Usual nutrient intakes of US infants and toddlers generally meet or exceed Dietary Reference Intakes: findings from NHANES 2009–2012[1,2]

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ABSTRACT

Background: To our knowledge, few studies have described the usual nutrient intakes of US children aged <2 y or assessed the nutrient adequacy of their diets relative to the recommended Dietary Reference Intakes (DRIs).

Objective: We estimated the usual nutrient intake of US children aged 6–23 mo examined in NHANES 2009–2012 and compared them to age-specific DRIs as applicable.

Design: Dietary intake was assessed with two 24-h recalls for infants aged 6–11 mo (n = 381) and toddlers aged 12–23 mo (n = 516) with the use of the USDA's Automated Multiple-Pass Method. Estimates of usual nutrient intakes from food and beverages were obtained with the use of the National Cancer Institute method. The proportions of children with intakes below and above the DRI were also estimated.

Results: The estimated usual intakes of infants were adequate for most nutrients; however, 10% had an iron intake below the Estimated Average Requirement (EAR), and only 21% had a vitamin D intake that met or exceeded the recommended Adequate Intake (AI). More nutrient inadequacies were noted among toddlers; 1 in 4 had a lower-than-recommended fat intake (percentage of energy), and most had intakes that were below the EAR for vitamins E (82%) and D (74%). Few toddlers (<1%) met or exceeded the AI for fiber and potassium. In contrast, 1 in 2 had sodium intakes that exceeded the Tolerable Upper Intake Level (UL); ≥16% and 41% of the children had excessive intakes (greater than the ULs) of vitamin A and zinc, respectively.

Conclusions: The estimated usual intakes of infants were adequate for most nutrients. Most toddlers were at risk for inadequate intakes of vitamins D and E and had diets low in fiber and potassium. The sources contributing to excessive intakes of vitamin A and zinc among infants and toddlers may need further evaluation. *Am J Clin Nutr* 2016;104:1167–74.

Keywords: infants and toddlers, nationally representative sample, nutrient adequacy, recommended intakes, usual nutrient intake

INTRODUCTION

The first 2 y of life are critical in human development, and nutrition practices during this developmental period can influence short- and long-term health (1–3). This period is marked by high nutrient needs and includes critical dietary changes that involve complementary feeding from ages 4–6 mo, transition to family foods in the first year of life, and the development of food preferences that affect long-term food choices and intake. Recognizing these needs and the importance of specific dietary guidance for children aged <2 y (2), the Agricultural Act of 2014 (4) mandated that the birth-to-24-mo age group be included in the Federal 2020 Dietary Guidelines for Americans and there onward.

The dietary (food and nutrient) intakes of US infants and toddlers are less well characterized than older children and adults. Older published tables of nutrient intakes for children aged <2 y are based on the 1994–1996 and 1998 Continuing Survey of Food Intake by Individuals and do not include breastfed children or describe usual intakes (5). The current knowledge on usual nutrient intakes of US infants and toddlers comes primarily from FITS[7] (Feeding Infants and Toddlers Study), which was conducted in 2002 (6) and 2008 (7) and involved large cross-sectional samples selected at the national level from a commercial list. Dietary intake was assessed with a 24-h dietary recall by telephone; a second recall by telephone was collected on a subsample (∼25%) to correct for the intraindividual variation to estimate usual nutrient intakes. The key findings were that most US infants and toddlers had adequate nutrient intakes; however, for certain micronutrients, inadequate or excessive intakes were noted (6, 7) in relation to the Dietary Reference Intakes (DRIs) set by the Institute of Medicine (IOM) (8–10).

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[2] The findings and conclusions in this report are those of the authors and not necessarily those of the CDC.

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[7] Abbreviations used: AI, Adequate Intake; AMDR, acceptable macronutrient distribution range; AMPM, Automated Multiple-Pass Method; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; IOM, Institute of Medicine; MEC, mobile examination center; PIR, poverty income ratio; UL, Tolerable Upper Intake Level.

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NHANES has been collecting dietary intake information continuously since 1999 on representative samples of US persons of all ages, including infants and toddlers (11). With the use of NHANES data from 2003 to 2010, reports have described the usual intakes for certain specific nutrients such as sodium and potassium for US infants and preschoolers (NHANES 2003–2010) as well as calcium and vitamin D for children aged 1–3 y (NHANES 2003–2006) (12, 13). Patterns of overconsumption of sodium and inadequate vitamin D intake among children aged <2 y were noted in these studies (12, 13).

DRIs for certain nutrients (e.g., vitamin D and calcium) have been updated by the IOM (8) since the publication of findings from FITS (6, 7) and the report on usual intake of calcium and vitamin D based on data from NHANES 2003–2006 (12). In addition, more dietary intake data have become available from the NHANES 2011–2012 cycle since then. Thus, the purpose of this study was to provide updated estimates of the usual intake of macro- and micronutrients for infants aged 6–11 mo and toddlers aged 12–23 mo based on dietary data from NHANES 2009–2012 and to evaluate the adequacy of nutrient intakes in relation to the DRIs. These findings may inform the development of dietary guidance for children aged <2 y.

METHODS

Study design

NHANES is a nationally representative cross-sectional survey on the nutrition and health status of the civilian noninstitutionalized US population conducted by the CDC's National Center for the Health Statistics (14). Its goal is to provide nationally representative estimates of health as well as nutritional status, including food, beverage, and nutrient intake, anthropometric measurements, and laboratory tests. NHANES involves a series of large, complex, stratified, multistage probability samples with a 4-y survey design. Briefly, NHANES is conducted yearly on ∼5000 individuals, and data are publicly released every 2 y on ∼10,000 individuals. Participants complete a series of questionnaires during a detailed in-home interview that is followed by a scheduled visit to a mobile examination center (MEC), during which participants receive a physical examination as well as a dietary interview, commonly referred to as the "What We Eat in America" component of NHANES as described below under Dietary interview and nutrient intakes. The continuous NHANES began collecting data from 1999 onward (14). The protocol was approved by the National Center for the Health Statistics Research Ethics Review board. Written parental consent was obtained for all participants aged <18 y (14). A parent or proxy provided all information for children aged <5 y.

The most recent available data on nutrient intake from foods and beverages from NHANES (2009–2012 cycles) were used for this analysis to describe the usual nutrient intakes of children aged 6–23 mo; data from these survey cycles were sufficient in providing stable national estimates for most nutrients. The overall response rates for the MEC exam for participants aged 0–5 y ranged from 78% to 87% for NHANES 2009–2012.

Demographic variables

Age at the time of exam was categorized as 6–11 mo (infants) and 12–23 mo (toddlers) to delineate 2 critical developmental periods of infancy and toddler years and to be consistent with previous reports that have provided national estimates of nutrient intake in US infants and toddlers (6, 7). Self-reported race/ethnicity was categorized as non-Hispanic white, non-Hispanic black, Hispanic, and other (includes multiracial groups). Participants who selected other were included in overall estimates, but findings from this very heterogeneous group are not reported because of the small sample size and unstable variance estimates. Socioeconomic status was defined with the use of the poverty income ratio (PIR), an index calculated as family income divided by a federal poverty guideline specific to family size. PIR was categorized as ≤130% and >130%; for reference, family income corresponding to a ≤130% PIR qualifies for the Supplemental Nutrition Assistance Program and free school meals (15).

Dietary interview and nutrient intakes

Dietary intake was assessed via 24-h recall obtained by a trained interviewer during the MEC visit with the use of a computer-assisted dietary interview system with standardized probes, i.e., the USDA's Automated Multiple-Pass Method (AMPM), as described previously (11, 16). Briefly, the type and quantity of all foods and beverages consumed in a single 24-h period before the dietary interview (from midnight to midnight) at the MEC were collected with the use of AMPM. AMPM is designed to enhance complete and accurate data collection while reducing respondent burden (16, 17). In NHANES, these interviews were obtained through proxies, generally (>95%) a parent, for children aged ≤5 y; during the 2009–2012 study period, mothers, fathers, and grandparents or caregivers reported data for 91%, 7%, and 2% of the children, respectively. Data on the second recall were obtained with the use of AMPM by telephone 3–10 d after the MEC exam (11).

Nutrient intakes from foods and beverages reported consumed during the 24-h period were calculated with the use of the USDA's Food and Nutrient Database for Dietary Studies (18). The basis of nutrient values for foods and beverages is the USDA National Nutrient Database for Standard Reference. Sources of nutrient data include scientific literature, data provided by food companies and trade associations, and USDA analytic contracts. For children who consumed breast milk on the day of recall, nutrient intakes from human milk were estimated and added to those from other foods and beverages as described in the paragraph below.

Breast milk consumption was not quantified in the survey, and for children who were reported to have had breast milk, the amount consumed was assessed following the approach used in FITS and consistent with previous studies (7, 19–21). Briefly, the volume of human milk consumed was imputed considering the child's age and the total volume of other types of milk consumed (e.g., infant formula, cow milk, soy milk) during the 24-h recall period. For infants aged 6–11 mo who consumed human milk as the sole source of milk, the amount of breast milk consumed was assumed to be 600 mL/d; for partially breastfed infants, the corresponding amount of breast milk consumed was computed by subtracting the amount of formula and other milks consumed from 600 mL. For toddlers who consumed breast milk, the amount of breast milk ingested was computed as 89 and 59 mL/feeding occasion for children aged 12–17 and 18–23 mo, respectively (7, 19–21). Nutrient consumption from dietary supplements was not included in this analysis. We focused instead on usual nutrient intakes from dietary sources (foods and beverages) to provide this updated information to inform the development of dietary guidance for children aged <2 y.

Analytic population

All children who participated in the examination component of NHANES were eligible for the dietary interview. In each survey cycle, a small proportion (3–4%) of participants were excluded because their 24-h recall did not meet the standards of reliability that ensure completeness of recall. As part of the standard quality-assurance procedures, NHANES dietary recall data are considered unreliable when an incomplete recall is provided (i.e., all 5 steps in the AMPM are not finished) or when recall includes a report of an eating occasion with missing foods or a missing amount of foods consumed. The final analytic sample consisted of 897 infants aged 6–11 mo (n = 381) and toddlers aged 12–23 mo (n = 516) whose proxies completed a 24-h dietary recall in the MEC. A second-day 24-h recall was available on 332 infants and 419 toddlers (84% of all infants and toddlers). Infants aged <6 mo were not included in these analyses to describe usual nutrient intakes because of the small variability in nutrient intake in their diets that are primarily based on breast milk and formula and because imputed breast milk contribution to nutrient intake would reduce that variation even further.

Statistical analysis

Usual nutrient intakes were computed according to the National Cancer Institute method (22–24) implemented in SAS version 2.1 (SAS Institute) with the use of 2 macros: MIXTRAN and DISTRIB. This method uses mixed-effects models to estimate the usual intake of ubiquitously consumed nutrients by correcting for the within-person variation in nutrient intake across days (11, 21, 23). For each nutrient and age group, the macros were used to estimate the mean usual intake and the distribution (25) after accounting for weekday and weekend effects. For ratio variables concerning percentage caloric intake from macronutrients (e.g., percentage of kilocalories from protein, fat, and carbohydrates), the usual intake of ratios and the corresponding distributions were estimated by first calculating the percentage of kilocalories from a given macronutrient on each 24-h recall for the study participant (26) and then using the macros.

Estimated usual nutrient intakes were compared to age-specific DRIs established by the IOM (8–10) to compute the percentage of children meeting the DRI. DRIs include the Estimated Average Requirement (EAR), Adequate Intake (AI), and Tolerable Upper Intake Level (UL) for various macro- and micronutrients. Briefly, EAR is "the average daily intake level estimated to meet the requirement of half of the healthy individuals in a particular life stage and gender group" and is considered the best measure of population adequacy of nutrient intake (10). Intakes lower than the EAR indicate the estimated prevalence of inadequate intakes within a group. AI is "a recommended average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate." AI is used when EAR cannot be determined (10). For nutrients with an AI rather than an EAR, the group mean intake is compared with the AI; group mean intake at or above the AI indicates that the prevalence of inadequacy is low (27). If a group's mean intake is below the AI, then intakes may need to increase, but it is not possible to precisely quantify the prevalence of inadequacy (27). The proportion of the population with intakes greater than the UL identifies those with excessive intakes who are potentially at risk for adverse effects (27). We estimated the percentage of children consuming less than the EAR, greater than or equal to the AI, or more than the UL as applicable (8–10) as in previous reports (6, 7, 21, 28).

Last, we compared the distributions for ratio variables (i.e., percentage of kilocalories from protein, fat, and carbohydrates) to acceptable macronutrient distribution ranges (AMDRs) as in previous reports (6, 7, 21). The percentage of children consuming each macronutrient at levels outside the upper or lower bounds of the AMDRs was also estimated.

Consistent with the analytic guidelines for modeling usual intake, balanced repeated replicate weights with a Fay coefficient of 0.3 were used to account for the complex survey design and to produce nationally representative estimates that accounted for the differential probability of selection and adjusted for nonresponse and noncoverage (29). Replicate weights were poststratified to match the age, sex, and race/ethnicity distribution of the original NHANES-examined sample. For a subset of nutrients, 2 analysts computed the estimates separately to ensure replicability. Analyses were conducted in SAS version 9.3.

RESULTS

Table 1 shows the characteristics of US children aged 6–23 mo by age group. Half of the population consisted of boys. More than one-third (38%) lived in households with an annual income ≤130% of the federal poverty guidelines. Half of the children were non-Hispanic white (50%), 13% were non-Hispanic black, and 30% were Hispanic. Overall, 13% were reported to have consumed breast milk during the dietary recall, and 14% were reported to have consumed dietary supplements. Multivitamin preparations were the most commonly consumed supplements.

The usual macronutrient intake distributions and their percentage contributions to total energy intake for infants aged 6–11 mo

TABLE 1
Characteristics of children aged 6–23 mo by age group: NHANES 2009–2012[1]

Characteristic	6–11 mo	12–23 mo	6–23 mo
n	381[2]	516	897
Boys	48.3 ± 2.8	50.7 ± 3.0	49.9 ± 2.3
Poverty income ratio			
≤130%	35.9 ± 3.8	38.5 ± 2.5	37.6 ± 2.3
>130%	64.1 ± 3.8	61.5 ± 2.5	62.4 ± 2.3
Race/ethnicity			
Non-Hispanic white	53.3 ± 4.5	48.6 ± 4.2	50.2 ± 3.9
Non-Hispanic black	12.7 ± 2.2	13.5 ± 1.9	13.2 ± 1.8
Hispanic	27.9 ± 4.4	30.4 ± 4.4	29.5 ± 4.0
Consuming breast milk	23.9 ± 3.3	7.2 ± 1.9	13.0 ± 1.7
Consuming dietary supplement	10.0 ± 2.2	16.8 ± 2.1	14.4 ± 1.9

[1]Values are weighted percentages ± SEs unless otherwise indicated.
[2]Unweighted sample size.

TABLE 2

Usual intakes of energy and macronutrients from food and beverages for infants aged 6–11 mo (n = 381) and proportions meeting DRIs[1]

		Usual intake percentiles					DRI			
Nutrient	Mean ± SE	10th	25th	50th	75th	90th	EAR	AI	% <EAR	% ≥AI
Energy, kcal	836 ± 13.9	574	676	809	966	1132	—	—	—	—
Carbohydrate, g	111.0 ± 2.2	74	89	107	129	152	—	95	—	67
Carbohydrate, % kcal	53.1 ± 0.5	46	49	53	57	60	—	—	—	—
Total sugar, g	75.5 ± 1.8	55	63	74	86	98	—	—	—	—
Fiber, g	5.2 ± 0.3	2	3	5	7	9	—	—	—	—
Protein, g	21.5 ± 0.6	11	14	19	26	35	—	—	—	—
Protein, $g \cdot kg^{-1} \cdot d^{-1}$	2.4 ± 0.1	1	2	2	3	4	1	—	5	—
Protein, % kcal	9.8 ± 0.2	7	8	10	11	13	—	—	—	—
Total fat, g	34.9 ± 0.6	24.0	28.3	33.9	40.4	47.0	—	30	—	68
Saturated fat, g	14.1 ± 0.5	9.0	10.9	13.6	16.7	20.0	—	—	—	—
Monounsaturated fat, g	11.7 ± 0.5	7.3	9.1	11.4	14.0	16.6	—	—	—	—
Polyunsaturated fat, g	6.9 ± 0.2	4.1	5.1	6.6	8.2	10.1	—	—	—	—
Linoleic acid, g	5.9 ± 0.2	3.4	4.3	5.6	7.2	8.9	—	4.6	—	69
Linolenic acid, g	0.65 ± 0.02	0.37	0.47	0.61	0.78	0.98	—	0.5	—	70
Cholesterol, mg	63.6 ± 6.7	8	19	42	83	144	—	—	—	—
Fat, % kcal	38.0 ± 0.4	31	34	38	42	45	—	—	—	—

[1]The National Cancer Institute method was used to estimate the usual nutrient intakes and distributions. Nonlinear mixed-effects models were used to estimate means, and parameter estimates and predicted values from these models were used in Monte Carlo simulations to estimate the weighted distributions of usual intake on the original scale as well as the percentage above or below DRIs when applicable. SEs were estimated with the use of balanced repeated replication weights. AI, Adequate Intake; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement.

and toddlers aged 12–23 mo are presented in **Tables 2** and **3**, respectively. The usual energy intake for infants was 836 kcal, with carbohydrates, protein, and fat contributing ∼53%, ∼10%, and ∼38% of the calories, respectively (Table 2). For infants, the EAR for protein is 1 $g \cdot kg^{-1} \cdot d^{-1}$; an estimated 5% of infants did not meet this EAR. For certain macronutrients, namely carbohydrates and fat and linoleic and linolenic acids, AI recommendations are available for infants; mean usual intakes were above the AI for all of these nutrients. For example, the AI for linolenic acid for infants is 0.5 g, and the mean intake was 0.65 g.

TABLE 3

Usual intakes of energy and macronutrients from food and beverages for toddlers aged 12–23 mo (n = 516) and proportions meeting DRIs[1]

		Usual intake percentiles					DRI						
Nutrient	Mean ± SE	10th	25th	50th	75th	90th	EAR	AI	AMDR	% <EAR	% ≥AI	% <AMDR	% >AMDR
Energy, kcal	1194 ± 24.7	880	1012	1175	1355	1533	—	—	—	—	—	—	—
Carbohydrate, g	157.3 ± 3.7	113	131	154	180	206	100	—	—	4[2]	—	—	—
Carbohydrate, % kcal	53.0 ± 0.6	44	48	53	57	62	—	—	45–65	—	—	12	4[2]
Total sugar, g	91.5 ± 2.9	61	73	89	106	125	—	—	—	—	—	—	—
Fiber, g	8.6 ± 0.3	5	7	8	10	13	—	19	—	—	<1[2]	—	—
Protein, g	45.8 ± 1.1	32	38	45	53	61	—	—	—	—	—	—	—
Protein, $g \cdot kg^{-1} \cdot d^{-1}$	4.1 ± 0.1	3	3	4	5	6	0.87	—	—	<1[2]	—	—	—
Protein, % kcal	15.5 ± 0.2	12	14	15	17	19	—	—	5–20	—	—	<1[2]	4[2]
Total fat, g	44.1 ± 1.0	28.6	35.1	43.1	52.0	60.9	—	—	—	—	—	—	—
Saturated fat, g	18.0 ± 0.5	11.1	13.9	17.5	21.5	25.5	—	—	—	—	—	—	—
Monounsaturated fat, g	14.5 ± 0.5	9.2	11.3	14.1	17.2	20.3	—	—	—	—	—	—	—
Polyunsaturated fat, g	7.6 ± 0.3	4.3	5.6	7.2	9.2	11.3	—	—	—	—	—	—	—
Linoleic acid, g	6.6 ± 0.2	3.8	4.8	6.3	8.1	9.9	—	7	—	—	39	—	—
Linolenic acid, g	0.86 ± 0.02	0.54	0.67	0.83	1.03	1.22	—	0.7	—	—	70	—	—
Cholesterol, mg	152.4 ± 11.2	73	100	140	191	248	—	—	—	—	—	—	—
Fat, % kcal	32.9 ± 0.4	26	30	33	36	39	—	—	30–40	—	—	28	8

[1]The National Cancer Institute method was used to estimate the usual nutrient intakes and distributions. Nonlinear mixed-effects models were used to estimate means, and parameter estimates and predicted values from these models were used in Monte Carlo simulations to estimate the weighted distributions of usual intake on the original scale as well as the percentage above or below DRIs when applicable. SEs were estimated with the use of balanced repeated replication weights. AI, Adequate Intake; AMDR, acceptable macronutrient distribution range; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement.

[2]Estimate potentially unreliable because the relative SE was >30%.

The usual energy intake for toddlers was 1194 kcal, with carbohydrates, protein, and fat contributing ∼53%, ∼15%, and ∼33% of the calories, respectively (Table 3). At least one-fourth of toddlers had diets that fell below the AMDR for fat (30–40% of energy). Most (≥95%) toddlers met their EAR for protein and carbohydrates. For certain types of macronutrients, dietary fiber, linoleic acid, and linolenic acid, AI recommendations are available for toddlers; mean usual intake for linolenic acid was above the AI, suggesting the risk of inadequacy was small. For dietary fiber and linoleic acid, however, the mean (and even the 90th percentiles) of intakes were below the corresponding AI, suggesting a high likelihood of inadequacy. Although precise estimates of inadequacy cannot be defined in relation to the AI, ∼40% of toddlers had intakes at or above the AI for linoleic acid, and for dietary fiber <1% of toddlers consumed diets that met the recommended AI of 19 g/d.

We compared the usual intakes for vitamin and minerals to the appropriate reference values for EAR or AI as available for infants and toddlers (**Tables 4** and **5**, respectively). For infants aged 6–11 mo, EARs are available for iron and zinc only. Only a small proportion of infants were at risk for inadequate iron or zinc intake (10% and 5%, respectively). On the other hand, a larger proportion of infants had usual intakes of preformed vitamin A (i.e., retinol) and zinc that exceeded the UL (21% and 61%, respectively). For most micronutrients for which AI levels are available for infants, intakes were generally adequate (i.e., usual mean intakes exceeded the AI). However, for vitamin D and choline, mean usual intakes were below the corresponding AI; specifically, 21% and 28% of infants, respectively, had intakes greater than the recommended AIs for these nutrients.

For the older age group, almost all toddlers met their EARs for vitamins and minerals examined with the exception of vitamins D and E (Table 5). Specifically, 74% and 82% of toddlers had usual intakes below the EAR for these 2 vitamins, respectively. For toddlers, a reference AI is available for the 4 nutrients that were examined (vitamin K, choline, potassium, and sodium); mean usual intakes were lower than the AI only for potassium. It is important to note that only <1% of US children aged 12–23 mo consumed diets that met or exceeded the AI for potassium of 3000 mg. The usual intakes of preformed vitamin A, sodium, and zinc exceeded the UL in 16%, 52%, and 41% of toddlers' diets, respectively.

DISCUSSION

To our knowledge, this is the first report to provide the most current and comprehensive estimates of usual intakes of both macro- and micronutrients for US children aged 6–23 mo. It updates and extends the limited literature on national-level findings from FITS (6, 7) and NHANES-based reports on selected nutrients (12, 13, 30). Estimating usual nutrient intake by statistical modeling techniques (such as the National Cancer Method method) that adjust for measurement error due to within-person variation (7, 21, 23, 31, 32) allows intakes to be compared to reference standards such as the DRI (10, 28).

TABLE 4
Usual intakes of vitamins and minerals from food and beverages for infants aged 6–11 mo (*n* = 381) and proportions meeting DRIs[1]

		Usual intake percentiles					DRI					
Nutrient	Mean ± SE	10th	25th	50th	75th	90th	EAR	AI	UL	% <EAR	% ≥AI	% >UL
Vitamin A retinol activity equivalents, μg	669 ± 18.0	420	522	652	796	940	—	500	600[2]	—	79	21[2]
Vitamin D, μg	7.0 ± 0.2	2	4	6	9	13	—	10	38	—	21	<1[3]
Vitamin E, mg	6.9 ± 0.2	3	4	6	9	11	—	5	—	—	67	—
Vitamin K, μg	52.5 ± 2.3	21	32	48	68	91	—	2.5	—	—	99	—
Thiamin, mg	0.98 ± 0.0	0.5	0.7	0.9	1.2	1.6	—	0.3	—	—	98	—
Riboflavin, mg	1.33 ± 0.0	0.7	1.0	1.3	1.6	2.0	—	0.4	—	—	99	—
Niacin, mg	12 ± 0.4	6	8	11	15	19	—	4	—	—	97	—
Vitamin B-6, mg	0.72 ± 0.0	0.4	0.5	0.7	0.9	1.2	—	0.3	—	—	95	—
Dietary folate equivalents, μg	195 ± 5.6	96	129	178	242	316	—	80	—	—	95	—
Vitamin B-12, μg	1.85 ± 0.1	0.7	1.0	1.6	2.4	3.4	—	0.5	—	—	96	—
Choline, mg	129 ± 3.9	76	94	121	154	192	—	150	—	—	28	—
Vitamin C, mg	91 ± 3.0	50	66	87	112	138	—	50	—	—	90	—
Calcium, mg	664 ± 14.7	376	477	621	802	1006	—	260	1500	—	99	1[3]
Phosphorus, mg	505 ± 13.3	242	328	456	626	828	—	275	—	—	85	—
Magnesium, mg	111 ± 2.8	60	79	105	136	170	—	75	—	—	79	—
Potassium, mg	1119 ± 20.5	678	844	1068	1336	1623	—	700	—	—	88	—
Sodium, mg	497 ± 24.8	163	247	395	625	946	—	370	—	—	54	—
Iron, mg	16.4 ± 0.7	6.8	10.2	15.1	21.1	27.5	6.9	—	40	10	—	1[3]
Zinc, mg	6.0 ± 0.2	3.1	4.1	5.6	7.4	9.4	2.5	—	5	5[3]	—	61
Copper, mg	0.70 ± 0.014	0.48	0.57	0.68	0.80	0.92	—	0.22	—	—	>99	—
Selenium, μg	27.4 ± 1.0	13.9	18.2	24.8	33.5	44.1	—	20	60	—	68	2[3]

[1]The National Cancer Institute method was used to estimate the usual nutrient intakes and distributions. Nonlinear mixed-effects models were used to estimate means, and parameter estimates and predicted values from these models were used in Monte Carlo simulations to estimate the weighted distributions of usual intake on the original scale as well as the percentage above or below DRIs when applicable. SEs were estimated with the use of balanced repeated replication weights. AI, Adequate Intake; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; UL, Tolerable Upper Intake Level.

[2]The UL and estimated proportion (%) with intakes greater than UL are based on preformed vitamin A only (i.e., retinol).

[3]Estimate potentially unreliable because the relative SE was >30%.

TABLE 5

Usual intakes of vitamins and minerals from food and beverages for toddlers aged 12–23 mo (n = 516) and proportions meeting DRIs[1]

		Usual intake percentiles					DRI					
Nutrient	Mean ± SE	10th	25th	50th	75th	90th	EAR	AI	UL	% <EAR	% ≥AI	% >UL
Vitamin A retinol activity equivalents, μg	573 ± 12.4	384	461	559	669	780	210	—	600[2]	<1[3]	—	16[2]
Vitamin D, μg	8.0 ± 0.2	4	5	8	10	13	10	—	63	74	—	<1[3]
Vitamin E, mg	3.8 ± 0.1	2	3	4	5	6	5	—	200[4]	82	—	<1[3]
Vitamin K, μg	35.5 ± 1.5	19	25	33	43	55	—	30	—	—	58	—
Thiamin, mg	1.02 ± 0.0	0.7	0.8	1.0	1.2	1.4	0.4	—	—	<1[3]	—	—
Riboflavin, mg	1.73 ± 0.0	1.1	1.4	1.7	2.0	2.3	0.4	—	—	<1[3]	—	—
Niacin, mg	12 ± 0.4	7	9	11	14	16	5	—	10	1[3]	—	ND[5]
Vitamin B-6, mg	1.13 ± 0.0	0.8	0.9	1.1	1.3	1.5	0.4	—	30	<1[3]	—	<1[3]
Dietary folate equivalents, μg	304 ± 10.3	189	234	292	361	434	120	—	300[6]	1[3]	—	1[3]
Vitamin B-12, μg	4.04 ± 0.2	2.1	2.8	3.8	5.0	6.2	0.7	—	—	<1[3]	—	—
Choline, mg	203 ± 4.7	135	163	198	238	279	—	200	1000	—	49	<1[3]
Vitamin C, mg	75 ± 3.6	30	45	67	97	130	13	—	400	1[3]	—	<1[3]
Calcium, mg	980 ± 25.7	617	765	953	1164	1376	500	—	2500	3[3]	—	<1[3]
Phosphorus, mg	957 ± 21.8	655	782	939	1112	1281	380	—	3000	<1[3]	—	<1[3]
Magnesium, mg	172 ± 3.8	127	146	170	195	220	65	—	—	<1[3]	—	—
Potassium, mg	1834 ± 38.5	1325	1540	1805	2096	2381	—	3000	—	—	<1[3]	—
Sodium, mg	1581 ± 48.3	949	1196	1520	1899	2292	—	1000	1500	—	87	52
Iron, mg	9.4 ± 0.3	5.2	6.7	8.9	11.5	14.4	3	—	40	1[3]	—	<1[3]
Zinc, mg	6.7 ± 0.2	4.7	5.6	6.6	7.8	8.9	2.5	—	7	<1[3]	—	41
Copper, mg	0.68 ± 0.02	0.45	0.54	0.65	0.79	0.94	0.26	—	1	<1[3]	—	7
Selenium, μg	59.9 ± 1.5	41.5	49.3	58.8	69.4	79.8	17	—	90	<1[3]	—	3[3]

[1]The National Cancer Institute method was used to estimate the usual nutrient intakes and distributions. Nonlinear mixed-effects models were used to estimate means, and parameter estimates and predicted values from these models were used in Monte Carlo simulations to estimate the weighted distributions of usual intake on the original scale as well as the percentage above or below DRIs when applicable. SEs were estimated with the use of balanced repeated replication weights. AI, Adequate Intake; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; ND, not determined; UL, Tolerable Upper Intake Level.

[2]The UL and estimated proportion (%) with intakes greater than UL are based on preformed vitamin A only (i.e., retinol).

[3]Estimate potentially unreliable because relative SEs were >30%.

[4]Percentage greater than UL for vitamin E based on synthetic (added) forms (e.g., α-tocopherol).

[5]Proportion of children with niacin intakes greater than UL could not be estimated because the UL for niacin is based on synthetic (added) forms, and this distinction is not available in the Food and Nutrient Database for Dietary Studies databank.

[6]Percentage greater than UL for folate based on synthetic (added) forms (e.g., folic acid).

Because of the absence of verified recovery biomarkers or other reference instruments for nutrient intake, the possibility of other sources of error, including recall bias in proxy-reported intakes, remains. To the extent that the measurement error structure in 24-h recall is stable over time, comparisons to previous results from FITS and other national studies that used similar methods are valid. All dietary data are limited by the accuracy and recency of the databases used to estimate nutrient intakes from the foods and beverages reported. Nutrient intakes were computed with the use of the Food and Nutrient Database for Dietary Studies versions that reflect the years of data collection (18). The imputed estimates of breast milk consumed with the use of the FITS approach, although broad and imprecise, allowed the inclusion of breastfed children (13% sample) as in other studies (7, 13, 19–21). Our study aimed to provide updated estimates of usual nutrient intakes with the use of the most recent dietary data available from NHANES; the 4-y sample size, however, did not allow for an evaluation of racial/ethnic differences or breastfeeding and mixed-feeding scenarios that were beyond the scope of the study.

For most infants and toddlers, macronutrient intakes were generally adequate. It is important to note that an estimated 28% and 12% of toddlers had macronutrient intakes that fell below the AMDR in terms of percentage calories from fat and carbohydrate intake, respectively. These findings are similar to previously reported estimates for the percentage of energy from fat (6, 7, 21) but higher than the estimates reported in FITS 2002 (6) and 2008 (7) of 8% and 5% respectively, for carbohydrate intake. As in FITS, the percentage of energy intake from protein increased with age from 10% to 15% for children aged 6–11 and 12–23 mo, respectively (7). Protein intake complied with the AMDR, and only a small proportion (<5%) of toddlers had intakes above the AMDR. In contrast, ∼1 in 4 toddlers had an estimated fat intake below the AMDR, which may put them at risk for not meeting the requirements for essential fatty acids. For instance, linoleic acid intakes were at or above the age-specific AI for 69% and 39% of infants and toddlers, respectively. Although the usual intake of linoleic acid increased with age, the increase was not large enough to keep up with the 1.5-fold higher recommended AI for toddlers. Our finding that the diets of toddlers do not seem to provide enough fiber is consistent with the FITS reports (6, 7). The dietary patterns among children aged 1–2 y may reflect family patterns; it is well known that fiber intake in the US population is low (31). It has also been suggested that the AI for fiber may be too high for young children (33).

We examined the prevalence of inadequate micronutrient intakes relative to the EAR when available (iron and zinc for infants and for most micronutrients for toddlers). Our finding that ∼10% of infants aged 6–11 mo did not meet the EAR for iron is similar to that in FITS 2008 (7); 12% of infants had inadequate iron intake from diet and supplements in that study. These data correspond well with the biochemical findings from NHANES that show that 14.4% of children aged 1–2 y were iron deficient (34). Meeting iron needs in young children is critical for optimal function, including cognition and immunity (35, 36), and the finding of insufficient iron intake in infants despite the wide availability of iron-fortified cereal and formula suggests further work may be needed to understand the factors associated with low intakes, including iron bioavailability from foods and beverages consumed.

Most toddlers had diets that consistently met DRIs for most micronutrients, and the risk of inadequacy was small for most nutrients for which EARs exist. However, we found that most (82%) toddlers had inadequate intakes of vitamin E. This is consistent with FITS (7) and for most age and sex subgroups in the United States (31) despite the lack of evidence of vitamin E deficiency (7, 37), suggesting that the current DRI may be too high (7).

To our knowledge, this is the first study to report on usual nutrient intakes of vitamin D in children aged <2 y compared to the updated DRI (8) that set an EAR for toddlers (10 μg/d) and higher AI and UL values for infants than previous DRIs. Our estimates show that for young children this vitamin may be a "shortfall" nutrient (31); ∼21% of infants aged 6–11 mo met or exceeded the AI (10 μg/d), and 74% of toddlers had vitamin D intakes below the EAR. Although the dietary intakes accounted for the fortification of vitamin D in foods and beverages, they did not include vitamin D from dietary supplements. Therefore, the dietary data in this study may have overestimated the inadequacy of vitamin D for infants and toddlers. This overestimation is further considered based on an analysis of blood samples on a limited sample of young children in NHANES to determine vitamin D status (38), the results of which showed that among children aged 1–11 y, only ∼10% had 25-hydoxyvitamin D <50 nmol/L (39)—the concentration consistent with the Recommended Dietary Allowance (40). In addition, it should be noted that these biochemical data may have underestimated suboptimal vitamin D status because NHANES does not sample individuals in northern climates during the winter months (31).

For several nutrients, particularly for infants, the IOM has set the AI level when an EAR could not be established (10, 28). Both infants and toddlers generally met or exceeded the AI for most micronutrients, implying a low risk of inadequacy (10, 27, 28). An important exception was potassium for toddlers. Few (<1%) toddlers had intakes greater than the AI, consistent with previous reports in children <2 y (7, 13) and across all age and sex subgroups in the United States (31), suggesting that the DRI for potassium may be too high and thus deserves further consideration.

We also examined the percentage of children whose dietary intakes exceeded the UL for various micronutrients. Our finding that ∼52% of toddlers consumed too much sodium is in line with previous reports from NHANES 2003–2010 (13) as well as FITS (41). The estimated usual zinc intakes exceeded the UL for 61% and 41% infants and toddlers, respectively. Usual intake of preformed vitamin A exceeded the UL for an estimated 21% and 16% of infants and toddlers, respectively. The corresponding proportions were similar for infants in FITS 2008 but lower for toddlers; only 4% of toddlers had dietary zinc and preformed vitamin A intakes that exceeded the corresponding UL (7). Differences in participant characteristics such as the FITS sample may overrepresent higher income and underrepresent certain racial/ethnic groups (19, 38) as well as differences in dietary methodologies may explain some of these discrepancies. Dietary data in NHANES are collected at the MEC exam with the use of the validated 5-step AMPM to ensure complete recall of foods and beverages consumed (16). The UL for vitamin A and zinc have also been questioned because they are close to the AI levels for young children (33).

Our analyses focused on nutrient intakes from food and beverages only, to provide important information toward developing food-based dietary guidance for infants and toddlers. Dietary supplement use was reported among 14% of the children. The nutrients included in the dietary supplements varied, with multivitamins (A, C, and D) being most predominantly consumed, and few parents reported the use of dietary supplements containing iron or zinc among infants. Overall, we believe that the use of dietary supplements in this age group would not affect the findings on the proportions of infants consuming below the EAR for iron or zinc. However, it is likely that our estimates of the proportions of children consuming excessive zinc and vitamin A in particular may be underestimated and those with inadequate vitamin D intakes overestimated.

In conclusion, this study shows that for the most part usual nutrient intakes were adequate for most US infants and toddlers compared to the recommendations with a few exceptions. An important proportion of infants (10%) was estimated to have inadequate iron intake. For ≥25% of toddlers, the macronutrient composition of their diets provided less than the recommended energy from fat, and for ≥7 of 10 toddlers, estimated intakes of vitamins D and E were inadequate. A large proportion of children aged 6–23 mo had excessive intakes of vitamin A and zinc, and ∼50% of toddlers consumed too much sodium. The dietary sources associated with inadequate or excessive intakes may need further examination.

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