at age 6 y, where exclusive breastfeeding

TABLE 4
Associations between any receipt of CSSF between 0 and 12 mo of age with subsequent child diet by amount of formula received among WIC-participating children in Los Angeles County, CA, United States, 2014–2020 (n = 1339)[1]

Dietary frequency	Fully formula fed		Mostly formula fed		Mostly breastfed	
	Any CSSF	No CSSF	Any CSSF	No CSSF	Any CSSF	No CSSF
	Children 12 to <24 mo					
Items WIC recommends limiting:						
Total SSB (daily)	0.71 (0.24, 2.11)	1.00 (ref)	0.76 (0.44, 1.31)	1.00 (ref)	1.25 (0.60, 2.60)	1.00 (ref)
Fruit-flavored SSB (daily)	0.81 (0.24, 2.70)	1.00 (ref)	0.77 (0.41, 1.46)	1.00 (ref)	0.86 (0.34, 2.19)	1.00 (ref)
Sweets (daily)	1.07 (0.51, 2.25)	1.00 (ref)	1.43 (1.02, 2.01)	1.00 (ref)	1.00 (0.60, 1.67)	1.00 (ref)
Juice (daily)	0.89 (0.54, 1.49)	1.00 (ref)	0.96 (0.73, 1.28)	1.00 (ref)	1.06 (0.69, 1.63)	1.00 (ref)
Fast food (weekly)	1.27 (0.78, 2.06)	1.00 (ref)	1.23 (0.93, 1.63)	1.00 (ref)	0.86 (0.70, 1.06)	1.00 (ref)
Items WIC encourages:						
Water (daily)	0.97 (0.70, 1.33)	1.00 (ref)	1.04 (0.85, 1.27)	1.00 (ref)	0.98 (0.69, 1.39)	1.00 (ref)
Fruit (daily)	0.94 (0.70, 1.25)	1.00 (ref)	1.14 (0.96, 1.35)	1.00 (ref)	0.79 (0.60, 1.05)	1.00 (ref)
Vegetables (daily)	0.78 (0.57, 1.07)	1.00 (ref)	0.95 (0.74, 1.24)	1.00 (ref)	0.92 (0.63, 1.34)	1.00 (ref)
Milk (daily)	0.85 (0.63, 1.15)	1.00 (ref)	0.96 (0.82, 1.12)	1.00 (ref)	0.82 (0.58, 1.15)	1.00 (ref)
	Children 24 to <60 mo					
Items WIC recommends limiting:						
Total SSB (daily)	1.14 (0.74, 1.75)	1.00 (ref)	0.85 (0.65, 1.13)	1.00 (ref)	0.72 (0.44, 1.18)	1.00 (ref)
Fruit-flavored SSB (daily)	1.08 (0.66, 1.75)	1.00 (ref)	1.03 (0.69, 1.54)	1.00 (ref)	0.55 (0.29, 1.04)	1.00 (ref)
Sweets (daily)	0.85 (0.63, 1.13)	1.00 (ref)	1.13 (0.95, 1.33)	1.00 (ref)	1.04 (0.81, 1.32)	1.00 (ref)
Juice (daily)	0.72 (0.56, 0.94)	1.00 (ref)	0.90 (0.74, 1.08)	1.00 (ref)	0.78 (0.58, 1.04)	1.00 (ref)
Fast food (weekly)	1.02 (0.90, 1.14)	1.00 (ref)	1.01 (0.94, 1.09)	1.00 (ref)	0.91 (0.79, 1.05)	1.00 (ref)
Items WIC encourages:						
Water (daily)	1.00 (0.85, 1.19)	1.00 (ref)	1.00 (0.91, 1.11)	1.00 (ref)	1.05 (0.89, 1.23)	1.00 (ref)
Fruit (daily)	1.00 (0.88, 1.14)	1.00 (ref)	0.98 (0.89, 1.08)	1.00 (ref)	0.97 (0.86, 1.10)	1.00 (ref)
Vegetables (daily)	0.98 (0.84, 1.14)	1.00 (ref)	0.92 (0.81, 1.05)	1.00 (ref)	1.00 (0.83, 1.21)	1.00 (ref)
Milk (daily)	0.90 (0.77, 1.05)	1.00 (ref)	1.00 (0.88, 1.12)	1.00 (ref)	0.87 (0.72, 1.04)	1.00 (ref)

Abbreviations: CSSF, lactose-reduced infant formula made with corn syrup solids; ref, reference; SSB, sugar-sweetened beverage; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

[1] All associations are incidence rate ratio (95% confidence interval) for any receipt of a CSSF compared with no receipt of a CSSF within each category of infant formula amount. The generalized estimating equation negative binomial regression models for average daily (or weekly) servings of each dietary indicator included terms for infant feeding category (fully formula fed, mostly formula fed, mostly breastfed, and fully breastfed), any receipt of a CSSF (yes, no), and a 2-way interaction between infant feeding category and any receipt of a CSSF. The models were adjusted for child age and race; maternal educational attainment and age; and the density of health and unhealthy food outlets in the census tract of residence.

duration was inversely associated with intake of fruit juice [38]. Water intake frequency at age 6 y was also positively associated with breastfeeding duration in IFPS-II [38], aligning with the present study's finding of lower intake of water among WIC-participating children who received any infant formula from the program. Prior research among WIC-participating households in California has reported significant associations between the duration of WIC participation (as a proxy for the dose of nutrition education received from WIC) and lower intake of SSBs and higher intake of water [39,40]. Prior interventions combining educational and environmental interventions are proven to have improved child beverage intake patterns in California [41,42]. The lack of an association between fully formula feeding (i.e., no breastfeeding) and daily frequency of vegetable intake in the present study also contrasts with a recent systematic review that identified a consistent association between longer breastfeeding duration with greater vegetable intake [43] and aligns with recent findings from WIC ITFPS-2 that failed to identify an association between breastfeeding duration and child vegetable intake [44]. The current sample consists of children who continue to participate in WIC and therefore receive WIC food benefits, which includes a cash value benefit for the purchase of vegetables and fruits. Thus, access to vegetables was consistently supported by WIC benefits for all children, regardless of feeding decisions in the first year.

This study did not identify consistent associations between the type of infant formula received and subsequent indicators of child diet, contrary to the hypothesis that CSSF receipt would be associated with more adverse subsequent diet. Prior research has identified associations between CSSF receipt and elevated risk of childhood obesity, and it was hypothesized that subsequent diet might explain part of this association [19]. Associations have also been identified between CSSF receipt and child temperament around feeding (fussiness, food enjoyment) [45], which represented a hypothetical mechanism by which CSSFs would have been expected to influence subsequent dietary intake. It was also anticipated that children who had received a CSSF compared with only other infant formulas would have exhibited a greater preference for sweet foods and beverages (SSBs, sweets, juice) due to the greater sweetness of the primary carbohydrate in CSSFs (being glucose instead of lactose) [46]. The absence of higher intake of sweet foods and beverages among CSSF recipients, except for 43% higher intake of sweets among the mostly formula fed at 12 to <24 mo of age, compared with recipients of only other infant formulas suggests that obesity risk differences may not be attributable to the programming of taste preferences from the relative sweetness of different types of infant formula [47].

Associations identified between infant feeding group and intakes of sweetened foods and beverages were mixed.

Significantly higher frequencies of sweets intake among children at 12 to <24 mo who had been mostly breastfed compared with children who were fully breastfed and higher total SSB intake among children at 24 to <60 mo of age who had been mostly formula fed compared with children who were fully breastfed conformed to the study hypotheses. The absence of an association between formula feeding and subsequent intake of fruit-flavored SSBs (all ages) and for total SSBs (12 to <24 mo of age) was unexpected. The significantly lower daily frequency of sweets intake at 24 to <60 mo of age among children who were fully formula fed compared with those who were fully breastfed was also unexpected. Prior studies have reported significant associations between longer breastfeeding duration and lower intake of junk food (fast food, soda, sweets, salty snacks) [48]. Reasons for this discrepancy between the present study and the prior study may be attributable to differences in the study population, with the present study being composed of primarily Hispanic children in Southern California, with all children living in low-income households and participating in WIC, in contrast to the prior study which used a nationally representative sample from the Early Childhood Longitudinal Study: Birth Cohort [48]. The age of introduction of sweets did not differ significantly by infant feeding category in the WIC ITFPS-2 [20], and the amount of sweets consumed did not differ by breastfeeding duration in the IFPS-II [38]. Collectively, these results suggest that the relationship between infant feeding characterized by infant formula and sweets intake may not be clear-cut, particularly among WIC-participating populations.

Receipt of infant formula may contribute to differences in subsequent diet through both biological and behavioral exposures. Breastfeeding exposes infants to diverse flavors, obtained from maternal diet, through breastmilk [11], and breastfeeding has been associated with higher intake of fruits and vegetables in early childhood [49,50]. Higher fussiness and lower enjoyment of eating are associated with lower diet quality [51], and given previously reported associations between infant formula receipt and increased fussiness from 12 to 24 mo [45], increased fussiness among formula recipients may explain differences in dietary behaviors between formula fed and breastfed infants. It is also possible that nutrition-consciousness is higher among females who breastfeed, and this maternal nutrition awareness explains healthier subsequent diet among children who were breastfed infants [52]. The absence of an association between CSSF compared with only other infant formula types with subsequent childhood diet may suggest that the previously reported association between CSSF receipt and elevated obesity risk functions via mechanisms other than child diet, such as by alteration of the infant gut microbiome [53,54] and glycemic or insulinemic programing of the metabolism [55,56].

This study has a number of strengths. These include WIC infant food package information, which are prospectively collected and have been validated as a proxy for infant feeding practices [23]. These data are collected every month of the infant year and allow for the detailed characterization of infant feeding practices including both the amount and type of infant formula issued by WIC. Another strength is the dietary outcome data, derived from 2014, 2017, and 2020 administrations of the LA County WIC Survey, using a battery of validated dietary intake items [22] among representative samples of WIC-participating children in LA County. The LA County WIC Survey data, in conjunction with the WIC administrative data, allowed for the detailed characterization

of the study sample and adjustment for child, maternal, and contextual factors, which were thought to be potential confounders of the association between infant feeding practices and subsequent child diet. The study also has limitations, including the exclusion of any children who were not issued an infant package by WIC for ≥12 mo of the first 13 mo of life, reducing the representativeness of the sample. The dietary frequency items used in this study are validated but represent a single point in time and are not a comprehensive dietary recall and therefore limit the strength of inferences that can be drawn from associations as overall diet quality and total intakes of energy and food groups cannot be assessed (for instance, a comprehensive assessment of all foods and beverages with added sugars). An additional limitation is that a path analysis evaluating the structural relationships between infant feeding, child diet, and obesity was not possible due to the fact that heights and weights after the date of survey completion were unavailable for 43% of the sample because 1) WIC services transitioned to fully remote in March 2020 in response to the COVID-19 pandemic [57] and 2) WIC does not routinely collect height and weight measurements for children after certification at age 4 y. Finally, the WIC participant population in Southern California is predominantly Hispanic and universally low-income, and this may limit the generalizability of results from the present study to populations with different racial-ethnic composition and of higher household income.

In conclusion, any amount of infant formula provided by WIC in the first year of life was adversely associated with subsequent dietary intake, including 20%–23% more juice at 24 to <60 mo of age and 11%–13% (at 24 to <60 mo) or 20%–22% (at 12 to <24 mo) less water. There were not any consistent associations between infant formula type (non-CSSF compared with CSSF) and child diet, suggesting that the association between CSSF receipt and elevated obesity risk may not be mediated through the elements of early childhood diets assessed in the present study. Regardless of infant feeding category, children aged 12 to <24 mo generally consumed items WIC recommends limiting, in addition to water, less frequently than children aged 24 to <60 mo. Children aged 12 to <24 mo consumed fruit, vegetables, and milk more frequently than children aged 24 to <60 mo. These differences reflect the known decline in average diet quality observed as children age. Further research is needed to identify whether there are associations between infant formula type and child diet assessed with more comprehensive dietary recalls. Longitudinal dietary assessments across early childhood are needed to understand how emergent dietary patterns develop as a child ages and vary by infant feeding practices including infant formula type, and repeated measurements of diet and child heights or weights would facilitate path analyses. The WIC program has broad reach among children in low-income households and more research is needed to understand how infant formula provided by WIC may be contributing to early life dietary patterns and obesity in children. Nutrition education around beverage choice in WIC may improve the healthfulness of beverage choices by tailoring messages based upon infant feeding practices to address the higher juice and lower water intake among children who were formula fed as infants.

Author contributions

research; CEA: performed the statistical analysis; CEA: wrote the initial draft of the manuscript; SEW, MIG: critically revised the manuscript; CEA: had primary responsibility for the final content; and all authors: read and approved the final manuscript.

Conflict of interest

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Data availability

The data described in the manuscript will not be made available because they are confidential administrative data of the WIC program. The code book and analytic code will be made available upon request.

References

[1] US Department of Agriculture and US Department of Health and Human Services, Dietary Guidelines for Americans, 2020-2025 [Internet]. 9th ed, 2020 [date cited; date updated]. Available from: https://www.dietaryguidelines.gov/.

[2] J. Liu, C.D. Rehm, J. Onopa, D. Mozaffarian, Trends in diet quality among youth in the United States, 1999-2016, JAMA 323 (12) (2020) 1161–1174, https://doi.org/10.1001/jama.2020.0878.

[3] S.A. Kim, L.V. Moore, D. Galuska, A.P. Wright, D. Harris, L.M. Grummer-Strawn, et al., Vital signs: fruit and vegetable intake among children - United States, 2003-2010, MMWR Morb. Mortal. Wkly. Rep. 63 (31) (2014) 671–676.

[4] J. Di Noia, C. Byrd-Bredbenner, Determinants of fruit and vegetable intake in low-income children and adolescents, Nutr. Rev. 72 (9) (2014) 575–590, https://doi.org/10.1111/nure.12126.

[5] S. Lioret, A. Betoko, A. Forhan, M.A. Charles, B. Heude, B. de Lauzon-Guillain, et al., Dietary patterns track from infancy to preschool age: cross-sectional and longitudinal perspectives, J. Nutr. 145 (4) (2015) 775–782, https://doi.org/10.3945/jn.114.201988.

[6] V. Mikkilä, L. Räsänen, O.T. Raitakari, P. Pietinen, J. Viikari, Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study, Br. J. Nutr. 93 (6) (2005) 923–931, https://doi.org/10.1079/bjn20051418.

[7] K.V. Dalrymple, C. Vogel, K.M. Godfrey, J. Baird, N.C. Harvey, M.A. Hanson, et al., Longitudinal dietary trajectories from preconception to mid-childhood in women and children in the Southampton Women's Survey and their relation to offspring adiposity: a group-based trajectory modelling approach, Int. J. Obes. (Lond.) 46 (4) (2022) 758–766, https://doi.org/10.1038/s41366-021-01047-2.

[8] M.B. Vos, J.L. Kaar, J.A. Welsh, L.V. Van Horn, D.I. Feig, C.A.M. Anderson, et al., Added sugars and cardiovascular disease risk in children: a scientific statement from the American Heart Association, Circulation 135 (19) (2017) e1017–e1034, https://doi.org/10.1161/CIR.0000000000000439.

[9] G.L. Ambrosini, Childhood dietary patterns and later obesity: a review of the evidence, Proc. Nutr. Soc. 73 (1) (2014) 137–146, https://doi.org/10.1017/S0029665113003765.

[10] A.D. Liese, S.M. Krebs-Smith, A.F. Subar, S.M. George, B.E. Harmon, M.L. Neuhouser, et al., The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance, J. Nutr. 145 (3) (2015) 393–402, https://doi.org/10.3945/jn.114.205336.

[11] A.K. Ventura, Does breastfeeding shape food preferences? Links to obesity, Ann. Nutr. Metab. 70 (Suppl 3) (2017) 8–15, https://doi.org/10.1159/000478757.

[12] D.M. Hoelscher, S. Kirk, L. Ritchie, L. Cunningham-Sabo, Position of the Academy of Nutrition and Dietetics: interventions for the prevention and treatment of pediatric overweight and obesity, J. Acad. Nutr. Diet. 113 (10) (2013) 1375–1394, https://doi.org/10.1016/j.jand.2013.08.004.

[13] V. Oliveira, E. Frazao, The WIC Program: Background, Trends and Economic Issues, Edition, EIB-134, US Department of Agriculture, Economic Research Service, Washington, DC, 2015, 2015.

[14] Food and Nutrition Service, United States Department of Agriculture, WIC Food Packages [Internet], 2013 [date cited; date updated]. Available from: https://www.fns.usda.gov/wic/wic-food-packages.

[15] Food and Nutrition Service, United States Department of Agriculture, National and State Level Estimates of WIC Eligibility and Program Reach in 2020 [Internet], 2023 [date cited; date updated]. Available from: https://www.fns.usda.gov/wic/eligibility-and-program-reach-estimates-2020.

[16] P. Wilde, A. Wolf, M. Fernandes, A. Collins, Food-package assignments and breastfeeding initiation before and after a change in the Special Supplemental Nutrition Program for Women, Infants, and Children, Am. J. Clin. Nutr. 96 (3) (2012) 560–566, https://doi.org/10.3945/ajcn.112.037622.

[17] C.E. Anderson, S.E. Whaley, C.M. Crespi, M.C. Wang, M.P. Chaparro, Every month matters: longitudinal associations between exclusive breastfeeding duration, child growth and obesity among WIC-participating children, J. Epidemiol. Community Health 74 (10) (2020) 785–791, https://doi.org/10.1136/jech-2019-213574.

[18] M.P. Chaparro, M.C. Wang, C.E. Anderson, C.M. Crespi, S.E. Whaley, The association between the 2009 WIC food package change and early childhood obesity risk varies by type of infant package received, J. Acad. Nutr. Diet. 120 (3) (2020) 371–385, https://doi.org/10.1016/j.jand.2019.09.014.

[19] C.E. Anderson, S.E. Whaley, M.I. Goran, Lactose-reduced infant formula with corn syrup solids and obesity risk among participants in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Am. J. Clin. Nutr. 116 (4) (2022) 1002–1009, https://doi.org/10.1093/ajcn/nqac173.

[20] M.P. Chaparro, C.E. Anderson, Differences in early childhood dietary behaviors by infant feeding type and sex, J. Nutr. 151 (7) (2021) 2001–2009, https://doi.org/10.1093/jn/nxab076.

[21] L.A. County WIC Data Sources, Los Angeles County WIC Survey Instruments [Internet], 2020 [date cited; date updated]. Available from: https://lawicdata.org/survey/.

[22] M. Koleilat, S.E. Whaley, Reliability and validity of food frequency questions to assess beverage and food group intakes among low-income 2- to 4-year-old children, J. Acad. Nutr. Diet. 116 (6) (2016) 931–939, https://doi.org/10.1016/j.jand.2016.02.014.

[23] S.E. Whaley, M. Koleilat, L. Jiang, WIC infant food package issuance data are a valid measure of infant feeding practices, J. Hum. Lact. 28 (2) (2012) 134–138.

[24] S.L. Matias, C.E. Anderson, M. Koleilat, Breastfeeding moderates childhood obesity risk associated with prenatal exposure to excessive gestational weight gain, Matern. Child Nutr. 19 (4) (2023) e13545, https://doi.org/10.1111/mcn.13545.

[25] C. Noelke, N. McArdle, M. Baek, N. Huntington, R. Huber, E. Hardy, et al., How we built it: the nuts and bolts of constructing the Child Opportunity Index 2.0 [Internet], 2020 [date cited; date updated]. Available from: https://www.diversitydatakids.org/research-library/research-brief/how-we-built-it.

[26] A. Gustafson, S. Hankins, S. Jilcott, Measures of the consumer food store environment: a systematic review of the evidence 2000-2011, J. Community Health 37 (4) (2012) 897–911, https://doi.org/10.1007/s10900-011-9524-x.

[27] T.A. Farley, J. Rice, J.N. Bodor, D.A. Cohen, R.N. Bluthenthal, D. Rose, Measuring the food environment: shelf space of fruits, vegetables, and snack foods in stores, J. Urban Health 86 (5) (2009) 672–682, https://doi.org/10.1007/s11524-009-9390-3.

[28] C.E. Anderson, C.M. Crespi, M.C. Wang, S.E. Whaley, M.P. Chaparro, The neighborhood food environment modifies the effect of the 2009 WIC food package change on childhood obesity in Los Angeles County, California, BMC Public Health 20 (1) (2020) 678, https://doi.org/10.1186/s12889-020-08779-2.

[29] M.P. Chaparro, S.E. Whaley, C.M. Crespi, M. Koleilat, T.Z. Nobari, E. Seto, et al., Influences of the neighbourhood food environment on adiposity of low-income preschool-aged children in Los Angeles County: a longitudinal study, J. Epidemiol. Community Health 68 (11) (2014) 1027–1033, https://doi.org/10.1136/jech-2014-204034.

[30] M.M. McDowell, C.Y. Wang, J. Kennedy-Stephenson, Breastfeeding in the United States: findings from the national health and nutrition examination surveys, 1999-2006, NCHS Data Brief 5 (5) (2008) 1–8.

[31] Centers for Disease Control and Prevention (CDC), Racial and ethnic differences in breastfeeding initiation and duration, by state – National Immunization Survey, United States, 2004-2008, MMWR Morb. Mortal. Wkly. Rep. 59 (11) (2010) 327–334.

[32] K. Mouratidis, Neighborhood characteristics, neighborhood satisfaction, and well-being: the links with neighborhood deprivation, Land Use Policy 99 (2020) 104886, https://doi.org/10.1016/j.landusepol.2020.104886.

[33] R. Engler-Stringer, H. Le, A. Gerrard, N. Muhajarine, The community and consumer food environment and children's diet: a systematic review, BMC Public Health 14 (2014) 522, https://doi.org/10.1186/1471-2458-14-522.

[34] P. Veugelers, F. Sithole, S. Zhang, N. Muhajarine, Neighborhood characteristics in relation to diet, physical activity and overweight of Canadian children, Int. J. Pediatr. Obes. 3 (3) (2008) 152–159, https://doi.org/10.1080/17477160801970278.

[35] K.J. Rothman, No adjustments are needed for multiple comparisons, Epidemiology 1 (1) (1990) 43–46, https://doi.org/10.1097/00001648-199001000-00010.

[36] R.J. Feise, Do multiple outcome measures require p-value adjustment? BMC Med. Res. Methodol. 2 (2002) 8, https://doi.org/10.1186/1471-2288-2-8.

[37] T.V. Perneger, What's wrong with Bonferroni adjustments, BMJ 316 (7139) (1998) 1236–1238, https://doi.org/10.1136/bmj.316.7139.1236.

[38] C.G. Perrine, D.A. Galuska, F.E. Thompson, K.S. Scanlon, Breastfeeding duration is associated with child diet at 6 years, Pediatrics 134 (Suppl 1) (2014) S50–S55, https://doi.org/10.1542/peds.2014-0646I.

[39] C.E. Anderson, K. O'Malley, C.E. Martinez, L.D. Ritchie, S.E. Whaley, Longer family participation in WIC is associated with lower childhood sugar-sweetened beverage intake, J. Nutr. Educ. Behav. 54 (3) (2022) 239–248, https://doi.org/10.1016/j.jneb.2021.10.003.

[40] C.E. Anderson, C.E. Martinez, K. O'Malley, L.D. Ritchie, S.E. Whaley, Longer participation in the Special Supplemental Nutrition Program for Women, Infants, and Children is not associated with reduced sugar-sweetened beverage intake among Black participants, Nutrients 14 (5) (2022) 1048, https://doi.org/10.3390/nu14051048.

[41] A.H. Grummon, M.D. Cabana, A.A. Hecht, A. Alkon, C.E. McCulloch, C.D. Brindis, et al., Effects of a multipronged beverage intervention on young children's beverage intake and weight: a cluster-randomized pilot study, Public Health Nutr 22 (15) (2019) 2856–2867, https://doi.org/10.1017/S1368980019001629.

[42] United States Department of Agriculture Food and Nutrition Service, WIC Program Nutrition Education Guidance [Internet], 2006 [date cited: date updated]. Available from: https://wicworks.fns.usda.gov/sites/default/files/media/document/ntredguidance.pdf.

[43] C. Barends, H. Weenen, J. Warren, M.M. Hetherington, C. de Graaf, J.H.M. de Vries, A systematic review of practices to promote vegetable acceptance in the first three years of life, Appetite 137 (2019) 174–197, https://doi.org/10.1016/j.appet.2019.02.003.

[44] H.R. Thompson, C. Borger, C. Paolicelli, S.E. Whaley, A. Reat, L. Ritchie, The relationship between breastfeeding and initial vegetable introduction with vegetable consumption in a national cohort of children ages 1-5 years from low-income households, Nutrients 14 (9) (2022) 1740, https://doi.org/10.3390/nu14091740.

[45] H.E. Hampson, R.B. Jones, P.K. Berger, J.F. Plows, K.A. Schmidt, T.L. Alderete, et al., Adverse effects of infant formula made with corn-syrup solids on the development of eating behaviors in Hispanic children, Nutrients 14 (5) (2022) 1115, https://doi.org/10.3390/nu14051115.

[46] D.K. Mahato, R. Keast, D.G. Liem, C.G. Russell, S. Cicerale, S. Gamlath, Sugar reduction in dairy food: an overview with flavoured milk as an example, Foods 9 (10) (2020) 1400, https://doi.org/10.3390/foods9101400.

[47] A.K. Ventura, J.A. Mennella, Innate and learned preferences for sweet taste during childhood, Curr. Opin. Clin. Nutr. Metab. Care 14 (4) (2011) 379–384, https://doi.org/10.1097/MCO.0b013e328346df65.

[48] D.B. Jackson, K.R. Johnson, Does breast-feeding reduce offspring junk food consumption during childhood? Examinations by socio-economic status and race/ethnicity, Public Health Nutr 20 (8) (2017) 1441–1451, https://doi.org/10.1017/S1368980016003517.

[49] D. Burnier, L. Dubois, M. Girard, Exclusive breastfeeding duration and later intake of vegetables in preschool children, Eur. J. Clin. Nutr. 65 (2) (2011) 196–202, https://doi.org/10.1038/ejcn.2010.238.

[50] J. Armstrong, E.C. Abraham, M. Squair, Y. Brogan, A. Merewood, Exclusive breastfeeding, complementary feeding, and food choices in UK infants, J. Hum. Lact. 30 (2) (2014) 201–208, https://doi.org/10.1177/0890334413516383.

[51] M.P. da Costa, M. Severo, A. Oliveira, C. Lopes, M. Hetherington, S. Vilela, Longitudinal bidirectional relationship between children's appetite and diet quality: a prospective cohort study, Appetite 169 (2022) 105801, https://doi.org/10.1016/j.appet.2021.105801.

[52] J.S. Gubbels, C. Thijs, A. Stafleu, S. van Buuren, S.P. Kremers, Association of breast-feeding and feeding on demand with child weight status up to 4 years, Int. J. Pediatr. Obes. 6 (2–2) (2011) e515–e522, https://doi.org/10.3109/17477166.2010.514343.

[53] J.D. Forbes, M.B. Azad, L. Vehling, H.M. Tun, T.B. Konya, D.S. Guttman, et al., Association of exposure to formula in the hospital and subsequent infant feeding practices with gut microbiota and risk of overweight in the first year of life, JAMA Pediatr 172 (7) (2018) e181161, https://doi.org/10.1001/jamapediatrics.2018.1161.

[54] R.B. Jones, P.K. Berger, J.F. Plows, T.L. Alderete, J. Millstein, J. Fogel, et al., Lactose-reduced infant formula with added corn syrup solids is associated with a distinct gut microbiota in Hispanic infants, Gut Microbes 12 (1) (2020) 1813534, https://doi.org/10.1080/19490976.2020.1813534.

[55] C.J. Wright, F.S. Atkinson, N. Ramalingam, A.E. Buyken, J.C. Brand-Miller, Effects of human milk and formula on postprandial glycaemia and insulinaemia, Eur. J. Clin. Nutr. 69 (8) (2015) 939–943, https://doi.org/10.1038/ejcn.2015.29.

[56] J. Brand-Miller, F. Atkinson, A. Rowan, Effect of added carbohydrates on glycemic and insulin responses to children's milk products, Nutrients 5 (1) (2013) 23–31, https://doi.org/10.2105/AJPH.2021.306211.

[57] S.E. Whaley, C.E. Anderson, The importance of federal waivers and technology in ensuring access to WIC during COVID-19, Am. J. Public Health 111 (6) (2021) 1009–1012, https://doi.org/10.2105/ajph.2021.306211.