REVIEW

Nutrition Monitoring of Children Aged Birth to 24 Mo (B-24): Data Collection and Findings from the NHANES

Namanjeet Ahluwalia

Division of Health and Nutrition Examination Surveys (DHANES), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD, USA

ABSTRACT

The first 2 y of life are characterized by several transitions that can affect growth, development, and eating patterns long term. These include a shift from a primarily milk-based eating pattern to introduction of complementary foods at ∼4–6 mo of age, and passage to family-meal patterns in toddler years. Recognizing the importance of this critical period, the Dietary Guidelines for Americans from 2020 onwards will include guidance for children aged birth to 24 mo (B-24). Few large-scale surveys provide comprehensive, nationally representative, quantitative, recent data on infant and toddler nutrition in the United States. The continuous NHANES has collected data relevant to this initiative since 1999 using standardized interview and examination protocols. These include data on infant feeding practices, dietary intakes (foods, beverages, and supplements), anthropometry, and blood-based nutritional status on nationally representative samples of infants and toddlers. NHANES data can be used to describe large group-level consumption patterns, as well as trends over time for B-24 children overall, and by demographic groups (e.g., race-ethnic and income groups). In addition, NHANES data can be analyzed to examine adherence to nutrition-related recommendations, such as those from the American Academy of Pediatrics (AAP), and to track Healthy People 2020 objectives. This paper provides an update on NHANES nutrition monitoring in B-24 children since our previous publication (which provided details through NHANES 2009–2010) and describes data collection since 2010 and plans for upcoming cycles. It also describes key NHANES-based findings published in the last 5 y on infant feeding practices, dietary intakes and supplement use, and nutritional status of US children aged <2 y. Findings related to existing recommendations, such as from the AAP, are presented when available. This information can inform researchers and policymakers on the state of nutrition in the US B-24 population and its subgroups of interest. *Adv Nutr* 2020;11:113–127.

Keywords: infant feeding, complementary feeding, food and nutrient intake, blood-based nutritional status, US children, disparities

Introduction

The first 2 y of life are critical in human development and can affect long-term health. Infancy is a period characterized by high nutrient needs and a time of rapid transition from a primarily milk-based diet (breast milk or infant formula) to a varied diet with consumption of several food groups on a daily basis (1, 2). The second year of life continues to be a critical time of steady growth and development whereby toddlers' nutrient needs remain high (1, 3). This period is characterized by continued transition to family foods and the development of food preferences (1, 4–6) which can influence food choices and dietary intakes in later life (1, 7–9). Recognizing these needs and the importance of specific dietary guidance for children aged birth to 24 mo (B-24) (10), the Agricultural Act of 2014 (also known as the 2014 US Farm Bill) mandated that beginning with the 2020–2025 edition, the Dietary Guidelines for Americans will include recommendations for B-24 children (11).

The dietary (food and nutrient) intakes and nutritional status of US infants and toddlers are less well-characterized compared to older children and adults. Data sources to describe infant and toddler nutrition in the United States

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Address correspondence to NA (e-mail: n.ahluwalia@cdc.gov).

Abbreviations used: AAP, American Academy of Pediatrics; AI, Adequate Intake; AMPM, Automated Multiple-Pass Method; BLL, blood lead level; B-24, birth to 24 mo; CRP, C-reactive protein; DBQ, Diet Behavior and Nutrition Questionnaire; EAR, Estimated Average Requirement; ECQ, Early Childhood Questionnaire; FITS, Feeding Infants and Toddlers Study; FSQ, Food Security Questionnaire; HP2020, Healthy People 2020; IFPS, Infant Feeding Practices Study; IOM, Institute of Medicine; MEC, mobile examination center; NHB, non-Hispanic black; NHW, non-Hispanic white; SSB, sugar-sweetened beverage; UL, Tolerable Upper Intake Level; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; 25(OH)D, 25-hydroxyvitamin D.

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include cross-sectional national surveys such as the 1994–1996 and 1998 Continuing Survey of Food Intake by Individuals (12). In addition, large-scale studies in this area include the Feeding Infants and Toddlers Study (FITS), conducted in 2002 (13), 2008 (14), and recently in 2016 (15), as well as the Infant Feeding Practices Study (IFPS) I and II conducted in 1992–1993 and 2005–2007, respectively, that include a prospective follow-up though infancy (2, 16, 17). The Continuing Survey of Food Intake by Individuals is a national survey by the USDA that described food intake by the US population, including the B-24 group; however, it did not include breastfed children. FITS was funded by Nestle Research Center and involved large cross-sectional samples of young children including the B-24 age group, selected at the national level from a commercial list and described food consumption patterns, feeding practices, and dietary intakes including usual nutrient intakes. Recently, FITS 2016 was conducted to update the knowledge on the diets and feeding patterns of young children in the United States (15). IFPS I (1992–1993) conducted by the FDA provided detailed information about general infant feeding patterns and infant health (17). IFPS II (2005–2007) was conducted by the FDA, CDC, and other agencies in the US Department of Health and Human Services, to better understand infant feeding practices by women in the United States in the context of changes in products, polices, and information regarding infant feeding choices since IFPS I (2, 16, 17). IFPS II was a large longitudinal study that followed women from late pregnancy through their infant's first year of life (17). The sample was based on a nationally distributed consumer opinion panel of households (17), and described breastfeeding, and the timing of introduction and nature of complementary foods through the first year of life (2). FITS and IFPS studies are important resources on infant and toddler nutrition, although these surveys are not nationally representative (i.e., they had more households with higher education/income and more non-Hispanic white participants) and did not collect direct anthropometric measurements or blood samples.

The continuous NHANES has been collecting data since 1999 on nationally representative samples of children, including diverse income and race-ethnic groups. NHANES collects detailed demographic information and comprehensive nutrition data on dietary intake, anthropometric measurements, as well as blood samples through standardized interviews and direct examination of participants. These data from NHANES provide a national resource to better understand the dietary patterns and nutritional status of the B-24 population and inform the development of future dietary guidance for this group.

Current Status of Knowledge

NHANES data relevant to the B-24 population from 1999 to 2010 have been previously described (1). This earlier report provided details on data collection methods, questionnaires used and nature of data collected, dietary interviews to obtain 24-h dietary recalls, physical measurements for anthropometry, and blood collection for nutrient status assessment. Website links to relevant resources and sample sizes for the B-24 population were also included in that report (1). However, recent findings on infant and toddler nutrition based on NHANES diverse and comprehensive nutrition monitoring data have not been summarized previously. With the mandate that future Dietary Guidelines for Americans include dietary guidance for children aged <2 y from 2020 onwards, a synthesis of the current understanding of infant feeding practices, nutrition intake and status of US children aged <2 y based on NHANES data may be useful.

This paper provides a brief overview of NHANES, with updates on data collection relevant to B-24 age groups since the previous report (1). Key NHANES-based findings on nutrition monitoring of infants (aged <12 mo) and toddlers (aged 12–23 mo) published in the last 5 y (1/2013–11/2018) are described. Specifically, previously published NHANES-based findings on infant feeding practices, food and beverage intake, nutrient intake, dietary supplement use, nutritional status based on blood-based tests, and anthropometric measurements are summarized here. Findings are described by age and major demographic characteristics such as race-ethnicity, income, and participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), when available. NHANES-based findings related to existing recommendations such as those by the American Academy of Pediatrics (AAP), and related to Healthy People 2020 (HP2020) objectives, as applicable, are also described.

NHANES Nutrition Monitoring Data Relevant to B-24 Children

The following section briefly describes the NHANES program and provides an update on data collection in NHANES relevant to nutrition monitoring of children aged <2 y.

NHANES program

The continuous NHANES is an ongoing nationally representative survey of the noninstitutionalized civilian household population of the United States, which has been collecting data since 1999 (18). The goal of the survey is to collect data on health, nutritional status including food, beverage, and nutrient intake, dietary supplements, anthropometric measurements, and laboratory tests. NHANES collects these data using a series of large, complex, stratified, multistage probability samples with a 4-y design that are released in 2-y cycles. Each year, the survey is conducted on ∼5000 participants and the data are released publically every 2 y for ∼10,000 total participants. From 2011 to 2020, the NHANES sample design includes an oversample of Asian Americans, in addition to the continued oversampling of Hispanic and non-Hispanic black individuals as well as older adults as in earlier years (19, 20). Survey participants are asked to complete a series of questions during a detailed household interview followed by a scheduled visit to the mobile examination center (MEC). At the MEC, they undergo a physical examination to

TABLE 1 NHANES data: sections and key information

Component	Information
Demographic[1]	Age, sex, income, race-ethnicity, family, health insurance, housing characteristics
Questionnaires	Diet, behavior, and nutrition[2]
	Early childhood[1]
	Food security[3]
	Consumer behavior[1]
	Medical conditions[1]
Dietary[4,5]	Individual food files–day 1 and day 2 (since 2002)
	Total nutrient intakes–day 1 and day 2 (since 2002)
	Nutrient supplements intake–30 d and 24 h (since 2007)
Examination[4]	Body measures
	Weight, recumbent length/height (>0 mo)
	Head circumference (0–6 mo)
	Midupper arm circumference (≥2 mo)
Laboratory[4]	Analyses vary by survey year

[1]Collected through interviews administered in the home.
[2]Questions relevant to infants and toddlers 0–24-mo old were collected through interviews administered in the home.
[3]Household food security questions were administered in the home and answered by the household reference person.
[4]Day 1 dietary recall, examination, and laboratory components were carried out at the mobile examination center.
[5]Day 2 dietary recall was administered over the telephone.

collect anthropometric and health data as well as biological specimens for conducting laboratory tests (e.g., nutritional status, health, and environmental exposures). At the MEC, individuals also participate in a dietary interview that is commonly referred to as "What We Eat in America"—the dietary component of NHANES administered in partnership with the USDA. Participants receive a follow-up dietary interview by phone 7–10 d after. The National Center for Health Statistics Research Ethics Review board approved the NHANES protocol. For all participants aged <18 y, written parental consent is obtained (21).

NHANES data collection relevant to nutrition monitoring of the B-24 population

NHANES data for the B-24 population are collected during a household interview and at the MEC, and during a follow-up telephone interview. Proxy informants, generally a parent (>95%), provide responses to all questions for young children aged <5 y.

Household interview.

Data pertinent to the B-24 population have been collected during the household interview since 1999 using several questionnaires (**Table 1**). These include the Diet Behavior and Nutrition Questionnaire (DBQ), Early Childhood Questionnaire (ECQ), and Food Security Questionnaire (FSQ) that can be accessed for each 2-y cycle on the NHANES website under questionnaires (22). Briefly, data from the DBQ include whether the participant child ever received breast milk, the timing of introduction of formula or other milk, and the ages at which breastfeeding and feeding formula were stopped. In certain cycles (1999–2008), data on timing of introduction of solid foods were also collected. Questions in the ECQ highlight events related to birth and early childhood including birth weight, weight status, newborn care, daycare attendance, and Head Start Program participation. Lastly, the FSQ provides data on household food security of both the adult and child and participation in food assistance programs such as WIC. These data are publically available through 2016 on the NHANES home page (23). The unweighted sample size for B-24 children with data from the household interview ranged between 735 and 912 for a 2-y cycle from 1999 to 2010 (1); during 2011–2016 it varied from 620 to 687.

Because of the public health needs identified by the B-24 project (10) and concerted efforts of several federal agencies in the B-24/Pregnancy Federal Consortium, additional questions on self-reported mother's prepregnancy height and weight, as well as expanded content on infant feeding practices and WIC participation have been added to DBQ, ECQ, and FSQ from 2019 to 2022 (24). These address the "mode of feeding," that is whether breast milk is fed from the mother's breast or a bottle or cup is used to feed milk or formula. The topic of "mixed feeding" is addressed further with questions on the consumption of human milk and/or infant formula, mixing breast milk with infant formula in the bottle, as well as addition of water, cereal, sweeteners, vitamins/minerals, and medicines to the bottle. A series of questions on the timing of the first introduction of various food groups and subgroups has also been added.

During the household interview, data on dietary supplement use during the past 30 d (i.e., nature, dose, frequency, duration, and motivations of dietary supplement use) are collected for all survey participants. Interviewers examine the bottles/containers of the dietary supplements to obtain detailed information on the amounts and nature of supplements consumed. This enhances the precision and the quality of data on dietary supplements use over the past month (18).

In addition, information on a range of demographic descriptors such as household size, family income, education, language spoken at home, and race-ethnicity are also collected during the household interview (19–21).

Visit at the MEC.

Three to 10 d after the household interview, children visit the MEC with the proxy respondent (generally a parent) for further data collection through direct examination and interviews including a dietary interview. Typically, sample sizes for the B-24 population examined at the MEC, based on age at exam ranged from 682 to 850 for a 2-y cycle from 1999 to 2010 (1, 25); the corresponding range was from 590 to 634 from 2011 to 2016.

A main component of the MEC exam is the collection of dietary intake data through a 24-h recall by a trained interviewer, using a computer-assisted dietary interview system with standard probes, that is USDA's Automated Multiple-Pass Method (AMPM) (18, 26). Information on the type and amount of all foods and beverages consumed in a single

24-h period (from midnight to midnight) before the dietary interview, is provided by the proxy for young children. The AMPM is used to enhance complete and accurate data collection as well as to reduce respondent burden (26, 27). Data for the second 24-h dietary recall using AMPM are collected by telephone 3–10 d after the MEC exam.

Data on various body measurements for the B-24 population including body weight, recumbent length, head circumference (<6 mo), and midupper arm circumference (≥2 mo) have been collected by trained personnel using standard protocols since 1999. During 1999–2010, triceps and subscapular skinfold thickness (≥2 mo) were also measured (28).

Blood specimens are collected by trained health technicians at the MEC for children aged >1 y in continuous NHANES (18). These samples are processed by trained laboratory staff at the MEC and analyzed either on site or sent to 1 of the collaborating laboratories for analysis. The analytes determined in these samples vary by survey cycle based on public health priorities, feasibility, and funding availability. The nutrition-related blood-based laboratory tests for 1-y-olds from 1999 to 2016 have included heavy metals (e.g., lead, mercury, and cadmium), and markers of iron and vitamin status using state-of-the-art techniques and standardized procedures. Iron status assessment has been based on a comprehensive panel including serum transferrin receptors through 2010 and in 2015–2016. C-reactive protein (CRP) was measured in some NHANES cycles (2003–2006 and 2015–2016) to control for inflammation (28). Status of water-soluble and lipid-soluble vitamins (i.e., folic acid and vitamin D) has also been determined since 2003. In a few NHANES cycles in the past, vitamins B-6 and B-12 were also assessed (28). Typically, the sample size for blood measures such as hemoglobin for toddlers (aged 12–23 mo) has varied between 155 and 226 per NHANES cycle during 1999–2010, and between 116 and 156 during 2011–2016 (1, 25). Because of the small sample sizes for blood-based tests in this age group, data from several cycles need to be pooled to have an adequate sample size for population subgroup analysis. NHANES is conducting a pilot study in 2019 to assess the feasibility of obtaining blood samples from infants. This feasibility study will assist in determining whether blood samples will be collected for children aged <1 y in future NHANES cycles (24).

Recent NHANES Findings on Nutrition Monitoring of B-24 Children

The following sections briefly summarize NHANES-based findings published in the last 5 y (2013–2018) identified primarily through searches on PubMed on infant feeding practices, beverage and food intake, dietary supplement use, nutrient intakes, anthropometric measurements, and blood-based tests of nutritional status for B-24 children. When available, the findings regarding adherence to AAP recommendations relevant to nutrition monitoring of B-24 children (29–33) are discussed. **Table 2** lists these AAP recommendations and whether they can be addressed with NHANES data. In addition, Table 2 also indicates whether NHANES-based findings have been published in the last 5 y on infant and toddler nutrition in relation to AAP recommendations. NHANES data have been analyzed to publish findings related to 12 AAP recommendations: breastfeeding, food introduction, healthy snacking, healthy drinks, nutrient supplements, and blood lead (Table 2). These findings are summarized in the following sections.

Infant feeding patterns

Beverages (including breast milk and infant formula) are an important contributor to nutrient intake among young children. Notably during early infancy, beverages are the main source of nutrients. The AAP recommends exclusive breastfeeding for the first 4–6 mo, continued breastfeeding to the first birthday and beyond if possible, and the use of infant formula for the first year of life for infants who are not breastfed (29, 34). In addition, the introduction of cow milk before 12 mo and juice during early infancy are discouraged (29, 35). Furthermore, the AAP recommends that infants should avoid consuming any sugar-sweetened beverages (SSBs) (29).

Beverage consumption.

Recent reports based on NHANES data by Grimes et al. (36, 37), Hamner et al. (38), Miles and Siega-Riz (39), and Demmer et al. (35) have described the proportion of young children who consumed key beverages such as breast milk, infant formula, milk (whole, and other categories), 100% fruit juice, SSBs, and water. Most reports used day 1 dietary recall information but used different cycles of NHANES: 2005–2012 (36, 37), 2009–2014 (38), and 2011–2014 (35) to provide estimates of intake at the group level on a given day.

Few publications have reported on exclusive breastfeeding rates based on NHANES data. Using single day 24-h dietary recall data from NHANES 2005–2012, Grimes et al. (36) reported that 21.4% and 0.8% of infants aged <6 and 6–11 mo, respectively, were exclusively breastfed on a given day (i.e., received no other food or beverage except breast milk during the 24-h period). Corresponding estimates for partially breastfed infants (received some breast milk during the 24-h period) were 20.1% and 23.5%, respectively.

Using day 1 24-h dietary recall NHANES data from 2009 to 2014, Hamner et al. (38) reported that 42.9%, 25.8%, 7.6%, and 5.5% of children aged 0–5, 6–11, 12–18, and 19–23 mo, respectively, consumed breast milk on a given day. Corresponding estimates for infant formula consumption for these age groups were 70.5%, 79.3%, 9.4%, and 5.9%, respectively. Grimes et al. (36) found a similar result based on NHANES 2005–2012 data, based on day 1 24-h dietary recall at the MEC; 41.5%, 24.3%, and 7.5% of children aged <6, 6–11, and 12–23 mo, respectively, were breastfed on a given day. Corresponding estimates for infant formula intake were 74.1%, 78.6%, and 6.0%, respectively (36, 37). Miles and Siega-Riz (39) also reported that 22.2% and 7.4% of children aged 6–11 mo and 12–23 mo, respectively, consumed breast milk on a given day during 2009–2012.

TABLE 2 NHANES nutrition monitoring data for children aged <2 y in relation to recommendations from the AAP[1]

AAP recommendation[2]	Adherence to AAP recommendation can be examined with NHANES data	NHANES based findings published in the last 5 y relatable to AAP recommendation
Breastfeeding		
Exclusive breastfeeding for ∼6 mo	Yes	Yes; limited[3]
Continue breastfeeding until the baby's first birthday or longer while mutually desired by mother and baby	Yes	Yes
Food introduction		
Introduce solid foods around age 6 mo	Yes	Yes; limited
Expose baby to a wide variety of healthy foods	Yes	Yes
Also offer a variety of textures	No	
Healthy snacking		
After 9 mo, offer 2–3 healthy and nutritious snacks per day	Yes	Yes; limited
Maintain fruit and vegetable consumption after finger foods are introduced	No	
Healthy drinks		
Babies should drink breast milk or formula for the first year of life	Yes	Yes
Try to avoid introducing juice until child is a toddler; if juice is introduced, wait until 6–9 mo and limit consumption to 4–6 oz (i.e., ∼120–180 mL)	Yes	Yes
Avoid introduction of sugar-sweetened beverages for infants	Yes	Yes
Avoid whole milk (cow milk) before age 12 mo[4]	Yes	Yes
Choose milk or water for beverages for toddlers[5]	Yes	Yes; limited
Picky eaters		
Introduce a variety of foods multiple times and in multiple ways to toddlers[5]	No	
Parent provides, child decides		
Offer healthy food in age-appropriate portions at meals and snacks to toddlers[5]	No	
Let toddler decide what and how much to eat[5]	No	
Nutrient supplements		
Vitamin D supplementation (400 IU/d) for all children except those who consume ≥1 L/d of vitamin D-fortified infant formula or whole milk[6]	Yes	Yes; limited
Iron supplementation for exclusively breastfed infants beginning at age 4 mo, until appropriate iron-containing complementary foods are introduced in the diet[4]	Yes	Yes; limited
Lead exposure		
There is no safe level of lead exposure in children[7]	Yes	Yes

[1] AAP, American Academy of Pediatrics.
[2] AAP (29).
[3] Data are available to address this; however, only a few publications examined this topic in the last 5 y (2013–2018).
[4] Baker and Greer (31).
[5] AAP (30).
[6] Wagner and Greer (33).
[7] AAP (32).

Zhang et al. (40) examined trends in breastfeeding by WIC eligibility and participation using NHANES 1994–2014 DBQ data among children aged <5 y. Significant improvements in breastfeeding rates were noted in the past 2 decades: ever-breastfeeding rates ("was the child ever breastfed or fed breast milk") increased from 52% (1994–1997) to 71% (2010–2014) among WIC participants; corresponding estimates were 57% and 77%, respectively, among WIC-eligible nonparticipants. The HP2020 objectives for infants who are ever-breastfed and breastfed at 6 mo (age child "completely stopped breastfeeding or being fed breast milk") are 81.9% and 60.6%, respectively. In 2010–2014, WIC-eligible infants or participating infants were ∼10% below the ever-breastfed target and 27% short of the target for breastfeeding rates at age 6 mo (40).

Herrick et al. (41) analyzed NHANES data from 1999 to 2012 and reported breastfeeding patterns based on DBQ data by age and birth weight status (<2500 g or ≥2500 g). In 2009–2012, 67.6%, 48.6%, and 42.0% of infants had received breast milk at 1, 4, and 6 mo of age, respectively. An increase in breastfeeding rates was noted between 1999 and 2012 for children aged 1, 4, and 6 mo. Based on data from 2009 to 2012, a lower proportion of infants with birth weight <2500 g had received breast milk compared to infants with birth weight ≥2500 g (65.4% and 77.5%, respectively).

Davis et al. (42) used DBQ data and reported that the mean age (95% CI) breastfeeding was stopped by mothers of US children aged <2 y was 4.9 mo (95% CI: 4.6, 5.2 mo) during 2003–2012. The mean age (95% CI) when B-24 children stopped getting formula was 11.3 mo (95% CI: 11.1, 11.5 mo), which is consistent with the AAP recommendation that babies should drink breast milk or formula through the first year of life.

NHANES data can also inform on the kinds of infant formula (e.g., cow milk, soy, gentle/lactose-reduced, and specialty) consumed among US infants. Cow milk-based formula was the most commonly consumed, while other formulas (soy-based, gentle/lactose-reduced, specialty) were also used by a small group of infants during 2003–2010 (43).

Recent publications based on NHANES data from 2005 to 2014 reported that between 8.2% and 20.1% of 6–11-mo-old infants consumed cow milk, and between 12.3% and 60.2% consumed 100% juice on a given day (35, 37–39). These findings do not align with the recommendations that discourage the introduction of cow milk and juice before 12 mo of age (29, 35). Although the AAP recommendations also suggest that infants should avoid consuming SSBs (29), NHANES data show that approximately 5.0–13.6% of 6–11-mo-old infants and 31.0–54.2% of toddlers consumed SSBs on a given day (35, 37–39).

Only a few reports have described the amounts of specific beverages consumed by infants and toddlers based on NHANES data (35, 37, 44). Grimes et al. (37) reported amounts (g/d) of major beverages consumed by infants and toddlers by age group (0–5, 6–11, 12–23 mo), for all children (per capita) and for consumers only, based on 2005–2012 NHANES data. Breast milk consumption was computed as described previously, based on child's age, whether child was exclusively breastfed, volume of "other milks" consumed, and by considering number of breastfeeding occasions (14, 37). Breast milk and infant formula consumption among infants aged 0–5 mo (264 and 618 g/d, respectively) and 6–11 mo (119 and 615 g/d, respectively) was higher compared to that reported for toddlers aged 12–23 mo (23 and 38 g/d, respectively). Cow milk and 100% fruit juice consumption was greatest among toddlers (472 and 158 g/d, respectively) compared to infants aged 0–5 mo (0 and 6 g/d, respectively) and 6–11 mo (46 and 53 g/d, respectively). Demmer and colleagues (35) recently described the amount of "total milk" (cow milk with varying fat, regular/flavored, dairy drink, and milk substitutes) consumed on any given day by type of milk consumed by infants (aged 0–5 and 6–11 mo) and toddlers. Whole milk was the predominant type of milk consumed by children aged <2 y, followed by reduced fat milk. Using NHANES 1999–2004 data, Beltran-Aguilar et al. (44) reported that toddlers (aged 12–23 mo), on average, consumed 21.6 mL/kg of water on a given day.

Beverage feeding patterns by race-ethnicity.

Differences in intake (prevalence, and amount consumed) of various beverages (breast milk, infant formula, juice, and SSBs) as well as age at which infants were first fed cow milk, have also been described by race-ethnicity (35, 37, 38, 42). Grimes et al. (37) showed that non-Hispanic black (NHB) children aged 0–24 mo had the lowest prevalence and amount of breast milk consumption on a given day, compared to all other groups based on race-ethnic origin. Hamner et al. (38) reported similar race-ethnic patterns regarding prevalence of breast milk consumption by 0–5-mo-old and 6–11-mo-old children. Davis et al. (42) reported that the age breastfeeding was stopped and the age infants were first fed formula, were earlier among Mexican American (4.2 and 1.3 mo, respectively) and NHB infants (3.6 and 1.1 mo, respectively) during 2003–2012, as compared to non-Hispanic white (NHW) infants (5.3 and 2.1 mo, respectively). The prevalence of infant formula consumption among children aged <2 y was higher among NHB compared to NHW children (47% compared with 39%, respectively) (37). Similar race-ethnic findings were noted by Hamner et al. (38) for more specific age groups (0–5 and 6–11 mo). The corresponding estimates for formula intake among NHB compared with NHW children aged 0–5 mo were 90.6% and 64.0%, respectively; and 91.5% and 71.5%, respectively for 6–11-mo-olds (38).

Grimes et al. (37) showed that NHB children (aged 0–24 mo) consumed 100% fruit juice more often than NHW children, and in greater amounts compared to NHW and Mexican American counterparts. Hamner et al. (38) found similar findings (NHB > NHW and NHB > Hispanic) for the prevalence of fruit juice consumption in children aged >12 mo. For children aged 12–18 mo, these authors also found that Hispanic children consumed fruit juice more often than NHW children. In addition, Grimes et al. reported that NHW children aged <2 y, consumed SSBs less often than NHB counterparts. Similar patterns were noted for toddlers by Hamner et al. (38). In another report, Davis et al. (42) found that Mexican American and NHB infants were fed cow milk earlier (11.1 and 11.0 mo, respectively) than NHW counterparts (11.5 mo).

Race-ethnic differences in the amounts of "total" milk and SSB consumption have also been reported for B-24 children (35). Data on Asians have been collected in more recent cycles (since 2011) and recent publications have begun to report on this group compared to other race-ethnic groups. Total milk consumption on a given day among NHB children aged 0–23 mo was lower (0.83 cup eq. or 202 g) compared to their NHW (1.3 cup eq. or 317 g) and Hispanic (1.2 cup eq. or 293 g) counterparts. SSB consumption on a given day was significantly higher among NHBs (3.5 oz, i.e., ∼104 mL) compared to Asians (0.63 oz, i.e., 19 mL) in children aged <2 y (35).

Beverage feeding patterns by income.

NHANES data also allow researchers to examine the associations of feeding practices and dietary intake with family income. A few studies have been published based on NHANES data on this topic in the past 5 y (37, 45). Grimes et al. (37) reported negative associations between poverty to income ratio and consumption of infant formula, 100% fruit juice, and SSBs using 4 cycles of NHANES data from 2005 to 2012. These authors also reported a positive association between income and breast milk consumption. However, these findings were presented for children collapsed into a single age group (0–24 mo). Wang et al. (45) analyzed NHANES 2009–2014 data and found a negative association between family income and the percentage of energy contributed by added sugars from SSBs among nonbreastfed US children aged <5 y. No associations were noted when analyses were conducted for infants or toddlers.

Trends in beverage intakes over time.
NHANES dietary data have been collected using the same methodology (i.e., USDA's AMPM) since 1999; these data provide a national resource to describe trends over time in dietary intake (18). Miles and Siega-Riz (39) described trends in beverage intake (cow milk, fruit juice, and SSBs) between 2005 and 2012 for 6–11-mo-olds and 12–23-mo-olds. A key finding was that fruit juice consumption among infants (age 6–11 mo) decreased from 60.2% (2005–2008) to 47.7% (2009–2012).

Food intake patterns

NHANES dietary intake data have been used to describe food intake among infants and toddlers. These include findings related to introduction of solid foods among infants and transition to family foods in toddlers and in later years.

Introduction of solid foods to infants.
The AAP recommends that infants begin consuming foods in addition to breast milk or formula after 4 mo of age, preferably at 6 mo (29, 34) (Table 2).

Limited information exists on the topic of age at which children were first fed solid foods. Davis et al. (42) pooled data over 5 NHANES cycles (2003–2012) and analyzed DBQ data for B-24 children. These authors reported that the mean age (95% CI) children were first fed solid foods was 5.5 mo (95% CI: 5.3, 5.7 mo).

A recent analysis of NHANES DBQ data for children aged 6–36 mo during 2009–2014 showed that using a broad definition of complementary foods ("any food or beverage other than breast milk or infant formula"), 16.3% of infants were introduced to complementary foods under 4 mo of age (46). Furthermore, the authors noted that 54.6% of infants had consumed food/beverages other than breast milk or infant formula before 6 mo of age.

The prevalence of consumption of specific categories of food by age was recently described based on NHANES day 1 24-h recall data from 2009 to 2014 (38). These authors found that 8.2%, 8.1%, and 21.1% of US infants aged <6 mo consumed fruit, vegetables (excluding white potatoes), and grains, respectively, on a given day.

The amount of food (fruit, vegetables, and grains) consumed by infants aged <1 y on a given day was described recently, based on NHANES 2011–2014 data (47). Mean fruit and vegetable consumption were 0.34 and 0.26 cups/d (i.e., 61 and 47 g/d, considering 1 cup of mixed vegetable or fruit corresponding to ∼180 g), respectively. Grain consumption among infants was 0.85 oz equivalent/d (i.e., 14 g/d, considering 16 g/oz equivalent).

The consumption of added sugars among infants aged 6–23 mo, a topic of increasing public health interest, was described based on NHANES 2011–2014 data (48). In fact, the AHA recommends that children aged <2 y avoid sugar consumption (49). Around 6 in 10 (61%) infants aged 6–11 mo consumed added sugars; mean intake was 0.9 tsp (4 g) on a given day (48).

Some of these papers also examined race-ethnic patterns in the prevalence of consumption of specific categories of foods and amounts consumed (38, 47). No race-ethnicity–related patterns were noted for fruit or vegetable intakes among 0–5-mo-olds; however, older NHW infants (age 6–11 mo) had higher fruit consumption on a given day compared to NHB and Hispanic counterparts, as well as higher vegetable intakes compared to Hispanic children aged 6–11 mo (38). With regard to grain consumption, a greater proportion of NHB infants (34.2%) aged <6 mo consumed grains compared to 20.8% of NHW and 16.7% of Hispanic counterparts. Similar race-ethnic findings were noted for older infants aged 6–11 mo regarding grain consumption. Furthermore, a greater percentage of Hispanic infants aged 6–11 mo (20.3%) consumed sweets (bakery products, candy, and other desserts) on a given day compared to NHW counterparts (9.2%) (38). Demmer et al. (47) did not find any major race-ethnic patterns except that NHW infants had higher fruit consumption on a given day compared to NHB and Asian counterparts.

Food intake among toddlers.
In recent years, several reports have begun to describe the intake of various foods including fruit, vegetables, grains, fish, and sugar among toddlers (38, 47, 50, 51). Hamner et al. (38) reported that the prevalences of fruit, vegetables (except white potatoes), grains, protein-rich foods, mixed dishes, snacks, and sweets on a given day among 12–18-mo-old children were 78.6%, 48.2%, 85.3%, 87.0%, 64.9%, 57.6%, and 58.9%, respectively. The corresponding estimates for children aged 19–23 mo were 68.8%, 45.1%, 87.1%, 90.2%, 70.8%, 56.7%, and 62.9%, respectively.

Based on 2005–2014 NHANES data, Kachurak et al. (52) described snacking patterns among 1–5-y-olds. Snacking was assessed using both days of dietary recall data collected (mean 2-d values for children were computed). During 2005–2014, on average, toddlers consumed 2–3 snacks on a given day. Grains and milk products were consumed most frequently at snacking occasions.

Demmer et al. (47) reported that the amount of major food groups consumed increased with age. On a given day, mean intakes were 1.2 cups (∼216 g) for fruit, 0.47 cups (∼85 g) for vegetables, and 3.1 oz equivalent (∼50 g) for grains by 12–23-mo-old children (47).

Few reports have described fish consumption among toddlers based on NHANES data (50, 53). The prevalence of fish consumption in the past 30 d, based on a FFQ on fish and shellfish consumption, among 12–23-mo-olds was similar in these reports, that is, 52–53% consumed fish and 22–24% consumed shellfish. In the report by Tran et al. (53), the authors estimated the usual amount of fish and shellfish consumption among toddlers by combining the frequency of consumption data during 30 d with the estimated usual amounts consumed at an eating occasion from 24-h recall data using the Monte Carlo procedure. Among consumers the usual intakes were small for both fish (mean: 4.2 g/d) and shellfish (mean: 0.56 g/d).

Lastly, regarding added sugar intake, Herrick and Cowan (48) reported that nearly all toddlers (>98%) consumed added sugars on a given day; mean intakes were 5.5 and 7.1 tsp (i.e., ∼22 and 29 g) on a given day for children aged 12–18 and 19–23 mo, respectively.

Race-ethnic patterns for consumption of foods among toddlers.

Hamner et al. (38) reported that the prevalence of fruit and vegetable consumption on a given day based on 6 y of NHANES data (2009–2014) was significantly higher among 12–18-mo-old NHW children compared to NHB and Hispanic counterparts. The prevalence of consumption of grains and snacks was significantly lower among 19–23-mo-old Hispanic children compared to other race-ethnic groups. For both age groups, there were no notable differences between race-ethnic groups in "sweets" intake (38).

On the other hand, Demmer et al. (47) did not find race-ethnic patterns in food intake (fruit, vegetables, grains, fats, oils, sugar, and protein-foods) on a given day based on analysis of 4 y of NHANES data (2011–2014). Similarly, Storey and Anderson (51) did not find any race-ethnic differences in total vegetable intake on a given day among 1–3-y-old children, using 4 y of NHANES data (2009–2012). However, these authors found that NHB children consumed greater amounts of potatoes compared to NHW and Mexican American children, while Mexican American children consumed less "other starchy vegetables" than the other 2 race-ethnic groups. With regard to added sugar intake, NHW children (aged 6–23 mo) consumed less added sugar on a given day compared to NHB counterparts during 2011–2014 (48).

Dietary supplement use

Adequate nutrient intakes can generally be obtained through dietary sources for most nutrients. However, for certain nutrients and depending on feeding practices (e.g., exclusive breastfeeding), the AAP recommends dietary supplement use (Table 2). Notably, recommendations on supplementation with vitamin D exist for children aged <2 y (33), and on iron supplementation for breastfed children (31).

There is limited information on dietary supplement use (prevalence, and amounts of nutrients from supplements) and motivations for supplementation among US infants and toddlers (54–56). Approximately 1 in 5 children aged <2 y (18.2%) used dietary supplements in the past 30 d, based on 2007–2014 NHANES data (55). Specifically, the prevalence of dietary supplement use was lower among infants (14.6% and 11.6% for ages 0–5 and 6–11 mo, respectively) compared to toddlers aged 12–23 mo (23.3%). Additional characteristics positively associated with dietary supplement use were breast milk consumption, NHW race-ethnicity, higher family income, and higher educational status of the head-of-the household. Vitamin D and multivitamin infant drops were the most commonly reported dietary supplements for children aged <12 mo, compared to chewable multivitamin products for toddlers (12–23 mo) (55). In an analysis of NHANES 2007–2010 data, Bailey et al. (54) reported that the most common reasons for taking dietary supplements by children aged <2 y were to improve overall health, supplement the diet, prevent health problems, prevent dental cavities, and boost immunity.

In 2008, the AAP updated its recommendation on vitamin D supplementation of children. The AAP recommends vitamin D supplementation of 400 IU/d (10 μg/d) for all children except those who consume ≥1 L of vitamin D-fortified formula or whole milk daily (33). Around a quarter (27.4%) of US infants aged 0–11 mo met the 2008 AAP vitamin D intake recommendation on a given day (i.e., either consumed ≥1 L of infant formula and/or received a supplement of ≥400 IU vitamin D) based on NHANES 2009–2012 data (57). Breastfed infants were less likely to meet the recommendations than nonbreastfed infants (0–11 mo) (19.3% compared with 31.4%, respectively) (57). Gahche et al. (55) examined dietary supplement use over the past month among B-24 children based on NHANES 2007–2014 data and found that nearly a quarter (24.3%) of infants aged 0–5 mo who consumed breast milk (but not formula) took a dietary supplement containing vitamin D. Overall, a greater percentage of toddlers aged 12–23 mo consumed vitamin D supplements (18.2%) compared to infants aged 0–11 mo (10.6%). The median daily intake of vitamin D from supplements was 268 IU (6.7 μg) for infants aged 0–11 mo and 196 IU (4.9 μg) for toddlers aged 12–23 mo.

Iron supplementation is recommended by the AAP for breastfed children around 4 mo of age until the introduction of appropriate iron-containing complementary foods (31). Gahche et al. (55) found that during 2007–2014, the use of iron supplements among infants (aged 0–11 mo) overall was low (1.6%). When analyses were stratified further by breast milk consumption, 2.1% of infants aged 0–5 mo who consumed breast milk and 1.5% of infants aged 0–5 mo who consumed both breast milk and infant formula, took iron supplements in the past 30 d. Although this report was based on 8 y of NHANES data, the sample size was not adequate to conduct detailed analysis for smaller age groupings, that is, 4–6 mo.

Nutrient intakes and food sources of nutrients

Nutrient intakes among US infants and toddlers have been described based on a single day of dietary recall obtained at the MEC (36, 51, 58). In recent years papers have also been published based on both days of dietary recall data collected in NHANES, to describe the usual nutrient intake distributions upon accounting for day-to-day variation using statistical approaches (e.g., PC-SIDE, National Cancer Institute method) (47, 59, 60).

Nutrient intakes on a given day.

Storey and Anderson (51) analyzed NHANES 2009–2012 data and described the intake of energy, macronutrient, and 9 micronutrients among 1–3-y-olds, as well as food sources of dietary fiber and 6 micronutrients of concern. Notably, all children were pooled together into a single category irrespective of age in this report. In contrast, Grimes et al. (36) described the intakes of energy, macronutrients as well as 16 micronutrients on a given day for 3 specific age groups: <6, 6–11, and 12–23 mo during 2005–2012. Moreover, these authors also described dietary sources of energy and 16 nutrients for these age groups. Infant formula, breast milk, and baby foods were the main sources of energy and nutrients for infants. In contrast, diverse food groups contributed to nutrient intakes among toddlers. Milk contributed the most to energy intake, followed by other sources such as 100% juice, grain-based mixed dishes, fruit, and sweet bakery products. Milk and ready-to-eat cereals were the chief contributors to micronutrient intakes among toddlers (36).

In a recent report, Maalouf et al. (58) described the top sources of dietary sodium intake among infants and toddlers based on 2003–2010 NHANES data. For 0–5-mo-old infants, the top contributors were formula (71.7%), human milk (22.9%), and commercial baby foods (2.2%); for infants aged 6–11 mo, these were formula (26.7%), commercial baby foods (8.8%), soups (6.1%), pasta mixed dishes (4.0%), and human milk (3.9%). For toddlers age 12–23 mo, the top contributors to sodium intake were milk (12.2%), soups (5.4%), cheese (5.2%), pasta mixed dishes (5.1%), and frankfurters and sausages (4.6%). These authors also examined race-ethnic group differences in sources of dietary sodium. Despite significant variation in top food categories across race-ethnic groups, commercial baby foods were a top food contributor in infants aged 6–11 mo; frankfurters and sausages were a top food contributor in children aged 12–23 mo. NHANES also collects detailed data on the source where the food/beverages consumed during the 24-h recall are obtained. Maalouf et al. (58) used those data and reported that most (83–90%) of the sodium consumed by US children aged <2 y came from store foods (e.g., supermarket).

Usual nutrient intakes.

Usual nutrient intakes have been described for children aged <2 y in a few reports (47, 59, 60). The strengths of the usual nutrient intake analysis are that researchers can describe the proportion of the population that does not meet recommended intakes, and provide estimates of nutrient inadequacy and excess. Two approaches have been taken for these analyses by either excluding breastfed children (47, 60) or including them (59, 61). Nutrient intakes from breast milk were imputed in the latter reports, following the approach used in FITS as well as other studies (14, 61–63). Infants' nutrient intakes from breast milk were estimated based on child's age, exclusively breastfed status, and volume of other types of milk consumed. The volume of breast milk was assumed as 600 mL/d for children aged 6–11 mo who were fed only human milk; 600 mL/d minus the volume of infant formula plus other milk for other children aged 6–11 mo. For toddlers, the amount of breast milk consumed was estimated based on number of breastfeeding occasions in the day, and an assumed volume of 89 and 59 mL/feeding occasion for children aged 12–17 and 18–23 mo, respectively (59, 61).

Findings on usual nutrient intakes from studies excluding breastfed children.

Demmer et al. (47) described the usual intakes of energy and macronutrients for 0–11-mo-old and 12–23-mo-old children (excluding those who were breastfed) using 4 y of NHANES data (2011–2014). The usual carbohydrate, protein, and fat intakes were 102, 20, and 37 g/d for infants (aged 0–11 mo) and 164, 47, and 47 g/d for toddlers (aged 12–23 mo).

The percentage of toddlers (aged 12–23 mo) who did not meet the recommended micronutrient intakes set by the Institute of Medicine (IOM) was described by Demmer et al. (47) for 9 micronutrients (calcium, magnesium, phosphorus, iron, zinc, and vitamins A, C, D, and E). Intakes below the Estimated Average Requirements (EARs) indicate the estimated prevalence of inadequate intakes within a group (64). A majority of toddlers had inadequate intake of vitamin D (78%) and vitamin E (66%); other micronutrient intakes were adequate (47). Similar findings were noted by Hamner et al. (60) for iron, zinc, and calcium intakes among toddlers (excluding those who were breastfed) based on NHANES 2003–2012 data. However, 1 in 2 children (50.8%) had zinc intakes that exceeded the upper limit set by the IOM (64). The authors noted that this finding should be interpreted with caution because of the limited data on adverse outcomes.

Race-ethnic patterns in macronutrient intakes were examined by Demmer et al. (47). No differences were noted among infants; however, among toddlers differences were seen for usual carbohydrate intake by race-ethnicity. NHB toddlers consumed more carbohydrates compared to NHW and Hispanic counterparts (47).

Race-ethnic patterns in the proportion of toddlers not meeting recommended micronutrient intakes were also described in 2 reports (47, 60). Certain race-ethnic differences in prevalence of children not meeting the recommended intakes were noted; these patterns varied by nutrients. More NHB toddlers (aged 12–23 mo) (92%) had usual vitamin D intake below the EAR compared to NHW (76%) and Hispanic (74%) counterparts (47). A larger percentage of Mexican American toddlers aged 12–23 mo did not meet recommended intakes for iron compared to NHB counterparts (60).

No differences were noted in the usual intakes of iron, calcium, and zinc among toddlers (aged 12–23 mo) in relation to family income (assessed using poverty to income ratio) based on NHANES 2003–2012 data (60).

Findings on usual nutrient intakes of children aged <2 y including breastfed children.

Ahluwalia and colleagues (59) reported on usual nutrient intakes among US infants and toddlers using 2009–2012 NHANES data. Usual energy intakes for infants (aged 6–11 mo) and toddlers (12–23 mo) were 836 and 1194 kcal/d, respectively. Intakes of macronutrients (g/d) were similar to those reported by Demmer et al. (47) (summarized above). For certain macronutrients, namely carbohydrate, fat, linoleic acid, and linolenic acid, recommended Adequate Intake (AI) values were available for infants (64); mean usual intakes were above the AI for all of these nutrients (59). Specifically, mean usual intakes of carbohydrate, total fat, linoleic acid, and linolenic acid for infants (aged 6–11 mo) were 111.0, 34.9, 5.9, and 0.65 g/d, compared to the AI of 95, 30, 4.6, and 0.5 g/d, respectively.

This report included all children irrespective of their breastfeeding status, thus national-level estimates of nutrient adequacy for B-24 population could be estimated by comparing usual intakes to the recommended DRI (64). The estimated usual intakes were adequate for most nutrients among infants (aged 6–11 mo); however, 10% had inadequate iron intake (i.e., intake below the EAR) and only 21% had a vitamin D intake that met or exceeded the AI (suggesting low risk of inadequacy) (59). In contrast, 21% and 61% of infants had usual vitamin A and zinc intakes that exceeded the Tolerable Upper Intake Level (UL) indicating a potential risk for adverse effects (64).

More nutrient inadequacies were noted among toddlers; 1 in 4 toddlers had a lower than recommended fat intake (% energy from fat), and most had intakes below the EAR for vitamins D (74%) and E (82%) during 2009–2012. On the other hand, 52% of toddlers had sodium intakes greater than corresponding UL (59). Carriquiry et al. (61) reported that 79% of 1–3-y-old US children had excess usual sodium intake during 2007–2010. The estimates in these 2 reports are not directly comparable because of different age ranges examined and different survey years. Carriquiry and colleagues also reported small but significant declines in the prevalence of excess sodium intake from 2003 to 2010 among children aged 1–3 y.

In our analyses of 2009–2012 NHANES, we found that 16% and 41% of toddlers had excessive intakes (i.e., $>$UL) for vitamin A and zinc, respectively (59). NHANES collects detailed data on dietary intakes and these could be analyzed in future studies to examine the dietary sources contributing to excessive intakes of vitamin A and zinc.

Another key finding from our study was that 21% of infants aged 6–11 mo had vitamin D intake that met or exceeded the recommended AI (10 μg/d). This indicates that only a small proportion of this age group have a low risk of inadequacy (64). Three in 4 toddlers (aged 12–23 mo) had inadequate vitamin D intake (below the EAR of 10 μg/d). These results may be overestimating inadequate vitamin D intake among the B-24 age group because intake from dietary supplements was not included in the analysis (59). An older report examined usual vitamin D intake from both diet and dietary supplement sources during 2005–2006; one-third of 1–3-y-old children consumed vitamin D supplements. Seven in 10 young children met IOM's Adequate Intake of 5 μg/d from diet alone (65), while this proportion was slightly higher ($\sim$8 in 10) when dietary supplement use was also included (66). Because the DRI for vitamin D have been updated since and a high prevalence of inadequate vitamin D intakes from dietary sources was noted in our recent analysis (59), it may be important for future studies to estimate usual total vitamin D intakes, from both diet and dietary supplement sources, to better understand the proportion of B-24 children who do not meet recommended intakes.

Nutritional status of children aged <2 y: blood-based tests

NHANES has a long history of collecting venous blood samples in young children (aged $\geq$1 y) to assess their nutrient and health status and environmental exposures. Specimen collection (blood, urine, hair, etc.) and laboratory tests conducted during specific NHANES cycles are determined by prevailing public health priorities, feasibility, respondent burden, and funding. Nutrients of public health concern identified based on NHANES data concerning laboratory tests among US infants and toddlers include iron, lead, and vitamin D.

Iron.

Iron deficiency based on blood tests of iron status, continues to be the most common nutritional deficiency globally, with infants and children being at greatest risk because of rapid growth (67, 68). Iron deficiency and iron deficiency anemia are associated with several adverse effects including behavioral and cognitive delays (69), impaired physical development and immune function, higher risk of infections, as well as infant mortality (67, 70).

NHANES has employed a range of blood-based methods including hematologic and biochemical indicators to assess iron status over the years (71). Monitoring the iron status of the US population, including children aged $\geq$1 y, has been a key component of NHANES since its inception in 1971. The battery of iron status tests has included a complete blood count, serum ferritin, transferrin saturation, and free erythrocyte protoporphyrin as well as serum transferrin receptors since 2003 (71, 72). Total body iron stores have been estimated based on the ratio of serum transferrin receptor to serum ferritin (73). Limitations in evaluating the iron status of young children aged <2 y with NHANES data include small sample sizes, and potential confounding because of inflammation and infection. Lack of data on biomarkers of subclinical inflammation such as CRP in young children in certain cycles of NHANES does not allow adjustment for inflammation for those cycles. CRP was measured in NHANES in 2003–2006 and 2015–2016 (28). In future cycles of NHANES there is interest in determination of CRP concentrations in children aged <2 y as well, and this would depend on funding and operational considerations.

The prevalence of iron deficiency has been evaluated in young children (aged 1–2 y) in the past, based on multiple tests of iron status indicative of iron deficiency (68) and in the last decade based on estimated total body iron stores (72, 74). Body iron stores <0 mg/kg represent tissue iron deficiency (73, 75). Gupta et al. (74) estimated the prevalence of iron deficiency among toddlers as 15.1% (body iron <0 mg/kg) based on NHANES data from 2003 to 2010. Iron deficiency prevalence did not differ among younger (12–17 mo) and older toddlers (18–23 mo) (74).

Race-ethnic differences in iron status were reported in older children (aged 1–3 y) in the United States, with Hispanic children having 2.1 times increased odds of iron deficiency (based on 2 of 3 abnormal iron indicators model) compared to NHW counterparts (70). However, a recent analysis of 8 y of NHANES data (2003–2010) did not find any association between race-ethnicity and iron deficiency among toddlers based on body iron stores (74).

Because NHANES collects data on representative samples of all major demographic groups in the United States in each 2-y cycle, time trends can be evaluated. Significant decline in the prevalence of iron deficiency based on total body iron stores was noted from 18.4% in 2005–2006 compared to 8.8% in 2009–2010 (74). HP2020 objectives track iron deficiency among young children aged 1–2 y based on body iron stores (<0 mg/kg) using NHANES data; in 2005–2008 the baseline estimate was 15.9% compared to the national target of 14.3% (76). Preliminary findings based on 2009–2010 NHANES data by Gupta et al. suggest that progress is being made towards this objective.

Lead.

Lead exposure among infants and toddlers is an important public health concern as it is associated with adverse neurological effects including intellectual and behavioral deficits (77). There is no safe blood lead level (BLL) recognized for infants or toddlers (29, 32).

NHANES data have been instrumental in monitoring BLL in young children since the mid-1970s. Data from 1976 to 1980 showed that an estimated 88% of 1–5-y-olds had BLLs ≥10 μg/dL (considered by the CDC as the level of concern) (78). This proportion fell to 0.8% during 2007–2010 (77).

The CDC have accepted use of the 97.5th percentile of blood lead as a population-based reference value to identify hazardous lead levels since 2012 (79). Using a BLL ≥5 μg/dL (97.5th percentile), 8.6% of young children (aged 1–5 y) had high BLLs during 1999–2002 compared to 2.6% in 2007–2010 (77). Tsoi et al. (80) showed that 2% and 0.5% of 1–5-y-olds had a BLL ≥5 μg/dL in 2011–2012 and 2013–2014, respectively. A parallel decline in mean BLL over this time period was also noted (77, 80–83). Mean BLL among 1–5-y-olds was <1 μg/dL based on NHANES data 2011–2014 (82), underscoring the success of policies concerning reducing lead exposure (paints, gasoline).

Race-ethnicity and income disparities in BLLs have been noted among young children (aged 1–5 y). Specifically, NHB children and children from low-income households had greater BLLs compared to their corresponding counterparts (i.e., NHW, and higher-income households, respectively) (81, 82). Ahrens et al. (84) examined the association between BLL and federal housing assistance among children aged 1–5 y during 2005–2012 with family income-to-poverty ratios <200%. Children living in the US Department of Housing and Urban Development-assisted housing had a significantly lower mean BLL (1.44 μg/dL) than comparable children who did not receive housing assistance (1.79 μg/dL). The proportion of children with an elevated BLL (≥3 μg/dL) was also higher among children who did not (compared with those who did) receive housing assistance.

Monitoring of blood lead concentrations in young children using over 40 y of national surveillance data from NHANES has allowed for the tracking of BLLs in young children and monitoring progress on the HP2020 objectives (76). The HP2020 objective tracking mean BLL in 1–5-y-old children has been met.

Vitamin D.

Vitamin D is involved in several biological functions including bone health, maintaining optimal immune response, and decreasing the risk of many chronic illnesses (85). Its role in childhood is particularly evident for healthy bone development and preventing rickets (33, 85).

NHANES has collected data on vitamin D biomarkers from 1988 onwards. Serum 25-hydroxyvitamin D [25(OH)D] is the biomarker of choice to assess vitamin D status because it integrates dietary vitamin D intake (from foods and supplements) with endogenously produced cholecalciferol (i.e., vitamin D3) from 7-dehydrocholesterol by the action of solar UV-B radiation (86). Serum 25(OH)D concentrations <30 and <50 nmol/L, are indicative of risk of vitamin D deficiency and insufficiency, respectively (87). Based on NHANES data, the risk of vitamin D deficiency was small in young children; 0.7% of 1–11-y-olds had 25(OH)D <30 nmol/L (88). About 10% of children (aged 1–11 y) had serum 25(OH)D <50 nmol/L, indicative of vitamin D insufficiency. Importantly, precise estimates on the prevalence of risk of vitamin D insufficiency or deficiency specifically for children aged <2 y have not been reported. In addition, although time trends in vitamin D status have been examined for the US population aged ≥12 y from 1988 to 2010 (86), trends have not been reported specifically for younger children.

Disparities among racial and ethnic groups have been described for young children aged 1–5 y based on 4 y of NHANES data (2007–2010) (88). All pairwise race-ethnic comparisons among 1–5-y-olds were significant, with NHB having the lowest, Hispanics having intermediate, and NHW children having the highest serum total vitamin D concentrations (88).

Anthropometric measurements

NHANES has a long history in collecting anthropometric data since its inception in 1971. Continuous NHANES has collected data on body weight, recumbent length, and various circumferences (head, upper-arm) using standardized methods by trained staff at the MEC exam. Triceps and subscapular skinfold thickness (≥2 mo) were measured in certain NHANES cycles (1999–2010) (1).

Trends in anthropometric measures among US children aged 6–23 mo were recently described (89). In 2011–2014, the prevalences of low and high length-for-age were 3.3% and 3.7%, respectively, based on WHO 2006 growth standards. Corresponding estimates for weight-for-age were 0.6% and 7.0%; and for weight-for-length 1.0% and 7.7%. These authors also examined trends in anthropometric measures over time. A decrease in high length-for-age was the only significant trend noted (5.5% in 1976–1980 compared with 3.7% in 2011–2014). Trends in relative weight gain between birth and survey participation did not differ over time, although certain race-Hispanic origin-related trends were observed. Weight gain between birth and survey participation increased among NHB children in 2011–2014 compared with 1988–1994, while no change was noted among other groups (89).

NHANES data on diverse components allow researchers to examine associations across various domains. Kachurak et al. (52) described the associations of snacking frequency with weight status among children aged 1–5 y based on 2005–2014 data. Toddlers who snacked more frequently than AAP recommendations (2–3 snacks/d) had greater odds of being overweight or having obesity. Snacking behavior was positively associated with weight status, and this association was stronger for children aged <2 y.

Strengths and limitations

NHANES data are critical in nutrition monitoring of US children including those aged <2 y. The NHANES program offers publically available, comprehensive, multidisciplinary data that can be used for describing large group-level estimates of feeding practices, dietary intakes, and nutritional status based on blood-based tests and anthropometric measurements, as well as examining associations between various survey components. Because standardized methods and protocols are used over time, NHANES data provide a critical resource for evaluating trends over time among the US population. The ability to describe such race-ethnic patterns at a national level is an additional strength of NHANES; although pooling of data over cycles may be needed for sufficient sample size.

NHANES data have certain limitations. Although data have been collected in continuous NHANES for certain core components such as dietary recall, questionnaires (e.g., ECQ, DBQ, FSQ), blood collection for toddlers, and anthropometric measurements, specific questions have changed or been dropped over time in various NHANES cycles. Similarly, the biochemical analytes determined across different NHANES cycles can also change considering funding, feasibility, and emerging public health concerns. This can make the evaluation of trends over time challenging. Furthermore, certain NHANES data (e.g., dietary intake, questionnaire data) are reported by proxies (usually a parent for B-24 children); such data may be subject to bias (recall bias, social desirability bias). The dietary databases are updated periodically to reflect current market supply and to capture the majority of foods, beverages, and supplements reported in each NHANES cycle; however, this may not fully capture all items nor all brands. Importantly, because the sample size of B-24 children per 2 y NHANES cycle is small, data need to be pooled over several NHANES cycles depending on the NHANES component of interest and need for stratified analyses. This review focused on studies published in the last 5 y (2013–2018) based on NHANES data; however, the data used in those studies may have included older survey cycles. Given the cross-sectional nature of the survey, NHANES data can be used to describe associations and not establish causality.

Conclusions

The diverse, comprehensive data relevant to nutrition monitoring of B-24 children in the continuous NHANES since 1999 are publicly available to researchers on the NHANES website. Several papers have been published in the last 5 y describing infant feeding practices, dietary intakes (foods, beverages, and supplements), nutrient intake, and nutritional status based on anthropometric measurements as well as blood-based tests for children aged <2 y. Various age and race-ethnic patterns were noted for infant feeding practices, dietary intakes, and biomarkers of nutritional status.

NHANES data may be analyzed further to examine additional factors related to B-24 monitoring including trends over time in food and beverage intake, differences in dietary intakes among participants compared with nonparticipants in various federal nutrition assistance programs, and to inform various guidelines related to infant and toddler nutrition and health. Data from several NHANES cycles may need to be pooled to explore race-ethnic differences and feeding patterns for more precise smaller age groups during infancy. Availability of additional questionnaire data from 2019 to 2020 will provide further information to researchers to describe infant feeding practices in the United States.

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