IDENTIFYING NUTRITION RISK AMONG U.S. INFANTS AND CHILDREN WITH LIMITED FINANCIAL RESOURCES

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To Mom, Dad, and my little sister, Suhnyoung

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ABSTRACT

Inadequate nutrition in childhood can inhibit optimal growth and development, and is also associated with increased risk of chronic diseases later in life. Children living in households with limited financial resources may face a number of challenges to meet nutrient needs through unhealthy eating patterns, which may lead to health inequalities throughout the life-course. Therefore, improving low-income children's diet would be an effective strategy for their health promotion and disease prevention, and potentially for narrowing health inequalities. The essential step for an efficient intervention would be to identify the unique nutrition risk that low-income children have. Therefore, the overarching aim of research in this dissertation was to identify nutrition risk of U.S. infants and children with low income or food insecurity, or participating in federal nutrition assistance programs using data from nationally representative surveys. An additional aim was to assess whether the inclusion of micronutrient intake from dietary supplements impacts micronutrient inadequacy in children.

For low-income infants and young children up to the age of 5 years, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) provides tailored food packages to improve dietary intake that may be inadequate due to economic constraints. Therefore, it is expected that nutrient intake of WIC participants would be more like those of higher-income nonparticipants and higher than those of lower-income nonparticipants who are likely to be eligible for WIC. The results from the Feeding Infants and Toddlers Study 2016 data analysis supported the hypothesis for several nutrients of concern, although WIC participants were more likely to exceed the recommended limits for sodium and added sugars compared to higher-income nonparticipants. However, higher-income nonparticipants were more likely to use dietary supplements than both WIC participants and lower-income nonparticipants, which can impact total nutrient intake (i.e., nutrient intake from all sources).

Systematic differences in dietary supplement use by income and WIC participation were also observed in a nationally representative sample of children aged 18 years and younger from the 2011-2014 National Health and Nutrition Examination Survey (NHANES). Dietary supplement use was lower among children in low-income families compared to those in higher-income families. Among children in low-income families, those participating in WIC were less likely to use dietary supplements compared to nonparticipants. In addition, food insecurity and

the Supplemental Nutrition Assistance Program (SNAP) participation were associated with lower use of dietary supplements. Overall, one-third of children used any dietary supplements, mostly multivitamin-minerals, with primary motivations for use as "improve" or "maintain" health.

The following analysis of the 2011-2014 NHANES data showed that the inclusion of dietary supplements in nutrient intake assessments may lead to wider disparities in dietary intake by food security. This study also demonstrated the dose-response relationship between food security status and mean adequacy ratio, a summary measure of micronutrient adequacy. The mean adequacy ratio, inclusive of dietary supplements, was the highest in high food-security group (mean of 0.77), lower in marginal and low food security group (mean of 0.74), and the lowest in very low food security group (mean of 0.66), based on classification by food security among household children. However, the mean adequacy ratio does not reflect the usual intake (i.e., a long-term, habitual intake).

Therefore, another analysis of the 2011-2016 NHANES data estimated total usual nutrient intake of U.S. children 18 years and younger by food security status, using the National Cancer Institute method that adjusts for random error by statistical modeling. The results suggested that food insecurity was associated with higher risks of inadequate intakes for some nutrients, such as vitamins D and E and magnesium among boys and girls and vitamin A and calcium among girls only. Poor overall dietary quality and excessive sodium intake were of concern, regardless of food security status.

Collectively, the results from the studies in this dissertation add value to the evidence base about the adverse association of low income level and food insecurity status with dietary intake and extend the finding to include nutrient intakes from dietary supplements, which widens the disparity in nutrition risk. These findings highlight a need for interventions to reduce nutrient inadequacies and improve dietary quality among children across all socioeconomic levels, but especially among those with low income or food insecurity.

CHAPTER 1 . LITERATURE REVIEW: THE IMPACT OF ECONOMIC STATUS ON CHILDREN'S DIETARY INTAKE

1.1. Introduction

Early life nutrition sets the foundation for life-long health and disease. Inadequate nutrition in childhood can inhibit optimal growth and development, and is also associated with increased risk of chronic diseases later in life (1, 2). In addition, food preferences and dietary behaviors are established in childhood (3, 4). Unfortunately, children in low-income households may be at a greater risk of inadequate nutrition and poor health due to a lack of resources (5, 6). Children in low-income households have a higher prevalence of childhood obesity (7, 8) and also have a higher risk of adulthood obesity and cardiovascular diseases (9-11). These adverse health outcomes associated with childhood poverty may lead to health inequalities through the life-course.

Diet is a modifiable risk factor for many health outcomes. Therefore, the diet in low resource settings may be an effective strategy for their health promotion and disease prevention, and potentially for narrowing health inequalities. This concept has served as a rationale for many federal nutrition assistance programs and smaller-scale interventions that aim to improve food security and dietary quality among low-income children. The first step for an effective and efficient intervention would be to identify disadvantaged children at high nutritional risk. Several indicators of economic status have been used to identify those at high nutritional risk, but there is little consensus on the optimal indicator. In addition, although economic gradients in U.S. adults' diets are well established (5, 12, 13), those in U.S. children's diets are not well summarized. Therefore, the aim of this study is to review the literature on the relationships between various poverty indicators and nutrition status among U.S. children up to the age of 18 y. In this review, we use the term poverty, broadly as economic disadvantage, as the lack of sufficient amount of money or material possessions.

1.2. Poverty indicators in the United States

The official poverty definition by the U.S. Census Bureau uses the poverty thresholds that vary by the family size, composition, and age of the members, and is updated annually to account for inflation, but not geographical variation within the contiguous U.S. (14). If a family's annual income is lower than the poverty threshold, that family and all the members are considered to be in poverty. The family's annual income includes all monetary income before taxes except capital gains or noncash benefits. In 2018, 11.8% of the U.S. population and 16.2% of US children were living in households below the poverty threshold (14).

The poverty guideline, a simplified version of the poverty threshold, is issued by the Department of Health and Human Services each year for administrative purposes, such as determining financial eligibility for federal assistance programs (15). The ratio of annual household income to the poverty guidelines, widely referred to as family income-to-poverty ratio (PIR), is used to identify financial eligibility for the Supplemental Nutrition Assistance Program (SNAP) and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). The PIR is intrinsically related to the household's food affordability because the poverty thresholds were calculated by multiplying the minimum food cost by three to account for other family expenses. However, the utility of PIR to identify material hardship, such as hunger, has been questioned (16, 17).

Food insecurity was developed as a more direct measure of food-related hardship in the U.S. (18) Food insecurity means having "difficulty at some time during the year to providing enough food for all of" household members because of a lack of resources (19). Food insecurity is strongly associated with lower incomes, but not synonymous (20). Some studies suggested that assets are protective against food insecurity and income volatility increases food insecurity (21, 22). The U.S. Food Security Survey Module is a validated measure of food security during the 12 month period (23). It includes 18 questions to assess the level of food-insecure conditions, 10 questions for all households, and 8 additional questions specific to children under the age of 18 years. Based on the number of food-insecure conditions, each household is classified into one of the four categories: high food security (no indications of food access problems), marginal food security (anxiety over food insufficiency), low food security (reduced quality or variety of diet), and very low food security (disrupted eating patterns and reduced food intake). High and marginal food security can be combined to classify food security, and low and very low food security can be combined to classify food insecurity (24). In 2018, 13.9% of U.S. households with children under age 18 y experienced food insecurity; in 6.8% of these households, only adults were food insecure, but in 7.1%, both adults and children were food insecure (19). Moreover, in 0.6% of households with children (220,000 households), children were at very low food security.

Federal food and nutrition assistance program participation can also be used as a tool to identify low-income children who are in need of food. As the federal assistance programs target groups based on income, they set income eligibility criteria ranging from PIR<130% for SNAP to PIR<185% for WIC. However, In addition, it is the choice of the eligible family to participate in these programs, so participation status may be correlated with many other predictors of nutrition risk, such as the severity of food insecurity. For example, food insecurity increased in the 7 to 8 months prior to SNAP entry, supporting the self-selection by households entering SNAP at a time when they are more in need of foods (25). Therefore, program participation may reflect material hardship more directly than lower-income status. For example, a study showed that, among food-insecure adults, those who received both SNAP and emergency food assistance had the poorest health in terms of self-rated health, functional limitations, depressive symptoms, obesity, arthritis, diabetes, and hypertension; while those who did not receive any assistance had the best health across all listed dimensions (26). Nonetheless, federal food and nutrition assistance programs can play a significant role in improving participants' diets. Therefore, the relationship between food assistance program participation and diet should be interpreted with these caveats in mind.

1.3. Relationship of poverty indicators with nutrition status among U.S. children

Nutrition status can be assessed from anthropometry, clinical assessment, self-reported dietary intake, and biomarkers. Self-reported dietary intake data can be used to assess nutrient inadequacy or dietary quality, the concept involving both quality and variety of the entire diet. Dietary quality can be measured as the adherence to the recommended intake targets for food groups and nutrients. For example, a Healthy Eating Index (HEI) score measures compliance with the Dietary Guidelines for Americans (27). However, self-reported dietary intakes are prone to error associated with the day-to-day variation, memory, difficulty in quantifying the amount and portion sizes, and personal characteristics (28). Biomarkers may complement dietary assessment and provide relatively more objective information than self-reported dietary intakes, but validated and cost-efficient biomarkers are limited in the nutrition context (29). Findings from studies that compared U.S. children's nutrition status by poverty indicators, including PIR, food insecurity, or federal nutrition assistance program participation, are summarized in this section.

1.3.1. Family income-to-poverty ratio

The PIR is one of the most widely used income measures in the U.S., partly because it is included in national surveys such as the National Health and Nutrition Examination Survey (NHANES). An analysis of the NHANES 2003-2004 data showed that the HEI-2005 scores were generally low among Americans, but children (2-17 y) generally had a higher score than adults (30). By income, there was no apparent pattern among children: children in the lowest income group (PIR<130%) had a higher HEI-2005 score than the lower-middle-income group (PIR 130-299%) and had a similar score with both the higher-middle-income group (PIR 300-499%) and the highest income group (PIR≥500%). With regard to HEI components for food groups, no differences were noted for whole grains, milk, meat and beans, and saturated fat; higher scores for total vegetables, dark green and orange vegetables and legumes, and sodium in the lowest income group were observed when compared to the highest income group. These findings are supported by Kirkpatrick et al. (31) that assessed usual food consumption in comparison to the 2005 Dietary Guidelines for Americans using the NHANES 2001-2004 data. There was no clear pattern among children (2-18 y): the low-income group (PIR≤130%) were more likely to meet recommendations for total vegetables, dry beans and peas, starchy vegetables, meat and beans, whereas they were less likely to meet minimum recommendations for other vegetables, milk, and oils, compared to the high-income group (PIR≥186%). The middle-income group (PIR 131-185%) showed very similar patterns with the low-income group. A recent trend study using the NHANES 1999-2012 data (32) also did not find economic gradient in the HEI-2010 scores; however, those in the high-income group (PIR>350%) achieved greater improvement over the 14-y period compared to the low- (PIR≤130%) and middle- (PIR 131-350%) income groups.

Some researchers focused on income differences in specific food intake. An analysis of the NHANES 2007-2010 data (33) examined whole fruit and 100% fruit juice consumption among children 4-19 y. The results suggested that whole fruit intake was greater in the high-income group (PIR≥350%) than either the low- (PIR<130%) or middle- (PIR 130-349%) income group, whereas 100% fruit juice intake was higher in the low-income group compared to the high-income group. Another study on the trend of children's fruit and vegetable intake (34) showed that, when stratified by income, mean total fruit intake of only the middle-income group (PIR 130-349%) increased significantly from 2003 to 2010. Across all income groups, whole fruit intake increased, whereas total vegetable intake did not change from 2003 to 2010.

Energy balance is a major concern given the U.S. obesity epidemic. Considering the higher obesity rate among children in low-income households (7), energy intake is expected to be higher in low-income children. A trend analysis of the 1971-2008 NHANES data found that U.S. children's energy intake increased only in the low-income group (PIR<130%), but not in the middle- (PIR 130-349%) and high- (PIR≥350%) income groups (35). As a result, during the period of 2003-2008, the inverse association between household income and energy intake was significant among 2-to-5-y-olds, which was not found in earlier periods. At the same time, the positive association between household income and energy intake among 12-to-19-y-olds found in 1971-1974 and 1976-1980 disappeared in the later surveys. Concerns for excessive consumption of added sugars also exist with regard to obesity (36). However, added sugars intakes among children (6-19 y) from the NHANES 2003-2010 were not significantly different by income when categorized into four groups: PIR<100%, PIR 100-199%, PIR 200-399%, and PIR≥400% (37). The percent of total calories from added sugars was also not different by income either for boys or girls (2-19 y) from the NHANES 2005-2008 (38). Lastly, dietary fiber intake didn't differ by income in children (2-19 y) who participated in the NHANES 2009-2010 (39).

A handful of studies documented the income gradient in micronutrient intakes. Among children aged 2-19 y in the NHANES 2003-2006, dietary vitamin C intake was higher in low-income (PIR<130%) children; but, intakes of vitamin A, vitamin B groups, vitamin E, carotenoids, and total and saturated fat were not different by income, after adjusting for covariates (40). A study on vitamin D among U.S. children aged 1-18 y from the NHANES 2007-2010 included vitamin D intake from dietary supplements as well as from food and beverages (41). The high- and low-income group (PIR>185% and PIR≤131%, respectively) had similar total vitamin D intakes, and the middle-income group (PIR 131.1-185%) had the lowest intake. The same pattern was found for either dietary or supplemental vitamin D intake. In general, vitamin and mineral supplement use is lower in poor children (42). Dietary supplements can contribute substantially to total nutrient intakes (i.e., nutrient intake from all sources) among children without adding calories, so further studies on disparities in total nutrient intake are warranted.

A few studies reported on difference in nutritional biomarkers by PIR. When adults and children were combined, mean selenium levels increased by increasing income levels, suggesting that income may be associated with nutritional biomarker levels (43). The NHANES 2003-2006 collected and released information on the largest number of nutritional biomarkers. Using these data, Kant and Graubard (2012) examined the income differentials in serum concentrations of water-soluble vitamins, fat-soluble vitamins and carotenoids, and serum lipids among U.S. children 2-19y (39). There were few statistically significant differences in biomarkers, except for increasing serum vitamin D concentrations with increasing income levels. Race and Hispanic origin were more predictive of nutritional biomarkers than PIR among US children.

No clear pattern by PIR was noted in children's diet quality. Income alone may not well predict children's nutritional risk as implied from previous studies showing that low income is not enough to measure economic disadvantage, especially among children (44). Interestingly, the diets of children living in households with middle income did not differ from lower-income children's diets. However, different PIR categories have been used in studies: PIR<100% (equivalent to poverty defined by the U.S. Census Bureau), PIR<130% (income eligibility criteria for SNAP), PIR<185% (income eligibility criteria for WIC), and PIR>350% (considered affluent). Future research comparing different PIR categories or harmonizing the PIR data for comparison purposes would provide useful insight into dietary disparities.

1.3.2. Food insecurity

A recent review has summarized age-specific evidence on the relationship between food security status and dietary intake in U.S. children (45). This review concluded that there is a strong, consistent, and "dose-response-type" association of lower vegetable consumption with food insecurity among 1-to 5-year-olds; and strong and consistent evidence of higher added sugars intake among 6-to 11-year-olds. Adolescents aged 12-19 years may be impacted the most by food insecurity, even though much less studied. A Canadian study supports these findings in which poorer dietary intakes in the food insecure were evident among adolescents, but less evident among younger children (46).

Compared to adults, food security is less consistently associated with children's dietary quality (47); many associations between food insecurity and dietary intake among children were not significant. Nonetheless, important insights can be gained from the studies reporting adverse association of food insecurity and dietary quality. Especially, at least four studies reported associations between food insecurity and lower fruit intake (48-51). In addition, food-insecure boys 8-11 y were more likely to fail to meet recommended levels of dairy foods and calcium intake, and had lower bone mineral content (52). With regard to iron, food-insecure toddlers < 36 months (53) and adolescents 12-15 y (54) were more likely to have iron deficiency anemia. Children 2-15 y with very low food security consumed less whole grains and more added sugars compared to children with food security (55).

The inconsistent findings among children may largely be attributable to three factors. First, children in the food-insecure household may be protected from reduced food intake by their parents or caregivers (56). Second, parent reports of children's food security may bias the results. To address the bias of parental reports, Fram et al. (57) measured child food insecurity experience by asking directly to children about their cognitive, emotional, and physical awareness of food insecurity. The results suggest that children's experience of food insecurity was associated with a higher intake of energy, fat, sugars, and fiber. Food insecurity experience was also associated with lower HEI-2005 score for total vegetables, but not with other HEI component scores. Lastly, considerable inconsistencies in study designs were noted, including food security measures and classifications, dietary assessments, covariates included in the model, and sample characteristics, complicating synthesis of the available data.

In summary, child food security may lead to a lower-quality diet in terms of lower fruit and vegetable consumption and possibly higher added sugars intake, but not all food components.

1.3.3. Federal nutrition assistance program participation

The WIC is a federal nutrition assistance program that specifically targets pregnant and post-partum women, infants, and children up to age 5 y who are in low-income households with PIR below 185% and at nutritional risk. WIC is also unique for providing free food packages tailored to the needs of specific age or lifestage groups. Ponza et al. (58) described food and nutrient intakes of infants and toddlers 4-24 months based on 2002 Feeding Infants and Toddlers Study. Both WIC participants and nonparticipants had nutritionally adequate diet in general, but many did not consume any fruit or vegetable on a given day. Between WIC participants and nonparticipants, the percentage of dairy and vegetable consumption was similar; however, WIC toddlers 12-23.9 months were less likely to consume any fruit, and more likely to consume any dessert, sweet food, or sweetened beverage compared to nonparticipants. The Feeding Infants and Toddlers Study 2008 data analysis suggested that this trend persisted over time for WIC toddlers and non-WIC toddlers (59). More recent NHANES 2005-2010 analysis supported the finding about sweetened beverage. WIC 2-to-4-y-olds drank more fruit juice and sugar-sweetened beverages than either low-income nonparticipants or higher-income nonparticipants (60). These FITS publications didn't adjust for covariates, thus any reported associations may reflect underlying factors related to material hardship such as deteriorated food security (25).

SNAP is the largest federal nutrition assistance program. The goal of SNAP is to reduce food insecurity and improve health of low-income individuals and families (PIR<130%) by providing cash benefits to purchase foods (5). SNAP participation has been associated with improved food security both at the household and at child levels (61, 62). However, SNAP participants had a lower quality diet compared to income-eligible nonparticipants, supporting that SNAP participation may be a marker of vulnerability to inadequate nutrition. For example, when no covariates were controlled for NHANES 2007-2010 data, overall dietary quality, measured by HEI-2005, was lower in SNAP children (1-18 y) than in income-eligible counterparts (63). In a different report, when multiple covariates were adjusted for, SNAP participating adolescents (12-19 y) had lower dietary quality, measured by Alternate HEI-2010 scores, than income-eligible nonparticipants in NHANES 2003-2010 (64). Another NHANES 1999-2008 analysis (65) suggested that SNAP participants (4-19 y) consumed more sugar-sweetened beverages, high-fat dairy, and processed meats, and less nuts, seeds, and legumes, although there were no differences in HEI-2005 scores, energy and macronutrient intakes between SNAP participants and income-eligible nonparticipants. Previous research using NHANES 1999-2012 data (32) also found no significant difference in HEI-2010 scores between SNAP participating children (2-18 y) and income-eligible nonparticipants, while WIC participants had a significantly higher score than income-eligible counterparts.It should be noted that temporal differences pending on survey year did yield differences in diet quality; when analyzed separately for a two-year cycle, SNAP participants tended to have lower HEI-2010 scores compared to nonparticipants in 2007-2008 and 2011-2012.

The Supplemental Nutrition Assistance Program-Education (SNAP-Ed) is one of the efforts to promote nutrition in low-income population, including those eligible for SNAP, via education and community-directed interventions. SNAP-Ed is a much smaller program compared to SNAP in terms of the number of participants and the budget, but has the potential to exert broad and long-term effects on recipients' food security status and nutrition outcomes (66). Improving overall dietary quality and fruit and vegetable consumption has been a major focus of SNAP-Ed. Participants who attended at least two SNAP-Ed lessons had higher fruit and vegetable intake compared to those who attended no or one classes (67, 68); although, these studies relied on a limited number of survey questions asking frequency of daily fruit and vegetable consumption. However, more evidence of the benefit of SNAP-Ed is needed.

In summary, participation in federal nutrition assistance program participation has the potential to improve nutrition status of its beneficiaries. Especially, WIC participation has consistently been demonstrated to improve dietary intakes with the food packages provided (69). However, SNAP participants tend to have lower diet quality compared to income-eligible nonparticipants; therefore, SNAP participation has the potential to identify disadvantaged children with nutritional risk. It is notable that low-income chidren, even those participating in WIC or SNAP were more likely to drink higher amount of sugar-sweeteneed beverages, demonstrating an area for future interventions.

1.3.4. Studies directly comparing predictive power of different poverty indicators

As identified in this review, various metrics exist to characterize nutrition risk relative to income and resources at the household and at the individual level. However, few studies have compared different poverty indicators with regard to nutritional outcomes. Bhattacharya et al. (2004) examined the association between poverty and nutrition status across all age groups, using two poverty indicators: poverty (PIR<100%) and food insecurity (70). The results suggested that poverty independently predicts poor nutritional outcomes among preschoolers and adults, and food insecurity independently predicts poor nutritional outcomes among adolescents and adults. When poverty is controlled, food insecurity had little predictive power among children. However, analyses adjusting for income demonstrated that food-insecure children are more likely to have poorer quality diet and adverse behavioral and academic outcomes (57, 71, 72), countering the findings from Bhattacharya et al. (70).

While comparisons of economic indicators are sparse in children, several other studies have examined their relationships with dietary quality among adults in order to determine predictive power of each socioeconomic factor in various regions of the world. A Luxemburg study of healthy and non-institutionalized adults examined demographic and socioeconomic factors with healthy food choices, and showed that living below the poverty threshold was associated with higher energy-density diet (73). An Australia study examined the association of education, occupation, and income with food purchasing through an interview with the adult who's responsible for food shopping for the household. The results demonstrated that income has a strong association with food choice, but that education and occupation also had independent associations with food choice (74). The findings imply that each socioeconomic indicator may identify a unique aspect of how socioeconomic position affects diet. In the U.S., race/ethnicity has been more predictive of nutrition status than PIR (39, 75). Future studies comparing different poverty indicators among U.S. children are warranted.

1.3.5. Suggested pathway through which poverty impacts diet

Several potential pathways exist by which socioeconomic status may influence diet and diet-related behaviors. Darmon and Drewnowski (5) have summarized evidence for the association between socioeconomic status and dietary quality, the authors concluded that there may be a causal relationship and suggested several potential pathways. The first pathway is higher monetary and time cost of nutritious foods. A cross-sectional study of 1,266 U.S. adults suggested that diet cost mediates the pathway between income and dietary quality (76). The second is limited access to healthy foods. Another review also concluded that residents of low-income and minority neighborhoods were more likely to have limited access to supermarkets and healthy foods and have more availability of fast-food restaurants and energy-dense foods (77). There was also moderate evidence of the association between food environment and dietary intake among children under the age of 18 y (78). In addition, culture and nutritional knowledge were also discussed as a possible link.

Laraia et al. (79) focused on psychological and biobehavioral challenges that low-income families may face in addition to economic constraints. The authors proposed that living in poverty, especially when accompanied by uncertainty with employment, housing, and food, may activate biobehavioral mechanisms such, as high stress level, poor sleep, and diminished cognitive capacity, that influence food choice and consumption. Maternal stressors, including maternal depression,can exacerbate the negative impact of food insecurity on child diet and health because parental presence and food resource managmenet skills may promote healthy eating in young children (80, 81).

1.4. Research needs

This review was narrative in approach. Primary search was performed in the PubMed database (www.ncbi.nlm.nih.gov/pubmed) with the following search terms: “poverty,” “income,” “food assistance,” “diet, food, and nutrition,” “child,” “adolescent,” “United States.” Secondary search of reference lists of identified articles was conducted. Both original research work and review articles were included.

This review highlights several important research gaps that should be addressed in future studies to help elucidate the impact of poverty on children’s diets. First, future studies comparing different poverty indicators among U.S. children would enable exploring the optimal indicator of economic status with regard to nutritional outcomes. Next, how we categorize our children by family income needs to be studied in depth with separation of the household and the individual child. The current PIR categories may not well identify children who are experiencing an urgent need for food, even though these children are expected to be at greater nutrition risk. Children who are not eligible for federal assistance programs by income status but still may be at nutrition risk are rarely studied. Similar issues exist for measuring food security; the thresholds for the U.S. Food Security Survey Module Child Food Security Scale that are widely used to classify ranges of food security have not been validated (82).

Low-income children may experience unique challenges to healthy eating. Pathways through which economic disadvantage impacts diet and health outcomes need elucidation. At the same time, what protects children’s diets from disadvantage should be further investigated. Evidence from longitudinal studies would be critical to determine causal mechanisms. Another identified need is how existing federal nutirition assistance programs may mediate the nutritional risk with regard to family income. As designed, such programs are targeted to reduce nutritional risk among lower resource populations, but little is known about how participation is causally related to the the diet and nutritional status.

Future studies should include nutrient intakes from dietary supplements when assessing dietary exposures. The use of dietary supplements is pervasive in the U.S., with a third of children using any supplements and children in higher-income households are more likely to use dietary supplements (83). Dietary supplements can provide very high amount of nutrients without being limited by energy intake. Therefore, not including nutrient intakes from dietary supplements will result in substantial underestimation of total nutrient intake as well as the prevalence of inadequacy (84). However, few studies have assessed total nutrient intake, and no studies have estimated total usual nutrient intake, long-term or habitual intake from all sources, in relation to economic status among children. Moreover, federal nutrition assistance programs do not include dietary supplements, so future work is needed to examine total usual nutrient intakes by participation in the programs.

Lastly, the timing of exposure to poverty may matter. Life course research suggests that exposure to food insecurity at early ages (i.e., in the year before kindergarten and in second grade) was associated with a higher odds of asthma in third grade (85). Another study suggests that exposure to food insecurity in kindergarten was associated with a higher risk of underweight in eighth grade, while food insecurity was associated with a higher risk of overweight/obesity when examined cross-sectionally (86). More research to explore childhood windows of vulnerability would inform early intervention to prevent the later-life onset of chronic diseases.

1.5. Conclusion

Results from studies examining associations between economic status indicators and nutritional outcomes among U.S. children have been largely mixed, indicating null or adverse associations with specific nutrients or food groups. Notably, the income gradient in nutrition status was not always evident with PIR, the most widely used indicator in nutrition context to date. Food insecurity was associated with lower fruit and vegetable consumption and higher added sugars intake, but not with other food components. WIC participation was associated with improved dietary outcomes, while children in SNAP participating households tended to have a lower quality diet. This may indicate that low-income children are effectively shielded from limited food intake by their parents or federal food assistance program, especially WIC. Thus, PIR alone may not effectively identify disadvantaged children at high nutritional risk. Whether food insecurity or SNAP participation can add predictive power should be further determined. Further research needs include comparing different indicators of economic status with regard to nutritional outcomes; and examining total nutrient intakes and biomarkers.

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CHAPTER 2 . USUAL NUTRIENT INTAKES FROM THE DIETS OF U.S. CHILDREN BY WIC PARTICIPATION AND INCOME

Jun S, Catellier DJ, Eldridge AL, Dwyer JT, Eicher-Miller HA, and Bailey RL. Usual nutrient intakes from the diets of US children by WIC participation and income: findings from the Feeding Infants and Toddlers Study (FITS) 2016. The Journal of Nutrition 2018; 148(9S): 1567S-1574S. doi: 10.1093/jn/nxy059.

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2.1. Abstract

Background: A recent report of the National Academies of Sciences, Engineering, and Medicine (NASEM) outlined priority nutrients for infants and children participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC).

Objective: The objective of this study was to assess usual nutrient intakes from foods and beverages (not supplements) among US children aged <4 y by WIC participation status.

Methods: A national random sample of children aged <4 y (*n* = 3,235) from the Feeding Infants and Toddlers Study (FITS) 2016 was categorized by WIC participation status (participants, lower-income nonparticipants, or higher-income nonparticipants) and age (younger infants aged 0–5.9 mo, older infants aged 6–11.9 mo, toddlers aged 12–23.9 mo, or preschoolers aged 24–47.9 mo). All participants contributed one 24-h dietary recall, with a second recall from a representative subsample (*n* = 799). Usual intakes and compliance with federal dietary recommendations were estimated by using the National Cancer Institute method. Differences between WIC participants and either lower-income nonparticipants or higher-income nonparticipants were tested using t tests.

Results: The diets of infants (aged <12 mo) were nutritionally adequate in general. Older infants participating in WIC had higher compliance with iron and vitamin D guidelines than either group of nonparticipants and greater compliance with calcium, zinc, and potassium guidelines than higher-income nonparticipants. WIC toddlers had a higher risk of inadequate calcium and excessive sodium intakes than higher-income nonparticipants. Eight percent of WIC toddlers exceeded added sugar guidelines compared with either nonparticipant group (∼2%). WIC

toddlers and preschoolers had a lower risk of inadequate vitamin D intake than lower-income nonparticipants, but inadequacy was >75% across all subgroups. WIC preschoolers had higher compliance with saturated fat guidelines but lower compliance with sodium and added sugar guidelines than higher-income nonparticipants.

Conclusions: WIC participants had better intakes of iron (ages 6–23.9 mo), zinc and potassium (ages 6–11.9 mo), saturated fat (ages 24–47.9 mo), and vitamin D (all ages). Regardless of WIC participation status, most infants and children met the calcium and zinc guidelines, but large proportions had intakes not meeting the recommendations for iron (ages 6–11.9 mo), vitamin D, potassium, fiber, saturated fat, and sodium.

2.2. Introduction

Approximately 1 in 5 US children lives in poverty (1). Lower socioeconomic status increases the likelihood of suboptimal nutritional intakes (2–4). In 1975, US Congress stablished the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) as a federal program "to safeguard the health of low-income women, infants and young children." The reach of the WIC program is extensive, with ~1.9 million infants and 4.2 million young children age <5 y participating in fiscal year 2015 (5). On average, approximately half of all infants in the United States and more than one-quarter of children <5 y old participate in WIC (5).

WIC provides free food packages, nutrition education, and health care referrals to pregnant and postpartum women, infants, and young children age <5 y who are in low-income households and at nutritional risk. WIC food packages are tailored to supplement dietary intakes, specific to age group or life stage (i.e., pregnancy). In 2009, significant changes to the WIC food package were made for the first time since its implementation. The package was revised to align more fully with the 2005 Dietary Guidelines for Americans and the infant feeding practice guidelines of the American Academy of Pediatrics, as well as to address concerns about the high prevalence of childhood obesity (6, 7). The revised food packages include more fruits, vegetables, whole grains, and lower-fat milk, and less juice than previous packages (8). Dietary supplements are not included in the WIC food package.

Little information is available on the nutrient intakes of infants and young children participating in WIC after the 2009 changes in the WIC food package. The nation's population-based survey, NHANES, does not report dietary intake estimates of breastfed infants, and the sample size of young children indicating participation in WIC is limited (8). Moreover, to our knowledge, there are no recent large, comprehensive studies that have investigated the diets of WIC infants and toddlers. The Feeding Infants and Toddlers Study (FITS) 2016 provides detailed dietary information and WIC participation status on a national sample of children from birth to age 4 y (9, 10). The objective of this study was to assess usual dietary intakes from foods and beverages among US children age <4 y by WIC participation status (current participants, lower-income nonparticipants, and higher-income nonparticipants) with the use of the FITS 2016 data, with a special focus on priority nutrients identified by the National Academies of Sciences, Engineering, and Medicine (NASEM) (8).

2.3. Methods

2.3.1. FITS survey methods

The FITS 2016 is a nationwide, cross-sectional study in parents or caregivers of children, from birth up to the age of 4 y, living in the 50 United States and Washington, DC. Data were collected from 4 sampling frames designed to cover the US population, and the resulting sample was weighted and calibrated to the US 2014 Census divisions, accounting for child age, WIC status, race/ethnicity, and educational attainment of the parent or caregiver. The FITS 2016 followed 2 previous FITS surveys conducted in 2002 and 2008 (11, 12). Full details of the study methodology for FITS 2016 are available elsewhere (10).

Demographic characteristics, including sex and race/ethnicity, were assessed with the use of questionnaire data; dietary supplement use was assessed by using dietary recall interview data. The 24-h dietary recalls were collected by telephone by trained interviewers from the University of Minnesota’s Nutrition Coordinating Center with the use of the Nutrition Data System for Research (version 2015; University of Minnesota). A random subsample of 25% of the total sampled population underwent a second 24-h recall (n = 799), of whom 275 were children participating in the WIC program. For volume of breastmilk consumed via breastfeeding, not fed in a bottle, coding rules established for FITS 2008 were applied according to the age of the child and whether the child was exclusively or partially breastfed, as in previous FITS surveys (12–16). Briefly, exclusively breastfed younger infants aged 0–5.9 mo and older infants aged 6–11.9

mo were assigned breast-milk volumes of 780 and 600 mL/d, respectively. Partially breastfed younger and older infants were assigned breast-milk volumes by subtracting the amount of formula or other milks consumed from the breast-milk volume assigned for exclusive breastfeeding. Breastfed toddlers aged 12–17.9 mo and young children aged 18–47.9 mo were assigned breast-milk volumes of 89 mL/feeding occasion and 59 mL/feeding occasion, respectively. All study instruments were pilot tested before use and were available in English and Spanish. The final instruments were reviewed and approved by the institutional review boards of RTI International, the University of Minnesota Nutrition Coordinating Center, and the Docking Institute of Public Affairs, Fort Hays State University. Data were collected from June 2015 to May 2016.

Stratified random sampling with targeted oversampling in 0- to 17.9-mo-olds was used to achieve prespecified sample size targets for age and WIC participants (n = 1161) and nonparticipants (n = 2068). For analysis, the nonparticipant group was further divided into 2 subgroups: lower-income (and likely WIC eligible) nonparticipants (n = 641) and higher-income (and likely WIC ineligible) nonparticipants (n = 1427). Children aged <5 y are eligible for WIC if their family's income is <185% of the federal poverty guidelines (which depend on household size) and if they are at nutritional risk. However, because family income data were collected in ranges, the income eligibilities were estimated for those not participating in WIC on the basis of the reported income range, household size, and the WIC income eligibility cutoffs. Ages were categorized as young infants (0–5.9 mo), older infants (6–11.9 mo), toddlers (12–23.9 mo), and preschoolers (24–47.9 mo).

2.3.2. Statistical analysis

Means and usual intake distributions of energy, macronutrients, and selected micronutrients were computed with the use of the National Cancer Institute (NCI) method (17). The NCI method partitions out the within-person (day-to-day) component of variation in reported intakes when estimating the distributions of intakes, and therefore requires replicate measures on at least a representative subsample. With replicate measures from a representative subsample (∼25%), we were able to estimate usual intakes across all age groups. The covariates in the NCI method macros included the sequence and the day of the week on which the 24-h dietary recall was collected, dichotomized as weekend or weekday.

The nutrients of interest were selected on the basis of the priority nutrients identified by a 2017 NASEM report (8) and included iron, zinc, calcium, vitamin D, fiber, and potassium as nutrients to increase and sodium, saturated fat, and added sugar as nutrients to limit when federal dietary recommendations are available for specific age groups. We compared usual mean intakes and adherence to the appropriate DRI to assess the likelihood of nutrient inadequacy or excess following methods recommended by the Food and Nutrition Board of the Institutes of Medicine (18). For nutrients with an Estimated Average Requirement (EAR), the percentile of the usual intake distribution below the EAR was used to estimate the percentage of children in the population predicted to be “at risk for nutrient inadequacy.” For nutrients with an Adequate Intake (AI), the percentile exceeding the AI was used to estimate the percentage of children predicted to be “at low risk of inadequacy.” Sodium intakes in children aged ≥12 mo were compared with the Tolerable Upper Intake Level (UL), and the percentile of the intake distribution exceeding the UL was used to estimate the prevalence of excessive intake. For macronutrients, it is recommended that mean intakes should fall within the Acceptable Macronutrient Distribution Range, expressed as a percentage of total energy intake. For added sugars, the NASEM guidelines are to limit intake to <25% of total energy for children aged ≥12 mo. In addition, the 2015–2020 Dietary Guidelines for Americans recommend that saturated fat consumption should be <10% of total energy for those aged ≥24 mo (19). The percentages of children consuming added sugars and saturated fat at amounts above the recommendations were estimated. Only AIs are available for infants aged <6 mo and therefore they were not part of this analysis for DRI compliance.

All of the statistical analyses were performed on weighted data with the use of SAS software (version 9; SAS Institute, Inc.) and SAS-callable SUDAAN (version 9; RTI International). Differences in demographic characteristics and dietary supplement use were determined by using chi-square tests. Multiple *t* tests were used to compare mean intakes and compliance with DRIs between WIC participants and either lower-income or higher-income nonparticipants within age group. Significance was considered at $P < 0.05$ unless otherwise noted; a Bonferroni-corrected P value of 0.002 was used to compare mean intakes presented in Supplemental Tables 1–4.

2.4. Results

2.4.1. Demographic characteristics and dietary supplement use

WIC participation was higher in 0- to 11.9-mo-olds (∼40%) than in 12- to 23.9-mo-olds (34%) and 24- to 47.9-mo-olds (27%). A detailed description of the FITS 2016 sample characteristics by WIC participation and income is published elsewhere (20). Briefly, approximately half of WIC participants were in households also receiving Supplementary Nutrition Assistance Program (SNAP) benefits, which is significantly higher than nonparticipants in lower-income households (27%). Across all ages, WIC participants were less likely to be non-Hispanic white and to have caregivers with a college or higher educational attainment than were lower-income and higher-income nonparticipants. WIC and lower-income non-WIC children were less likely to have ever been breastfed than were higher-income non-WIC children. WIC infants aged ≥6 mo were less likely to be currently breastfed than were either lower-income or higher-income nonparticipants (20). Dietary supplement use was highest in higher-income nonparticipants for infants and preschoolers (**Figure 2.1**).

2.4.2. Nutrient intakes of young infants (0- to 5.9-mo-olds) and older infants (6-to 11.9-mo-olds)

Regardless of WIC participation status, mean intakes of almost all micronutrients among both younger (0–5.9 mo) and older (6–11.9 mo) infants exceeded AIs, except for vitamins D and E. Only mean vitamin E intakes of younger and older infants participating in WIC were above the AIs. Younger infants participating in WIC had higher mean intakes of most micronutrients than did lower-income nonparticipants (except for vitamin A, riboflavin, vitamin C, magnesium, potassium, and sodium) or higher-income nonparticipants (except for vitamin A and sodium). Similarly, older infants participating in WIC had higher mean intakes of most micronutrients, except for riboflavin, vitamin B-6, calcium, magnesium, phosphorous, potassium, and sodium, than did lower-income nonparticipants and had higher mean intakes of almost all micronutrients, with only the exception of vitamin A, than did higher-income nonparticipants. WIC infants (<12 mo) had lower mean intakes of saturated fat as a percentage of total energy intake (percentage of energy) than did either subgroup of nonparticipants. However, total energy and sodium intakes for older infants were higher in WIC participants than in higher-income nonparticipants (**Tables 2.1 and 2.2**).

In older infants, the risk of inadequate iron intakes was substantially lower in WIC participants (13%) compared with either lower-income (26%) or higher-income (34%) nonparticipants (**Table 2.3**). Similarly, the percentage of intakes exceeding the AI for vitamin D was higher in WIC-participating older infants (24%) than in either subgroup of nonparticipants (~8%). The risk of inadequate zinc intake was significantly lower in WIC participants (2%) compared with higher-income nonparticipants (9%). Most older infants had usual intakes above the AIs for calcium and potassium, with a significantly larger proportion of WIC older infants meeting or exceeding the AIs compared with higher-income nonparticipants.

2.4.3. Nutrient intakes of toddlers (12-to 23.9-mo-olds)

The risk of inadequate calcium intake was higher in WIC toddlers (11%) than in lower-income nonparticipants (6%) (**Table 2.4**). Interestingly, the risk of inadequate iron intakes was only found among higher-income non-WIC toddlers (6%). Risks of inadequate vitamin D intake were high (>75%) across all subgroups, but WIC toddlers had a lower risk of inadequate vitamin D intake than did lower-income nonparticipants. No significant difference in DRI compliance by WIC participation group existed for zinc, fiber, or potassium. For fiber and potassium, very small proportions (<5%) of toddlers were meeting the AIs, regardless of WIC participation status. The prevalence of excessive sodium intake was notably high in both WIC participants and lower-income nonparticipants (~45%), whereas 30% of toddlers from families with higher incomes exceeded the sodium recommendation. A higher proportion of WIC toddlers (8%) had added sugar intakes exceeding the recommendation than either category of nonparticipants (~2%).

Mean usual intakes of nutrients were largely similar between WIC toddlers and lower-income non-WIC toddlers, whereas mean usual intakes of carbohydrate (percentage of energy), total sugar (percentage of energy), niacin, vitamin C, and sodium were higher and those of total energy, saturated fat (percentage of energy), fiber, and vitamins A and K were lower in WIC toddlers than in higher-income non-WIC toddlers (**Table 2.5**).

2.4.4. Nutrient intakes of preschoolers (24-to 47.9-mo-olds)

No substantial difference in the percentage of children meeting the DRI recommendations by WIC participation were noted for calcium, iron, zinc, fiber, or potassium in 24- to 47.9-mo-old children (**Table 2.6**). The risk of inadequate vitamin D intake was significantly lower in WIC participants (80%) compared with lower-income nonparticipants (89%). WIC preschoolers had the lowest prevalence of exceeding the energy contribution from saturated fat (61%). In contrast, ~75% and 14% of WIC preschool children consumed sodium and added sugars, respectively, at amounts above the recommendations, which is significantly higher than their higher-income counterparts.

In WIC participants, mean usual intakes of protein (percentage of energy), vitamin C, and calcium were higher than those in lower-income nonparticipants, and mean usual intakes of thiamin, vitamin B-6, folate, vitamin B-12, vitamin C, and potassium were higher than those in higher-income nonparticipants (**Table 2.7**). Only fat intake (percentage of energy) was lower in WIC participants than in higher-income nonparticipants.

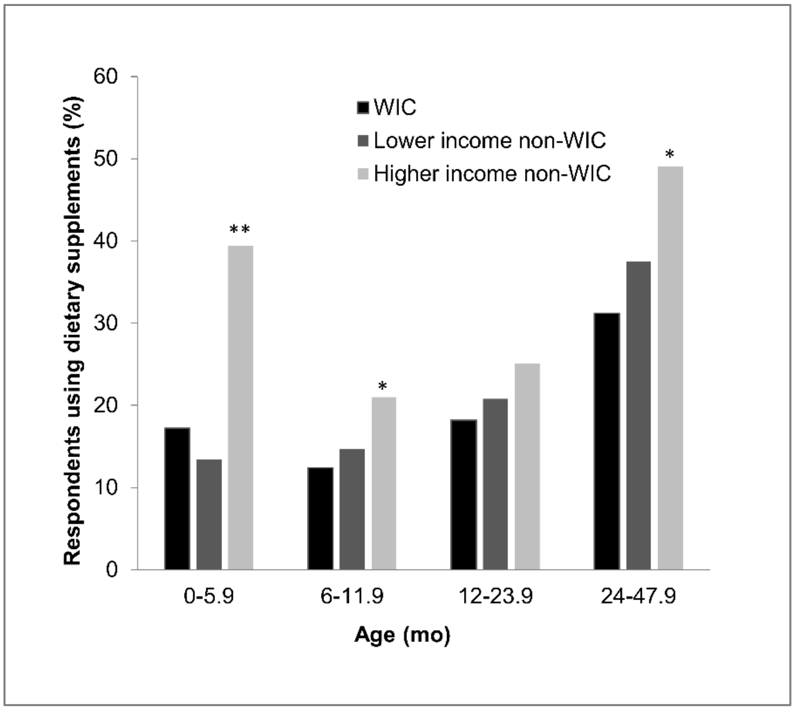

Figure 2.1. Prevalence of dietary supplement use by WIC participation and income, FITS 2016

Chi-square tests for differences across WIC categories within age group were conducted, *P <0.05, **P <0.001. FITS, Feeding Infants and Toddlers Study; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

Table 2.1. Usual dietary intake from food and beverages by WIC participation status for young infants 0-5.9 mo, FITS 2016[1]

	DRI Values			Nonparticipants	
Macronutrients[2]	**AI**	**UL**	**WIC participants (*n*=245)**	**Lower-income (*n*=104)**	**Higher-income (*n*=251)**
Energy (kcal/d)	–	–	671 ± 10.9	662 ± 19.5	637 ± 10.0
Fat (g/d)	31	–	37 ± 0.7	37 ± 1.3	37 ± 0.7
Saturated fat (g/d)	–	–	15 ± 0.4	16 ± 0.5	16 ± 0.4
Carbohydrate (g/d)	60	–	75 ± 1.4	75 ± 1.4	69 ± 1.2*
Protein (g/d)	9.1	–	14 ± 0.3	13 ± 0.5	12 ± 0.2*
Dietary fiber (g/d)	–	–	1.5 ± 0.1	1.4 ± 0.1	0.8 ± 0.1*
Fat (% kcal)	–	–	48 ± 0.3	49 ± 0.3	51 ± 0.3*
Saturated fat (% kcal)	–	–	20 ± 0.2	21 ± 0.2*	22 ± 0.2*
Carbohydrate (% kcal)	–	–	43 ± 0.3	43 ± 0.4	41 ± 0.4*
Total Sugar (% kcal)	–	–	34 ± 0.4	38 ± 0.5*	37 ± 0.3*
Protein (% kcal)	–	–	8.1 ± 0.1	7.7 ± 0.1	7.4 ± 0.1*
Micronutrients					
Vitamin A (μg RAE/d)[3]	400	600	610 ± 14.2	622 ± 13.8	582 ± 10.0
Thiamin (mg/d)[4]	0.2	–	0.4 ± 0.01	0.3 ± 0.01*	0.3 ± 0.01*
Riboflavin (mg/d)[4]	0.3	–	0.7 ± 0.02	0.6 ± 0.03	0.5 ± 0.02*
Niacin (mg/d)[4]	2	–	5.5 ± 0.2	4.1 ± 0.2*	3.4 ± 0.1*
Vitamin B-6 (mg/d)[4]	0.1	–	0.3 ± 0.01	0.3 ± 0.01*	0.2 ± 0.01*
Folate (μg DFE/d)[4,5]	65	–	130 ± 3.8	101 ± 4.0*	86 ± 2.1*
Vitamin B-12 (μg/d)[4]	0.4	–	1.6 ± 0.1	1.3 ± 0.1*	1.1 ± 0.05*
Vitamin C (mg/d)[6]	40	–	77 ± 1.8	77 ± 2.1	63 ± 1.6*
Vitamin D (μg/d)[7]	10	25	6.5 ± 0.2	4.5 ± 0.3*	3.3 ± 0.2*
Vitamin E (mg/d)[6]	4	–	4.3 ± 0.1	3.0 ± 0.2*	2.1 ± 0.1*
Vitamin K (μg/d)[3]	2	–	32 ± 1.2	21 ± 1.4*	13 ± 0.6*
Calcium (mg/d)[7]	200	1,000	517 ± 14.1	447 ± 17.1*	398 ± 11.3*
Iron (mg/d)[3]	0.27	40	7.8 ± 0.3	5.1 ± 0.3*	3.1 ± 0.1*
Magnesium (mg/d)[8]	30	–	53 ± 1.4	48 ± 2.0	40 ± 1.1*
Phosphorus (mg/d)[8]	100	–	270 ± 7.6	229 ± 10.2*	200 ± 6.1*
Potassium (mg/d)[9]	400	–	689 ± 14.7	661 ± 26.8	586 ± 13.2*
Sodium (mg/d)[9]	120	–	222 ± 6.2	212 ± 11.1	196 ± 5.9
Zinc (mg/d)[3]	2	4	4.4 ± 0.1	3.7 ± 0.2*	2.8 ± 0.1*

AI, Adequate Intake; DFE, dietary folate equivalents; DRI, Dietary Reference Intake; FITS, Feeding Infants and Toddlers Study; RAE, retinol activity equivalents; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

1 Values are mean ± SEs. *Significantly different from WIC participants by multiple t tests at Bonferroni-corrected *P* value of 0.002.

2 All macronutrient DRIs are from 2005 DRI book for energy, carbohydrates, etc. (24).

3 DRIs are from 2001 DRI book for vitamin A, vitamin K, and various metals including iron and zinc (23).

4 DRIs are from 1998 DRI book for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, and others(25).

5 Synthetic Folate (folic acid) from supplements multiplied by 1.6 to convert it to the dietary folate equivalent metric.

6 DRIs are from 2000 DRI book for vitamin C, vitamin E, selenium, and carotenoids (26).

7 DRIs are from 2011 DRI book for calcium and vitamin D (21).

8 DRIs are from 1997 DRI book for calcium, phosphorus, magnesium, vitamin D, and fluoride (27).

9 DRIs are from 2005 DRI book for water, potassium, sodium, chloride, and sulfate (22).

Table 2.2. Usual dietary intake from food and beverages by WIC participation status for older infants 6-11.9 mo, FITS 2016[1]

	DRI Values			WIC	Nonparticipants	
				participants	Lower-income	Higher-income
Macronutrients[2]	**AMDR**	**AI**	**UL**	**(*n*=375)**	**(*n*=169)**	**(*n*=357)**
Energy (kcal/d)	–	–	–	873 ± 11.4	861 ± 19.8	796 ± 10.6*
Fat (g/d)	–	30	–	38 ± 0.6	39 ± 1.1	38 ± 0.6
Saturated fat (g/d)	–	–	–	15 ± 0.3	16 ± 0.4	16 ± 0.3
Carbohydrate (g/d)	–	95	–	116 ± 1.6	110 ± 2.5	100 ± 1.5*
Protein (g/d)	–	–	–	21.0 ± 0.4	21 ± 0.6	19 ± 0.3*
Dietary fiber (g/d)	–	–	–	6.6 ± 0.2	6.4 ± 0.2	5.8 ± 0.2*
Fat (% kcal)	–	–	–	39 ± 0.2	40 ± 0.3	41 ± 0.3*
Saturated fat (% kcal)	–	–	–	15 ± 0.2	16 ± 0.2*	17 ± 0.2*
Carbohydrate (% kcal)	–	–	–	52 ± 0.3	50 ± 0.3*	48 ± 0.3*
Total Sugar (% kcal)	–	–	–	33 ± 0.3	33 ± 0.4	34 ± 0.3
Protein (% kcal)	–	–	–	9.4 ± 0.1	9.8 ± 0.1	9.4 ± 0.1
Micronutrients	**EAR**	**AI**	**UL**			
Vitamin A (µg RAE/d)[3]	–	500	600	806 ± 13.7	739 ± 12.6*	789 ± 10.2
Thiamin (mg/d)[4]	–	0.3	–	0.7 ± 0.02	0.6 ± 0.02*	0.6 ± 0.01*
Riboflavin (mg/d)[4]	–	0.4	–	1.1 ± 0.02	1.0 ± 0.03	0.9 ± 0.02*
Niacin (mg/d)[4]	–	4	–	9.2 ± 0.2	7.8 ± 0.2*	7.2 ± 0.1*
Vitamin B-6 (mg/d)[4]	–	0.3	–	0.7 ± 0.01	0.7 ± 0.02	0.6 ± 0.01*
Folate (µg DFE/d)[4,5]	–	80	–	221 ± 4.9	190 ± 5.6*	168 ± 3.2*
Vitamin B-12 (µg/d)[4]	–	0.5	–	2.3 ± 0.1	2.0 ± 0.1*	1.8 ± 0.1*
Vitamin C (mg/d)[6]	–	50	–	101 ± 1.8	85 ± 1.8*	80 ± 1.6*
Vitamin D (µg/d)[7]	–	10	38	7.4 ± 0.2	5.6 ± 0.2*	4.8 ± 0.2*
Vitamin E (mg/d)[6]	–	5	–	6.3 ± 0.2	4.8 ± 0.2*	4.4 ± 0.1*
Vitamin K (µg/d)[3]	–	2.5	–	55 ± 1.5	41 ± 2.1*	39 ± 1.4*
Calcium (mg/d)[7]	–	260	1,500	672 ± 14.1	612 ± 17.0	561 ± 12.5*
Iron (mg/d)[3]	6.9	–	40	14 ± 0.3	10 ± 0.3*	9.4 ± 0.3*
Magnesium (mg/d)[8]	–	75	–	103 ± 1.9	101 ± 3.1	88 ± 1.8*
Phosphorus (mg/d) [8]	–	275	–	425 ± 8.9	427 ± 13.0	368 ± 8.2*
Potassium (mg/d)[9]	–	700	–	1158 ± 18.9	1161 ± 32.6	1019 ± 18.2*
Sodium (mg/d)[9]	–	370	–	416 ± 9.3	436 ± 16.4	349 ± 8.3*
Zinc (mg/d)[3]	2.5	–	5	6.3 ± 0.1	5.3 ± 0.2*	4.7 ± 0.1*

AI, Adequate Intake; DFE, dietary folate equivalents; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; RAE, retinol activity equivalents; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

1 Values are mean ± SEs. *Significantly different from WIC participants by multiple t tests at Bonferroni-corrected *P* value of 0.002.

2 All macronutrient DRIs are from 2005 DRI book for energy, carbohydrates, etc. (24).

3 DRIs are from 2001 DRI book for vitamin A, vitamin K, and various metals including iron and zinc (23).

4 DRIs are from 1998 DRI book for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, and others (25).

5 Synthetic Folate (folic acid) from supplements multiplied by 1.6 to convert it to the dietary folate equivalent metric.

6 DRIs are from 2000 DRI book for vitamin C, vitamin E, selenium, and carotenoids (26).

7 DRIs are from 2011 DRI book for calcium and vitamin D (21).

8 DRIs are from 1997 DRI book for calcium, phosphorus, magnesium, vitamin D, and fluoride (27).

9 DRIs are from 2005 DRI book for water, potassium, sodium, chloride, and sulfate (22).

Table 2.3. Percentage of older infants 6-11.9 mo with intakes below or above the recommendations by WIC participation and income, FITS 2016[1]

Nutrient	**WIC participants (*n*=375)**	**Nonparticipants** Lower-income (*n*=169)	**Nonparticipants** Higher-income (*n*=357)
Nutrients to Increase			
Calcium[2] (%>AI)	97.7 ± 1.0	97.9 ± 2.6	93.9 ± 1.5[*]
Iron[3] (%<EAR)	12.6 ± 5.6	25.6 ± 6.6[**]	34.0 ± 2.3[**]
Zinc[3] (%<EAR)	1.8 ± 0.8	4.8 ± 1.5	8.9 ± 1.3[**]
Vitamin D[2] (%>AI)	23.7 ± 1.5	8.2 ± 5.1[**]	8.0 ± 2.6[**]
Potassium[2] (%>AI)	92.2 ± 2.0	88.3 ± 2.6	83.1 ± 1.8[**]

[1] Values are means ± SEs. Nutrients of interest were selected based on the NASEM report (8). [*]Significantly different from WIC participants by t tests at P value <0.05. [**]Significantly different from WIC participants by t tests at P value <0.001. AI, Adequate Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

[2] Nutrient with only an AI available (21, 22).

[3] Nutrient with an established EAR (23).

Table 2.4. Percentage of toddlers 12-23.9 mo with intakes below or above the recommendations by WIC participation and income, FITS 2016[1]

Nutrient	**WIC participants (*n*=380)**	**Nonparticipants** Lower-income (*n*=233)	**Nonparticipants** Higher-income (*n*=519)
Nutrients to Increase			
Calcium[2] (%<EAR)	10.7 ± 1.5	5.9 ± 1.8[*]	7.5 ± 2.1
Iron[2] (%<EAR)	0.0 ± 3.1	0.0 ± 6.6	6.0 ± 1.3[*]
Zinc[2] (%<EAR)	1.5 ± 2.6	1.1 ± 6.8	0.9 ± 1.1
Vitamin D[2] (%<EAR)	76.1 ± 1.5	82.6 ± 2.3[*]	78.3 ± 1.5
Fiber[3] (%>AI)	2.3 ± 2.7	2.4 ± 2.8	4.9 ± 1.3
Potassium[3] (%>AI)	2.0 ± 0.8	3.7 ± 1.7	2.5 ± 1.3
Nutrients to Limit			
Sodium[4] (%>UL)	45.0 ± 0.03	46.0 ± 2.8	30.5 ± 2.0[**]
Added Sugars[5] (%>guideline)	7.9 ± 0.7	2.4 ± 0.8[**]	2.0 ± 0.8[**]

[1] Values are means ± SEs. Nutrients of interest were selected based on the NASEM report (8). [*]Significantly different from WIC participants by t tests at P value <0.05. [**]Significantly different from WIC participants by t tests at P value <0.001. AI, Adequate Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

[2] Nutrient with an established EAR (21, 23).

[3] Nutrient with only an AI available (22, 24).

[4] Nutrient with an established UL (22).

[5] Nutrient with an established guideline based on energy intake (% >25% of kcal) (24).

Table 2.5. Usual dietary intake from food and beverages by WIC participation status for toddlers 12-23.9 mo, FITS 2016[1]

	DRI Values			WIC participants	Nonparticipants	
Macronutrients[2]	**AMDR**	**AI**	**UL**	**(*n*=380)**	**Lower-income (*n*=233)**	**Higher-income (*n*=519)**
Energy (kcal/d)	–	–	–	1188 ± 15.3	1237 ± 23.8	1125 ± 12.2*
Fat (g/d)	–	–	–	44 ± 0.7	48 ± 1.0	43 ± 0.6
Saturated fat (g/d)	–	–	–	17 ± 0.3	19 ± 0.4	17 ± 0.3
Carbohydrate (g/d)	–	–	–	156 ± 2.2	159 ± 3.0	146 ± 1.6*
Protein (g/d)	–	–	–	46 ± 0.8	47 ± 1.0	45 ± 0.6
Dietary fiber (g/d)	–	19	–	9.5 ± 0.2	9.9 ± 0.3	10.8 ± 0.2*
Fat (% kcal)	30–40	–	–	32 ± 0.3	34 ± 0.2*	33 ± 0.2
Saturated fat (% kcal)	–	–	–	13 ± 0.2	13 ± 0.1	14 ± 0.1*
Carbohydrate (% kcal)	45–65	–	–	52 ± 0.3	51 ± 0.3	50 ± 0.2*
Total Sugar (% kcal)	–	–	–	29 ± 0.3	28 ± 0.4	27 ± 0.2*
Protein (% kcal)	5–20	–	–	16 ± 0.2	16 ± 0.2	16 ± 0.1
Micronutrients	**EAR**	**AI**	**UL**			
Vitamin A (μg RAE/d)[3]	210	–	600	560 ± 10.9	576 ± 8.7	635 ± 7.3*
Thiamin (mg/d)[4]	0.4	–	–	1.0 ± 0.02	1.1 ± 0.02	1.0 ± 0.01
Riboflavin (mg/d)[4]	0.4	–	–	1.6 ± 0.03	1.6 ± 0.04	1.6 ± 0.03
Niacin (mg/d)[4]	5	–	–	12 ± 0.2	12 ± 0.3	11 ± 0.2*
Vitamin B-6 (mg/d)[4]	0.4	–	–	1.1 ± 0.02	1.1 ± 0.02	1.1 ± 0.02
Folate (μg DFE/d)[4,5]	120	–	300	302 ± 6.3	298 ± 7.2	289 ± 4.3
Vitamin B-12 (μg/d)[4]	0.7	–	–	3.6 ± 0.1	3.5 ± 0.1	3.7 ± 0.1
Vitamin C (mg/d)[6]	13	–	400	67 ± 1.3	64 ± 1.2	59 ± 1.1*
Vitamin D (μg/d)[7]	10	–	63	7.4 ± 0.2	6.9 ± 0.2	7.1 ± 0.2
Vitamin E (mg/d)[6]	5	–	200	4.7 ± 0.1	4.9 ± 0.2	4.8 ± 0.1
Vitamin K (μg/d)[3]	–	30	–	37 ± 1.1	44 ± 1.9*	44 ± 1.3*
Calcium (mg/d)[7]	500	–	2,500	872 ± 17.2	902 ± 19.3	927 ± 15.0
Iron (mg/d)[3]	3	–	40	9.1 ± 0.3	8.7 ± 0.3	8.7 ± 0.2
Magnesium (mg/d)[8]	65	–	65	169 ± 2.8	173 ± 4.1	174 ± 2.7
Phosphorus (mg/d)[8]	380	–	3,000	865 ± 15.4	887 ± 19.3	886 ± 13.1
Potassium (mg/d)[9]	–	3,000	–	1732 ± 27.0	1793 ± 38.7	1734 ± 23.6
Sodium (mg/d)[9]	–	1,000	1,500	1549 ± 33.6	1549 ± 41.9	1318 ± 21.7*
Zinc (mg/d)[3]	2.5	–	7	6.5 ± 0.1	6.5 ± 0.1	6.7 ± 0.1

AI, Adequate Intake; AMDR, Acceptable Macronutrient Distribution Range; DFE, dietary folate equivalents; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; RAE, retinol activity equivalents; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

1 Values are mean ± SEs. * Significantly different from WIC participants by multiple t tests at Bonferroni-corrected *P* value of 0.002.
2 All macronutrient DRIs are from 2005 DRI book for energy, carbohydrates, etc. (24).
3 DRIs are from 2001 DRI book for vitamin A, vitamin K, and various metals including iron and zinc (23).
4 DRIs are from 1998 DRI book for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, and others (25).
5 Synthetic Folate (folic acid) from supplements multiplied by 1.6 to convert it to the dietary folate equivalent metric.
6 DRIs are from 2000 DRI book for vitamin C, vitamin E, selenium, and carotenoids (26).
7 DRIs are from 2011 DRI book for calcium and vitamin D (21).
8 DRIs are from 1997 DRI book for calcium, phosphorus, magnesium, vitamin D, and fluoride (27).
9 DRIs are from 2005 DRI book for water, potassium, sodium, chloride, and sulfate (22).

Table 2.6. Percentage of preschoolers 24-47.9 mo with intakes below or above the recommendations by WIC participation and income, FITS 2016[1]

Nutrients	WIC participants (*n*=161)	Nonparticipants Lower-income (*n*=135)	Nonparticipants Higher-income (*n*=300)
Nutrients to Increase			
Calcium[2] (%<EAR)	6.6 ± 1.5	9.5 ± 3.6	8.3 ± 2.0
Iron[2] (%<EAR)	1.7 ± 3.6	3.7 ± 4.0	2.6 ± 1.1
Zinc[2] (%<EAR)	0.4 ± 4.6	0.2 ± 2.9	0.5 ± 0.8
Vitamin D[2] (%<EAR)	79.3 ± 4.1	88.7 ± 6.1*	84.2 ± 2.1
Fiber[3] (%>AI)	8.4 ± 3.5	6.6 ± 1.4	8.5 ± 2.7
Potassium[3] (%>AI)	7.0 ± 2.1	4.2 ± 2.6	3.5 ± 2.3
Nutrients to Limit			
Sodium[4] (%>UL)	75.3 ± 2.6	76.3 ± 4.3	68.9 ± 2.0*
Saturated Fat[5] (%>guideline)	61.0 ± 4.6	67.2 ± 4.7*	71.6 ± 2.3**
Added Sugars[6] (%>guideline)	13.7 ± 2.2	11.1 ± 2.9	8.8 ± 2.3*

[1] Values are means ± SEs. Nutrients of interest were selected based on the NASEM report (8). *Significantly different from WIC participants by t tests at P value <0.05. **Significantly different from WIC participants by t tests at P value <0.001. AI, Adequate Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.
[2] Nutrient with an established EAR (21, 23).
[3] Nutrient with only an AI available (22, 24).
[4] Nutrient with an established UL (22).
[5] Nutrient with an established guideline based on energy intake from Dietary Guidelines for Americans (<10% of kcal) (19).
[6] Nutrient with an established guideline based on energy intake (<25% of kcal) (24).

Table 2.7. Usual dietary intake from food and beverages by WIC participation status for preschoolers 24-47.9 mo, FITS 2016[1]

	DRI				Nonparticipants	
Macronutrients[2]	**AMDR**	**AI**	**UL**	**WIC Participants (*n*=161)**	**Lower-income (*n*=135)**	**Higher-income (*n*=300)**
Energy (kcal/d)	–	–	–	1442 ± 28.5	1444 ± 36.0	1339 ± 19.5
Fat (g/d)	–	–	–	50 ± 1.1	52 ± 1.5	49 ± 0.9
Saturated fat (g/d)	–	–	–	18 ± 0.5	18 ± 0.5	18 ± 0.3
Carbohydrate (g/d)	–	–	–	198 ± 4.2	198 ± 4.8	180 ± 2.6*
Protein (g/d)	–	–	–	56 ± 1.4	52 ± 1.5	52 ± 0.9
Dietary fiber (g/d)	–	19	–	12 ± 0.4	12 ± 0.4	12 ± 0.3
Fat (% kcal)	30-40	–	–	30 ± 0.4	31 ± 0.3	32 ± 0.3*
Saturated fat (% kcal)	–	–	–	11 ± 0.2	11 ± 0.1	12 ± 0.2
Carbohydrate (% kcal)	45-65	–	–	54 ± 0.4	54 ± 0.4	52 ± 0.3
Total Sugar (% kcal)	–	–	–	29 ± 0.5	28 ± 0.5	27 ± 0.3
Protein (% kcal)	5-20	–	–	16 ± 0.2	15 ± 0.2*	16 ± 0.1
Micronutrients	**EAR**	**AI**	**UL**			
Vitamin A (µg RAE/d)[3]	210	–	600	588 ± 17.5	565 ± 11.8	597 ± 9.4
Thiamin (mg/d)[4]	0.4	–	–	1.3 ± 0.03	1.3 ± 0.03	1.2 ± 0.02*
Riboflavin (mg/d)[4]	0.4	–	–	1.8 ± 0.05	1.7 ± 0.05	1.6 ± 0.04
Niacin (mg/d)[4]	5.0	–	–	15 ± 0.4	15 ± 0.5	14 ± 0.3
Vitamin B-6 (mg/d)[4]	0.4	–	–	1.4 ± 0.04	1.3 ± 0.04	1.2 ± 0.02*
Folate (µg DFE/d)[4,5]	120	–	300	388 ± 12.2	384 ± 11.8	342 ± 6.7*
Vitamin B-12 (µg/d)[4]	0.7	–	–	4.2 ± 0.1	3.7 ± 0.1	3.6 ± 0.1*
Vitamin C (mg/d)[6]	13	–	400	81 ± 2.4	67 ± 1.8*	63 ± 1.5*
Vitamin D (µg/d)[7]	10	–	63	7.0 ± 0.3	6.0 ± 0.3	6.2 ± 0.2
Vitamin E (mg/d)[6]	5.0	–	200	5.6 ± 0.2	5.8 ± 0.3	5.9 ± 0.2
Vitamin K (µg/d)[3]	–	30	–	48 ± 2.1	53 ± 3.0	49 ± 1.9
Calcium (mg/d)[7]	500	–	2,500	966 ± 28.8	840 ± 24.4*	916 ± 19.8
Iron (mg/d)[3]	3.0	–	40	11 ± 0.5	10 ± 0.4	9.5 ± 0.3
Magnesium (mg/d)[8]	65	–	65	202 ± 5.0	187 ± 5.8	194 ± 3.9
Phosphorus (mg/d) [8]	380	–	3,000	1020 ± 27.2	933 ± 26.4	979 ± 18.9
Potassium (mg/d)[9]	–	3,000	–	2017 ± 47.8	1822 ± 51.8	1820 ± 33.0*
Sodium (mg/d)[9]	–	1,000	1,500	2155 ± 72.1	2128 ± 71.9	1900 ± 39.9
Zinc (mg/d)[3]	2.5	–	7	7.8 ± 0.2	7.5 ± 0.2	7.3 ± 0.2

AI, Adequate Intake; AMDR, Acceptable Macronutrient Distribution Range; DFE, dietary folate equivalents; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; FITS, Feeding Infants and Toddlers Study; RAE, retinol activity equivalents; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

1. Values are mean ± SEs. * Significantly different from WIC participants by multiple t tests at Bonferroni-corrected *P* value of 0.002.
2. All macronutrient DRIs are from 2005 DRI book for energy, carbohydrates, etc. (24).
3. DRIs are from 2001 DRI book for vitamin A, vitamin K, and various metals including iron and zinc (23).
4. DRIs are from 1998 DRI book for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, and others (25).
5. Synthetic Folate (folic acid) from supplements multiplied by 1.6 to convert it to the dietary folate equivalent metric.
6. DRIs are from 2000 DRI book for vitamin C, vitamin E, selenium, and carotenoids (26).
7. DRIs are from 2011 DRI book for calcium and vitamin D (21).
8. DRIs are from 1997 DRI book for calcium, phosphorus, magnesium, vitamin D, and fluoride (27).
9. DRIs are from 2005 DRI book for water, potassium, sodium, chloride, and sulfate (22).

2.5. Discussion

The WIC program was established to help decrease poverty-related nutritional risk by providing food assistance to low-income families with young children. Despite the program's success over many decades, infants and children from low-income families still face some unique nutritional challenges that were outlined by a recent NASEM expert panel (8). The panel prioritized the nutrients that need to be increased to prevent disease and promote health, including the following: iron and zinc for older breastfed infants; iron, fiber, and potassium for toddlers; and calcium, iron, vitamin D, fiber, and potassium for 2- to 4-y-old children. The panel also prioritized the nutrients to limit, including sodium and added sugars for toddlers and sodium, added sugars, and saturated fat for 2- to 4-y-olds (8). In this study, we evaluated the risk of these nutrients relative to federal dietary recommendations, when available (21–27). This FITS 2016 report highlights similar concerns for toddlers and preschoolers as the NASEM expert committee, with additional concerns about low vitamin D intakes compared with DRIs among infants and toddlers.

The expectation of the WIC program is that it helps improve dietary intakes that may be inadequate due to lack of money by providing a food package and nutrition education. The current WIC package provides iron-fortified infant formula to partially or not-breastfeeding younger infants, iron-fortified infant formula and infant foods (cereal, fruit, and vegetables) for partially or not-breastfeeding older infants, and infant foods and infant meat for fully breastfeeding older infants. The WIC food package for 1- to 4-y-olds includes vitamin D–fortified milk, iron-fortified breakfast cereal, eggs, whole-grain breads, legumes or peanut butter, fruit and vegetables, and vitamin C–rich juice (7). Thus, we assumed that the nutrient intakes of WIC participants would be more like those of higher-income children and that those at the greatest nutritional risk would be lower-income nonparticipants, with all other factors being equal. However, all other factors were not equal in the sample. In particular, the use of dietary supplements was substantially higher in higher-income nonparticipants, so it was not possible to test such an assumption. Therefore, we compared only the nutrient intakes from the diets of WIC participants with those of either lower-income or higher-income nonparticipants, because the WIC package provides foods and beverages but not dietary supplements.

In infants (aged 0–11.9 mo), WIC participation was associated with a higher mean nutrient intake of most micronutrients, with lower saturated fat as a percentage of energy when compared with those not participating in WIC, regardless of eligibility. The WIC program appears to be especially beneficial to older infants (aged 6–11.9 mo), particularly in that it is associated with a lower risk of iron and zinc inadequacy. This finding on iron is consistent not only with the WIC program goals but also with previous reports (28–30), which may be attributed to a higher likelihood of consumption of iron-fortified cereal, infant formula, and baby-food meats by WIC participants in FITS 2016 (20). However, 13% of WIC-participating older infants were still at risk of inadequate iron intakes, compared with 1% among WIC infants aged 7–11.9 mo in FITS 2002 (16). This may be partly attributable to increased breastfeeding rate (31), decreased infant cereal consumption (31), and low infant meat consumption (20) in this age group. Iron stores at birth may meet iron needs during the first 6 mo, but iron supplementation through complementary feeding is suggested from ages 4 to 6 mo (32, 33). The results highlight the continued need for education on the importance of complementary foods containing iron. Furthermore, in older infants, WIC participants had better nutritional risk profiles in general when compared with recommendations for all nutrients examined, even though only iron and zinc were listed by NASEM as priority nutrients in this age group.

In toddlers (aged 12–23.9 mo), the priority nutrients are iron, potassium, and fiber as nutrients to increase and sodium and added sugars as nutrients to limit. Paradoxically, in this age group, iron intakes were only of concern for the higher-income nonparticipants. The results might be different if iron intake from dietary supplements was included, but iron supplement use was very low (5%) among this age group (34). Meanwhile, WIC participation was associated with higher compliance with sodium and added-sugars guidelines, with no significant differences noted in compliance with potassium or fiber guidelines. A FITS 2016 food-based analysis (20) suggested that WIC toddlers tended to have a higher consumption of fruit-flavored drinks and sweetened beverages that may be contributing added sugars, but it is not clear which food groups are responsible for differences in sodium intake.

For preschoolers, the same nutrients are prioritized as for toddlers, plus calcium, vitamin D, and saturated fat. The revised food packages limit milk fat content to ≤1% for children aged >2 y. As a consequence, several regional studies have reported reduced saturated fat intakes, with a concomitant shift toward lower-fat milks (2%, 1%, or nonfat), in WIC children aged ≥2 y after the food package change (35–37). In FITS 2016,1% low-fat milk was the most commonly consumed milk among WIC children aged 24–47.9 mo, whereas 2% reduced-fat milk was more prevalently consumed among both subgroups of nonparticipants (20), which may contribute to a lower percentage of WIC children aged 24–47.9 mo exceeding the recommendations for saturated fat intakes. In terms of compliance with recommendations for sodium and added sugars (percentage of energy),WIC preschoolers were similar to lower-income nonparticipants but were less likely to comply with the recommendations than their higher-income counterparts. Added sugar is an area of controversy, especially in young children (38). We used the NASEM guidelines of 25% of energy from added sugar as the benchmark, but other authoritative bodies have endorsed <10% of total energy intake from added sugars or free sugars (19, 39). Certainly, a much higher prevalence of exceeding added sugar would be reported on the basis of the FITS 2016 data if 10% were used as the guideline. However, the 10% recommendation may be very difficult to achieve and experts differ on the strength of evidence supporting such a recommendation (40–42). NHANES 2011–2012 data suggested that 80% of WIC participants (ages 2–4 y) exceeded the 10% recommendation (8).

Although vitamin D is only highlighted as a nutrient of concern in those aged ≥24 mo, most infants and young children failed to meet vitamin D recommendations, regardless of WIC participation status. This study as well as national and program-specific reports have shown that most US infants and children have suboptimal vitamin D intakes from foods and beverages (43, 44). The American Academy of Pediatrics recommends routine vitamin D supplementation for breastfed infants (45); with more than three-quarters of toddlers and preschoolers at risk of vitamin D inadequacy from foods alone, supplementation may be warranted in older children as well. In this supplement issue, Bailey et al. (34) showed that, for users of vitamin D supplements, the supplements added an average of ∼10 μg vitamin D/d, which corresponds to the amount recommended as the AI (<12 mo) or EAR (≥12 mo), but when vitamin D supplement users and nonusers were combined, most infants and young children still failed to meet recommendations. Nonetheless, it is important to note that WIC participation was consistently associated with better vitamin D intakes compared with lower-income nonparticipants across all age groups.

Some limitations should be noted in the interpretation of the present study. Dietary information was reported by parents or caregivers and may not fully represent the actual intake of the child. However, 24-h recalls were conducted by trained interviewers with the use of the automated multiple-pass approach to minimize this inaccuracy. Usual nutrient intakes were estimated with the use of the NCI method, which relies on the assumption that a 24-h dietary recall is unbiased for single-day intake; this may or may not be the case (46, 47). Biomarkers of nutritional status would be preferable, if they exist, and would be especially helpful in evaluating the iron and vitamin D findings of this report. We compared WIC participants with lower-income (likely income-eligible) nonparticipants, but the factors related to the decision to participate in WIC (48, 49) were not assessed. In addition, approximately half of WIC participants were also participating in SNAP. SNAP provides benefits to buy food to low-income individuals and families, and it is possible to participate in both WIC and SNAP. Thus, it is more difficult to attribute associations here exclusively to WIC, because infant formula and most foods can also be purchased with the use of SNAP benefits. However, WIC participation has been found to increase nutrient intakes of young children, whereas SNAP had no additional benefit in those already participating in WIC (28). In the 24-h recall, we did not identify which foods were provided by WIC. Finally, we evaluated differences between WIC participants and others on the basis of nutrient intakes from foods and beverages alone because dietary supplements are not part of the WIC package. This may underestimate the nutrient intakes, especially for children from higher-income families because they consumed more dietary supplements than both lower-income groups. Future work could investigate total nutrient intakes from both diet and supplements by WIC participation status and identify major sources of priority nutrients to target for improvement, such as breast milk, infant formula, and supplements.

Although we acknowledge that there is great interest in comparing the impact of WIC food package revision on usual nutrient intakes, we could not immediately compare the results from FITS 2016 with FITS 2008 or FITS 2002 because the sampling frames were different, WIC participants and nonparticipants were classified in a different way, and usual nutrient intakes were estimated by using a different methodology (PC-SIDE from Iowa State University). In fact, the FITS 2008 study only reported on food-group consumption related to WIC participation status rather than nutrient intakes (9). Even looking outside FITS, there are few data on the impact of the WIC food package change on nutrient intakes (28, 50). Instead, the impact has been measured by improvements in the Healthy Eating Index score (51) or food-group consumption (35, 36, 52). This is a priority area that would benefit from future exploration. Nonetheless, the findings may be useful for enhancing understanding of the dietary intakes of WIC participants, identifying the remaining dietary issues after the 2009 WIC food package revision, and comparing findings against the latest NASEM committee recommendations for further changes in the WIC food package. The present study provides the most comprehensive and recent estimates on nutrient intakes of WIC infants and young children, updating and extending the previous national-scope studies that were conducted before the 2009 WIC food package revision (16, 28, 44, 53, 54). To our knowledge, this is the first study to report usual dietary intakes of infants aged 0–5.9 mo by WIC participation status.

In conclusion, WIC participation may be nutritionally beneficial (e.g., participants had dietary intakes closer to recommendations), especially for iron (ages 6–23.9 mo), zinc (ages 6–11.9 mo), saturated fat (ages 24–47.9 mo), and vitamin D (all age groups). Nevertheless, it is notable that 13% of WIC infants (6–11.9 mo) were still not meeting iron recommendations. No substantial differences in nutritional risk profiles were noted for calcium, iron, zinc, potassium, or fiber between WIC and non-WIC toddlers and preschoolers. However, of concern, WIC participation among toddlers and preschoolers was associated with an increased prevalence of exceeding the energy recommendations for added sugar and sodium intakes. Future work is needed to determine how to best support food and beverage choices to reduce added sugar and sodium consumption in all children, but especially among those in lower-income families. In addition, greater effort to encourage more consumption of fiber, vitamin D, iron, and potassium and less consumption of saturated fat among WIC children as well as non-WIC children is warranted.

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CHAPTER 3 . DIETARY SUPPLEMENT USE BY FAMILY INCOME, FOOD SECURITY LEVEL, AND NUTRITION ASSISTANCE PROGRAM PARTICIPATION STATUS

Jun S, Cowan AE, Tooze JA, Gahche JJ, Dwyer JT, Eicher-Miller HA, Bhadra A, Guenther PM, Potischman N, Dodd KW, and Bailey RL. Dietary supplement use differs by family income, food security level, and nutrition assistance program participation status in 2011-2014. *Nutrients* 2018; 10(9), 1212. doi: 10.3390/nu10091212.

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3.1. Abstract

This analysis characterizes use of dietary supplements (DS) and motivations for DS use among U.S. children (≤ 18 years) by family income level, food security status, and federal nutrition assistance program participation using the 2011–2014 National Health and Nutrition Examination Survey data. About one-third (32%) of children used DS, mostly multivitamin-minerals (MVM; 24%). DS and MVM use were associated with higher family income and higher household food security level. DS use was lowest among children in households participating in the Supplemental Nutrition Assistance Program (SNAP; 20%) and those participating in the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC; 26%) compared to both income-eligible and income-ineligible nonparticipants. Most children who used DS took only one (83%) or two (12%) products; although children in low-income families took fewer products than those in higher income families. The most common motivations for DS and MVM use were to “improve (42% or 46%)” or “maintain (34 or 38%)” health, followed by “to supplement the diet (23 or 24%)” for DS or MVM, respectively. High-income children were more likely to use DS and MVM “to supplement the diet” than middle- or low-income children. Only 18% of child DS users took DS based on a health practitioner’s recommendation. In conclusion, DS use was lower among children who were in low-income or food-insecure families, or families participating in nutrition assistance programs.

3.2. Introduction

Dietary supplement (DS) use is widespread in the United States. More than half of adults (1,2) and approximately one-third of infants, children, and adolescents (henceforth children) use DS (3). The use of DS is associated with socioeconomic status indicators such as family income level and food security in adults (4–6) and children (7–10). For example, data from the 2007–2010 National Health and Nutrition Examination Survey (NHANES) demonstrated that children using DS tended to have higher income (9). In a study using the 1999–2004 NHANES data, children using micronutrient supplement were more likely to have higher food security (8). However, whether the type of DS used and motivations for their use differ by socioeconomic status remain unclear.

In the U.S., federal nutrition assistance programs such as the Supplemental Nutrition Assistance Program (SNAP) and the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children (WIC) serve many low-income individuals or households with the goal of reducing food insecurity and nutritional risk (11). These programs are targeted to improve the food and nutrition resources of participants. However, little is known about DS use of these nutrition assistance program participants (7,8,12), especially how they differ from income-eligible nonparticipants.

This analysis characterized DS use and examined motivations for use of DS among U.S. children aged 18 years and younger by family income level, food security status, and SNAP and WIC participation status using the most recent 2011–2014 NHANES data sets.

3.3. Materials and methods

3.3.1. Study design, population, and setting

The NHANES is a nationally representative, cross-sectional survey that samples U.S. noninstitutionalized civilians using a complex multistage probability sampling design (13). The present analysis combined the 2011–2012 and 2013–2014 NHANES data of children (≤18 years), excluding those with missing DS use data. The final analytic sample was $n = 8{,}288$. All participants or their proxies provided written informed consent, and the Research Ethics Review Board at the National Center for Health Statistics (NCHS) approved the survey protocol.

The NHANES protocol includes an in-home interview and a physical examination in a mobile examination center. During the in-home interview, a proxy provided information for survey participants who were under 16 years of age. Demographic, socioeconomic, and lifestyle information was collected via computer-assisted software in the home interview. Age groups were aligned with the Dietary Reference Intakes (DRI) age groupings: <1, 1–3, 4–8, 9–13, and 14–18 years of age. Self-reported race and Hispanic origin groups as defined in the NHANES are non-Hispanic white, non-Hispanic black, non-Hispanic Asian, Hispanic, and other races; the "other" race group was only included in the estimates for the total sample as recommended (13). Education level of the "household reference person," defined as an adult household member who owns or rents the residence, was used to indicate the household's education level. Education was categorized as less than high school, high school graduate or general equivalency diploma, some college or associate degree, and college graduate or above. Health insurance was categorized as none, private, or public; public health insurance included Medicaid, Children's Health Insurance Program, state-sponsored or other government-sponsored health plan, and military health care (14). Screen time was calculated as the sum of the total time spent looking at a television and/or computer screen per day for those aged ≥2 years (n = 4,006) using the Physical Activity Questionnaire. The response of "<1 h" was assigned 0.5 hours as recommended (15) and screen time was categorized as follows: ≤1, >1–≤2, >2–≤4, and >4 h/day. The American Academy of Pediatrics recommends limiting leisure screen time to two hours or less a day (16).

Family income was represented by the family income-to-poverty ratio (PIR), a ratio of family income to the poverty guideline established by the Department of Health and Human Services. The poverty guidelines are updated every year and vary by family size and geographic location (48 contiguous states, the District of Columbia, Alaska, and Hawaii) (17). We categorized family income as PIR ≤130%, 131–350%, and >350% because a PIR of ≤130% is used as an eligibility criterion for several federal food assistance programs such as the Supplemental Nutrition Assistance Program (SNAP). Household food security status was measured using the U.S. Food Security Survey Module; an adult responded to 18 items for households with children. Households with more than three affirmative responses were categorized as food-insecure (18). SNAP participation status was also collected at household level with the question, "Do you/does any member of your household currently receive SNAP or Food Stamp benefits?" and categorized as current participants, income-eligible nonparticipants

(PIR ≤130%), and income-ineligible nonparticipants (PIR > 130%). WIC participation status was collected at individual level with the question "Is participant now receiving benefits from the WIC program?" and classified as current participants, income-eligible nonparticipants (PIR ≤185%), and income-ineligible nonparticipants (PIR > 185%).

During the household interview, detailed information about DS use during a 30-day period prior to the interview was collected using a product inventory, Dietary Supplement Questionnaire (DSQ). Participants or proxies were asked if they had taken any DS, and trained interviewers recorded each supplement's name and manufacturer from the label, if available, or from the participant's verbal report. Trained nutritionists at NCHS reviewed incoming data, obtained product labels, and incorporated DS information from the label into a database, including the name, ingredients, and product form. Data on the products participants reported and questions from the DSQ, along with product-level information from the labels, are all available on the NHANES website. For this analysis, DS were categorized into mutually exclusive categories based on their nutrient contents as published in a previous study (4): (i) multivitamin and minerals (MVM) defined as a single product containing three or more vitamins and at least one mineral; (ii) multivitamins as a single product containing two or more vitamins without minerals; (iii) calcium-containing supplements (calcium as the primary ingredient with or without vitamin D or other nutrients); (iv) single-nutrient supplements, such as vitamin C, vitamin D, or iron; (v) botanicals; and (vi) fatty acids (any products with omega-3 or omega-6 fatty acids as the primary ingredient). The specific types of products shown by interviewers were selected based on high frequency of use; only the top products were reported. The reasons for taking each dietary supplement were also collected using a hand card with a list of reasons identified in previous surveys; participants were also able to provide other reasons not specified in the list and could choose more than one reason for each product. In addition, participants were asked if they used the supplement on their own or based on the advice of a doctor or other health practitioner.

During the physical examination, trained health technicians measured weight and height. Percentiles of body mass index (BMI) were used to categorize each participant's weight status as underweight (<5th percentile), healthy weight (5th–85th percentiles), overweight (85th–95th percentiles), and obese (≥95th percentile) according to the growth charts developed by the

Centers for Disease Control and Prevention (2000) for children 2–18 years; weight status was only available for children who attended the physical examination (*n* = 6,606).

3.3.2. Statistical analysis

Data were analyzed using SAS (version 9.4; SAS Institute, Inc, Cary, NC, USA) and SAS-callable SUDAAN (version 11; RTI International, Research Triangle Park, NC, USA) software programs. The 2011–2014 NHANES 4-year sample weights were used to account for differential probabilities of selection, nonresponse, and planned oversampling of some groups for all analyses. Interview weights were used for all analyses, except for the weight status analysis that used examination weights. Standard errors (SE) were estimated using a Taylor series linearization method. The statistical reliability of estimates were determined based on the relative standard error as recommended by NCHS (19). Estimates with a relative SE > 30% may be statistically unreliable, so those with a relative SE > 30% and ≤40% were noted and those with the relative SE > 40% were not presented. Numbers of DS taken and motivations for DS use are estimated only from those who used DS in a 30-day period prior to the home interview (*n* = 2,365). We used pairwise t-tests to examine statistical significance of differences in categorical variables. To test for linear trends in ordinal variables, the null hypothesis of a nonlinear trend was examined with orthogonal polynomial contrasts. Statistical significance was determined at a Bonferroni-corrected p-value < 0.0167.

3.4. Results

In 2011–2014, an estimated 32% of children used DS in a 30-day period, with little difference by sex (**Table 3.1**). Infants (<1 year) were the least likely to use DS (16%). When infants were excluded, there was a significant trend toward lower DS use with increasing age. DS use was higher in non-Hispanic white (38%) and non-Hispanic Asian children (42%) compared to non-Hispanic black (21%) and Hispanic children (23%). Children with private health insurance (40%) were more likely to use DS than those with public (24%) or no health insurance (28%). The household’s education level was positively associated with DS use; whereas screen time in both boys and girls and weight status in girls were inversely associated with DS use.

When stratified by DRI age group, infants <1 year had distinct patterns of DS use compared to other age groups (**Table 3.2**). About a half of infant DS users were taking vitamin D, and 30% and 11% were using multivitamins and MVM, respectively. When infants were excluded, the proportion of MVM decreased with increasing age; older children tended to have greater diversity in terms of product type. Most used only one product, but the mean number of products used increased with age.

The most popular products used by children were the MVM (24%), followed by multivitamins (3.1%), vitamin C (2.4%), and vitamin D (1.6%) (**Table 3.3**). There were significant linear trends toward higher use of any DS, MVM, multivitamins, and vitamin D supplements with higher income (i.e., PIR). Use of any DS, MVM, and vitamin D supplement was also higher among children in food-secure than those in food-insecure households. Children in SNAP-participating households were least likely to use DS (20%) compared to either those in income-eligible (28%) or income-ineligible (40%) nonparticipating households in SNAP. Similarly, DS use was lowest in infants and young children participating in WIC (26%), compared with either income-eligible (36%) or income-ineligible nonparticipants in WIC (47%). Among children who used DS, the majority took one (83%) or two (12%) products (**Table 3.4**). The mean number of supplements taken was lower for low-income children (mean 1.15) than in either middle (mean 1.30) or higher-income (mean 1.30) children using the PIR criterion, but did not differ by SNAP or WIC participation and food security status among income-eligible children.

The top five motivations for DS use were “to improve overall health (42%),” “to maintain health (34%),” “to supplement the diet (23%),” “to prevent colds, boost immunity (15%),” and “to prevent health problems (11%)” (**Figure 3.1**). Most DS use was self-directed; only 18% of children were taking at least one product under the recommendation of a health care practitioner. Children in high-income families (i.e., PIR > 350%) were more likely to use DS “to supplement the diet” than those in middle- or low-income families. Among income-eligible children, motivations for DS use were not different by SNAP or WIC participation status. There were no significant differences in motivations for DS use by food security status (**Table 3.5**). Motivations for MVM use indicated that the high-income group was more likely to use MVM “to supplement diet” than were their lower-income counterparts (**Table 3.6**). The percentage of children who were using MVM at the recommendation of a health practitioner among SNAP participants (21%) was significantly higher than that of income-eligible non-SNAP (9%) children and income-ineligible nonparticipants (15%). The percentage of those who were using MVM due to health care provider's recommendations was similar between WIC participants (26%) and income-eligible nonparticipants (22%).

Table 3.1. Estimated percentage of U.S. children (≤18 years) who used any dietary supplement in a 30-day period by demographic, lifestyle, and anthropometric characteristics, NHANES 2011–2014[1]

Characteristic	All		Male		Female	
	n	**% (SE)**	***n***	**% (SE)**	***n***	**% (SE)**
Total	8,288	32.4 (1.2)	4,217	32.2 (1.35)	4,071	32.7 (1.46)
Age						
<1 year	797	16.4 (1.5)	394	16.4 (2.4)	403	16.5 (2.2)
1–3 years	1,537	38.6 (2.4)	768	39.0 (3.0)	769	38.3 (3.1)
4–8 years	2,265	39.4 (1.7)	1,196	38.5 (2.2)	1,069	40.5 (2.3)
9–13 years	1,995	30.9 (1.5)	1,008	30.5 (1.9)	988	31.2 (2.4)
14–18 years	1,694	26.3 (1.7) *	851	26.0 (2.7) *	843	26.5 (2.4) *
Race/Ethnicity [2]						
Non-Hispanic white	2,055	38.1 (1.7) [a]	1,073	38.2 (2.2) [a]	982	37.9 (2.3) [a]
Non-Hispanic black	2,221	21.2 (1.6) [b]	1,147	21.2 (1.9) [b]	1,074	21.2 (1.5) [b]
Non-Hispanic Asian	869	41.7 (3.2) [a]	434	38.9 (3.9) [a]	435	44.8 (3.1) [a]
Hispanic	2,632	22.8 (1.1) [b]	1,311	21.7 (1.4) [b]	1,321	24.1 (1.6) [b]
Health Insurance						
Private	3,255	40.0 (1.7) [a]	1,639	41.3 (2.2) [a]	1,616	38.8 (2.2) [a]
Public	4,321	24.1 (1.3) [b]	2,219	22.7 (1.5) [b]	2,102	25.7 (1.6) [b]
None	663	27.5 (2.7) [b]	337	26.7 (4.3) [b]	326	28.5 (2.7) [b]
Household's Education Level						
Less than high school	2,014	18.6 (1.6)	1,044	19.6 (2.3)	970	17.6 (1.8)
High school grad/GED or equivalent	1,822	25.1 (1.4)	928	24.9 (2.1)	894	25.2 (1.8)
Some college or associate degree	2,344	32.7 (1.9)	1,192	32.6 (2.3)	1,152	32.9 (2.1)
College graduate or above	1,823	47.1 (2.2) *	910	45.7 (2.5) *	913	48.5 (3.2) *
Screen Time (≥2 years)						
≤ 1 h/day	1,120	37.7 (2.8)	511	36.0 (2.9)	609	39.1 (3.5)
>1–≤ 2 h/day	1,477	36.9 (1.9)	709	38.7 (2.9)	768	35.1 (2.4)
>2–≤ 4 h/day	2,527	34.9 (1.6)	1,328	33.8 (2.2)	1,199	36.0 (2.3)
>4 h/day	1,753	26.5 (1.2) *	959	26.4 (2.1) *	794	26.6 (2.1) *
Weight Status (≥2 years) [3]						
Underweight	239	38.2 (4.3)	130	33.6 (5.4)	109	43.4 (6.3)
Normal Weight	4,171	36.9 (1.5)	2,119	36.8 (1.6)	2,052	37.0 (1.9)
Overweight	1,028	31.2 (2.0)	530	32.0 (3.5)	498	30.5 (2.9)
Obese	1,168	24.5 (1.8) *	599	25.0 (2.4)	569	24.0 (2.5) *

Abbreviations: GED, general equivalency diploma. [1] Estimates with different letter subscripts (i.e., a or b) are significantly different across subgroups within each category at $p < 0.0167$; asterisk (*) indicates significant linear trend at $p < 0.0167$. For age comparison, infants <1 year were not included in the contrast. [2] "Other" race group (n = 259) was not presented as recommended by the National Center for Health Statistics (NCHS).[3] Data were examined separately using the examination weight.

Table 3.2. Estimated percentage distribution and mean number of dietary supplement taken by U.S. children (≤18 years) in a 30-d period, by age group, NHANES 2011−2014[1,2]

Characteristic	All (*n* = 2,365)	<1 year (*n* = 119)	1-3 years (*n* = 509)	4-8 years (*n* = 800)	9-13 years (*n* = 519)	14-18 years (*n* = 419)
	% (SE)					
Type or products						
MVM*	74.3 (1.7)	10.6 (2.6)	78.5 (2.6)	82.6 (2.2)	76.1 (2.7)	62.7 (3.6)
Multivitamins	9.6 (1.4)	29.7 (4.7)	10.8 (1.8)	10.2 (2.2)	9.3 (1.9)	5.7 (1.4)
Vitamin C*	7.3 (1.0)	0.0 (0.0)	—	4.4 (1.1)	8.3 (1.6)	16.2 (3.0)
Vitamin D*	5.0 (0.7)	47.3 (6.2)	1.8 (0.7)[2]	2.7 (0.9)[2]	3.0 (0.7)	8.9 (2.3)
Calcium*	4.7 (0.7)	0.0 (0.0)	—	5.0 (1.3)[2]	3.6 (1.3)[2]	8.3 (2.2)
Botanicals*	4.2 (0.9)	—	—	—	—	8.3 (1.8)
Fatty acids*	2.4 (0.6)	0.0 (0.0)	—	—	1.4 (0.5)[2]	7.6 (2.6)[2]
Iron	1.6 (0.4)	—	1.2 (0.4)[2]	—	—	4.2 (1.2)
Number of supplements taken, % (SE)						
1*	82.7 (1.5)	91.8 (2.7)	90.1 (2.1)	85.6 (2.3)	82.9 (2.3)	71.0 (2.8)
2*	11.9 (1.1)	5.8 (2.1)	9.3 (2.0)	8.8 (1.6)	13.1 (1.9)	18.0 (2.3)
3 or more*	5.4 (0.8)	—	—	5.6 (1.4)	4.0 (1.1)	11.0 (2.4)
Mean number of supplements taken, mean (SE)*	1.3 (0.03)	1.1 (0.04)	1.1 (0.02)	1.2 (0.04)	1.2 (0.04)	1.5 (0.08)

Abbreviations: MVM, multivitamin-minerals; NHANES, National Health and Nutrition Examination Survey.
[1] Asterisk (*) indicates significant linear trend across age groups at P < 0.0167. Infants <1 year were not included in the contrast. [2] The relative SE is >30% but ≤40% and may be statistically unreliable. If the relative SE>40%, data are not shown (—).

Table 3.3. Estimated percentage of U.S. children (≤18 years) who used dietary supplement in a 30-day period by economic indicators, NHANES 2011−2014[1,2]

Characteristic	*n*	Any DS	MVM	Multivitamins	Vitamin C	Vitamin D
		% (SE)				
Total	8,288	32.4 (1.2)	24.1 (1.2)	3.1 (0.5)	2.4 (0.3)	1.6 (0.2)
PIR						
≤130%	3,726	22.2 (1.6) [a]	17.1 (1.4) [a]	1.8 (0.4) [a]	1.1 (0.3) [a]	0.9 (0.2) [a]
131–350%	2,379	34.6 (1.5) [b]	24.4 (1.6) [b]	4.0 (0.9) [a,b]	3.2 (0.7) [b]	1.7 (0.4) [a,b]
>350%	1,533	44.7 (2.4) [c,*]	33.6 (3.0) [c,*]	4.0 (0.8) [b,*]	3.3 (0.9) [a,b]	2.7 (0.6) [b,*]
Food security						
Food-insecure	2,169	22.3 (2.0) [a]	15.8 (1.3) [a]	2.8 (0.8)	1.9 (0.6)	0.4 (0.1) [a,2]
Food-secure	6,055	35.1 (1.3) [b]	26.2 (1.5) [b]	3.2 (0.5)	2.5 (0.4)	2.0 (0.3) [b]
SNAP participation						
Participant	2,922	19.5 (1.5) [a]	14.4 (1.3) [a]	1.6 (0.5) [a]	0.6 (0.2) [a,2]	0.8 (0.3) [a,2]
Income-eligible nonparticipant	1,377	27.9 (1.9) [b]	22.4 (1.9) [b]	1.6 (0.5) [a]	2.0 (0.7) [a,b,2]	0.8 (0.3) [a,2]
Income-ineligible nonparticipant	3,509	40.3 (1.6) [c]	29.3 (1.9) [c]	4.3 (0.8) [b]	3.5 (0.5) [b]	2.3 (0.4) [b]
WIC participation						
Participant	1,562	25.9 (1.8) [a]	19.4 (1.7) [a]	3.3 (0.8)	—	0.8 (0.3) [a,2]
Income-eligible nonparticipant	386	35.5 (3.9) [b]	28.6 (3.7) [a,b]	4.1 (1.4) [2]	—	—
Income-ineligible nonparticipant	764	47.1 (2.3) [c]	33.7 (3.0) [b]	5.2 (1.0)	1.1 (0.4) [2]	3.7 (0.7) [b]

Abbreviations: DS, dietary supplement; MVM, multivitamin-minerals; NHANES, National Health and Nutrition Examination Survey; PIR, family income-to-poverty ratio; SNAP, Supplemental Nutrition Assistance Program; WIC, the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children. [1] Estimates with different letter subscripts (i.e., a, b, or c) are significantly different across subgroups within each indicator category at $p < 0.0167$; asterisk (*) indicates significant linear trend across PIR subgroups at $p < 0.0167$; [2] The relative SE is >30% but ≤40% and may be statistically unreliable. If the relative SE > 40%, data are not shown (—).

Table 3.4. Estimated percentage distribution and mean number of any dietary supplement taken by U.S. children (≤18 years) in a 30-day period by economic indicators, NHANES 2011–2014[1,2]

	All (*n* = 2,365)	**PIR (*n* = 2,189)**			**Food security (*n* = 2,339)**		**SNAP Participation (*n* = 2,220)**			**WIC Participation (<5 years; *n* = 793)**		
		≤130% (*n* = 736)	**130–350% (*n* = 768)**	**>350% (*n* = 685)**	**Food-Insecure (*n* = 443)**	**Food-Secure (*n* = 1,896)**	**Participant (*n* = 532)**	**Income-Eligible Non-SNAP (*n* = 344)**	**Income-Ineligible Non-SNAP (*n* = 1,344)**	**Participant (*n* = 339)**	**Income-Eligible Non-WIC (*n* = 113)**	**Income-Ineligible Non-WIC (*n* = 341)**
Number of supplements taken, % (SE)												
1	82.7 (1.5)	89.1 (2.1) [a]	81.9 (2.6) [b]	78.9 (2.8) [b,*]	81.8 (1.7)	87.2 (2.5)	91.3 (1.9) [a]	86.7 (3.6) [a,b]	79.9 (1.9) [b]	92.2 (3.0)	95.2 (2.5)	86.6 (3.0)
2	11.9 (1.1)	7.6 (1.5) [a]	12.0 (2.1) [a,b]	14.8 (2.0) [b,*]	12.5 (1.2)	9.0 (2.3)	5.9 (1.7) [a]	10.0 (2.5) [a,b]	13.6 (1.6) [b]	—	—	12.0 (3.0)
3 or more	5.4 (0.8)	3.3 (1.3) [2]	6.1 (1.4)	6.3 (1.5)	5.7 (0.9)	—	—	—	6.4 (0.9)	—	—	—
Mean number of supplements taken, mean (SE)	1.26 (0.03)	1.15 (0.03) [a]	1.30 (1.3) [b]	1.30 (0.04) [b,*]	1.28 (0.03)	1.18 (0.04)	1.13 (0.03) [a]	1.17 (0.05) [a]	1.31 (0.03) [b]	1.09 (0.03)	1.06 (0.03)	1.16 (0.03)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; PIR, family income-to-poverty ratio; SNAP, Supplemental Nutrition Assistance Program; WIC, the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children. [1] Estimates with different letter subscripts (i.e., a or b) are significantly different across subgroups within each indicator category at $p < 0.0167$; asterisk (*) indicates significant linear trend across PIR subgroups at $p < 0.0167$. [2] The relative SE is >30% but ≤40% and may be statistically unreliable. If the relative SE > 40%, data are not shown (—).

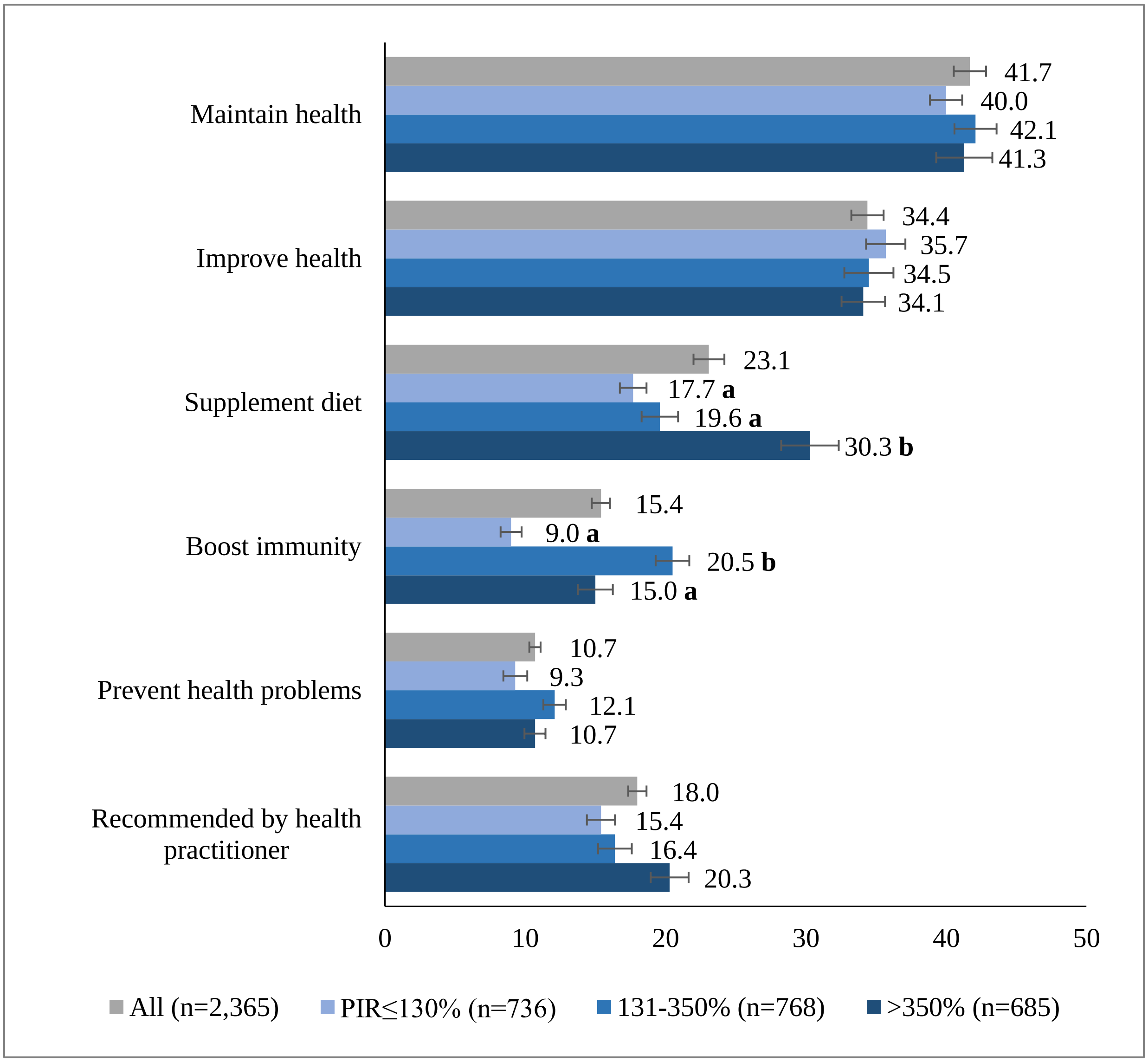

Figure 3.1. Estimated percentage (%(SE)) of dietary supplement users (≤18 years) who had the listed motivations for any dietary supplement use in a 30-day period by family income level, NHANES 2011-2014

PIR, family income-to-poverty ratio. Estimates with different letter subscripts (i.e., a or b) are significantly different across PIR subgroups at $p < 0.0167$. Participants could select more than one motivation for each product.

Table 3.5. Estimated percentage (%(SE)) of any dietary supplement users (≤18 years) and motivations for use in a 30-d period by food security and SNAP and WIC participation status, NHANES 2011−2014[1,2]

	Food security (*n* = 2,339)		**SNAP participation (*n* = 2,220)**			**WIC participation (<5 years; *n* = 793)**		
	Food-insecure (*n* = 443)	**Food-secure (*n* = 1,896)**	**Participant (*n* = 532)**	**Income-eligible non-SNAP (*n* = 344)**	**Income-ineligible non-SNAP (*n* = 1,344)**	**Participant (*n* = 339)**	**Income-eligible non-WIC (*n* = 113)**	**Income-ineligible non-WIC (*n* = 341)**
Top 5 motivations								
To maintain health	41.3 (3.8)	41.6 (2.7)	41.0 (3.8)	39.3 (4.0)	41.7 (3.2)	39.1 (3.8)	46.8 (4.7)	38.1 (4.1)
To improve overall health	36.5 (4.9)	34.1 (2.6)	35.4 (3.6)	35.6 (4.4)	34.2 (3.0)	29.2 (3.8)	36.5 (8.3)	34.8 (3.2)
To supplement diet	16.9 (2.7)	24.2 (2.7)	16.3 (2.5)	18.5 (2.2)	25.8 (3.2)	24.0 (2.8)	22.1 (4.7)	29.9 (3.9)
To prevent health problems	14.8 (2.8)	15.4 (1.6)	11.1 (1.8) [a,b]	9.8 (2.4) [a]	17.6 (2.0) [b]	10.4 (2.5)	—	14.8 (2.7)
To prevent colds, boost immunity	9.6 (2.0)	11.1 (0.9)	9.6 (1.7)	9.9 (2.5)	11.4 (1.0)	12.1 (2.5)	12.1 (4.6) 2	8.2 (2.0)
Health practitioner recommended								
Yes	15.4 (2.0)	18.3 (1.6)	22.9 (3.0) [a]	10.8 (1.9) [b]	18.0 (1.8) [a,b]	30.9 (3.2) [a]	14.6 (3.5) [b]	28.9 (4.6) [a]

Abbreviations: NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program; WIC, the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children.

[1] Estimates with different letter subscripts (i.e., a or b) are significantly different across subgroups within each indicator category at $P < 0.0167$. [2] The relative SE is >30% but ≤40% and may be statistically unreliable. If the relative SE>40%, data are not shown (—).

Table 3.6. Estimated percentage (%(SE)) of multivitamin-mineral users (≤18 years) and motivations for use in a 30-day period by economic indicators, NHANES 2011–2014[1,2]

		PIR (*n* = 1,588)			Food Security (*n* = 1,694)		SNAP Participation (*n* = 1,609)			WIC Participation (<5 years; *n* = 544)		
	All (*n* = 1,716)	**≤130% (*n* = 537)**	**130–350% (*n* = 543)**	**>350% (*n* = 508)**	**Food-Insecure (*n* = 314)**	**Food-Secure (*n* = 1,380)**	**Participant (*n* = 387)**	**Income-Eligible Non-SNAP (*n* = 254)**	**Income-Ineligible Non-SNAP (*n* = 968)**	**Participant (*n* = 225)**	**Income-Eligible Non-WIC (*n* = 84)**	**Income-Ineligible Non-WIC (*n* = 235)**
Top 5 motivations												
To maintain health	45.7 (2.3)	44.0 (3.2)	45.0 (4.2)	46.0 (4.2)	43.1 (4.1)	45.8 (2.8)	45.5 (3.9)	43.9 (4.9)	45.4 (3.4)	43.0 (4.2)	50.0 (5.7)	41.7 (4.8)
To improve overall health	38.0 (2.9)	41.5 (3.5)	38.7 (4.1)	35.5 (3.8)	42.1 (5.5)	37.4 (3.1)	40.6 (4.3)	39.7 (5.5)	37.2 (3.6)	31.0 (4.6)	43.6 (10.0)	40.6 (4.0)
To supplement diet	23.9 (2.6)	17.1 (2.4) [a]	19.9 (2.9) [a]	32.3 (4.6) [b,*]	18.6 (3.1)	24.7 (3.1)	15.3 (2.7) [a]	18.4 (3.1) [a,b]	27.2 (3.6) [b]	26.9 (3.2)	22.5 (5.8)	29.9 (4.6)
To prevent health problems	10.4 (0.9)	10.0 (2.0)	12.8 (2.4)	8.6 (1.6)	9.5 (2.2)	10.7 (1.1)	10.0 (2.0)	10.4 (3.0)	10.8 (1.3)	13.1 (3.4)	13.0 (4.5) [2]	9.0 (2.8) [2]
To prevent colds, boost immunity	10.4 (1.0)	7.1 (1.3) [a]	12.5 (2.0) [b]	10.1 (1.8) [b]	11.4 (2.5)	10.0 (1.1)	9.0 (1.9)	6.6 (1.8)	11.3 (1.6)	7.9 (2.1)	—	13.6 (3.3)
Health practitioner recommended												
Yes	15.3 (1.6)	12.4 (2.5)	13.9 (2.4)	17.2 (3.4)	15.1 (2.4)	15.0 (2.0)	20.5 (3.6) [a]	8.7 (2.2) [b]	15.0 (2.2) [b]	26.4 (3.9)	—	21.8 (4.7)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; PIR, family income-to-poverty ratio; SNAP, Supplemental Nutrition Assistance Program; WIC, the Special Supplemental Nutrition Assistance Program for Women, Infants, and Children. [1] Estimates with different letter subscripts (i.e., a or b) are significantly different across subgroups within each indicator category at $p < 0.0167$; asterisk (*) indicates significant linear trend across PIR subgroups at $p < 0.0167$. [2] The relative SE is >30% but ≤40% and may be statistically unreliable. If the relative SE > 40%, data are not shown (—).

3.5. Discussion

The prevalence of DS use among U.S. children has remained relatively consistent over time; about a third of U.S. children use DS, mostly micronutrient supplements such as MVM and multivitamins. Children in households with low incomes and food insecurity were less likely to use DS than those in more affluent households, as suggested in previous studies (7–10). In addition, DS users in low-income families took fewer products and were less likely to have “supplementing the diet” as the motivation for their use of DS and MVM than those in higher-income families, even though low-income families may face barriers to nutrient-dense diets (20–24). The impact of income differences in DS use on total nutrient intakes (i.e., nutrient intake from foods, fortification, and DS) among children should be further investigated, but results from adult NHANES data analysis suggested that income differences in DS use lead to larger disparities in total nutrient intake than when only nutrient intakes from foods are calculated (6,25).

DS use was lowest among children currently receiving WIC benefits (26%) and those in households receiving SNAP benefits (20%). This may be because the programs are linked to income. It is also notable that SNAP and WIC did not permit the purchase of DS with program benefits. Another possible explanation can be that the programs increase the amount of resources available for buying food, which may have eased parents’ concerns about the adequacy of their children’s diets. Previous studies also suggest that children receiving nutrition assistance (e.g. WIC, SNAP, and reduced/free school meals) were less likely to use any DS or nutrient supplements than nonparticipants of these nutrition assistance programs (7,8). However, these studies did not further divide nonparticipants into income-eligible and income-ineligible nonparticipants, making it difficult to distinguish the effect of family income from that of nutrition assistance program participation. Nevertheless, USDA reports based on NHANES data have shown that DS use is lowest among SNAP and WIC participating children compared to both income-eligible and higher-income nonparticipants (26,27).

The proportion of the products taken by child users of DS on the basis of health care professional’s recommendations were about 16% in 2007–2010 survey (9). Overall, 18% of children who used DS and 15% of those who used MVM took at least one product based on health practitioners’ recommendations. SNAP and WIC participants were more likely to use DS based on the recommendations of a health practitioner than income-eligible nonparticipating counterparts. WIC provides health care referrals in addition to food vouchers, and those referrals may have increased the program participant's access to health practitioner's recommendations (28,29) that may have served as cues for action (8).

Although DS are defined to supplement the diet under the Dietary Supplement Health and Education Act, four of the top five motivations for DS or MVM use were related to health promotion and disease prevention: "to maintain health," "to improve overall health," "to prevent colds," and "to prevent health problems". Our results supported that many DS users perceive supplements as "insurance" against health problems (30–32), although evidence of the health benefits of dietary supplements are controversial and complex (33–35). DS use information of children aged <16 y was given by their proxies, so some motivations reported may be of parents or caregivers, not of children themselves. Moreover, it is possible that even motivations of children themselves were determined or largely influenced by parents and caregivers. Further research is needed on how parent's perceptions and use of DS affect children's DS use. So far, Yu et al. (36) reported that DS use of preschoolers was associated with mother's supplement use before pregnancy and the mother's perception of child's eating behavior, and Dwyer et al. (37) showed that child DS use is similar to parents' use in terms of type of product type.

The characteristics of supplement users in our study were consistent with previous reports. Users tended to be younger (1–3 years and 4–8 years), be non-Hispanic white, have private health insurance, spend less time in front of television or computer screens, and have lower BMI (girls only) (7–10). Because NHANES 2011–2014 oversampled non-Hispanic Asian persons, this study is the first to report estimates for non-Hispanic Asian children using NHANES data. The prevalence of DS use in non-Hispanic Asians was similar to that in non-Hispanic whites. The trends in use by sex, age, and weight status among children were different than those found in adults. In adults, DS use was higher in women, increased linearly with age, and was greatest among normal weight and lowest among underweight and obese adults (1,4). Child DS users also had different patterns regarding the number and type of DS taken compared with adult users. The vast majority of child DS users (83%) were taking only one product, while 5% were taking 3 or more products; whereas about half of adult users took only one product and about 10% were using 5 or more products (38).

MVM were the most commonly used DS products across all age groups except infants (<1 year). Among infants, vitamin D as single-ingredient product was most frequently used.

After infancy, the products used were more diverse in older children, similar to a greater variety of products used by adults (1,4). For some age-sex groups, there may be a need for products containing certain ingredients. For example, under-consumption of iron by female adolescents was noted in the 2015–2020 Dietary Guidelines for Americans (39). However, only 9.0% (SE 0.7%) took any iron-containing supplements (data not shown); this estimate was much lower than the estimate of 13.8% (SE 0.7%) for 14–18-year-old girls from a 1999–2002 NHANES analysis (7).

A limitation of our analysis was that DS use information of children under 16 years was obtained mainly from proxies who may not remember or observe whether their children actually consumed the product or how much they consumed. Another limitation is that the motivations for DS use were assessed at one point in time due to cross-sectional nature of the NHANES. Strengths of our study include the large nationally representative sample of children and rigorous methods used for DS information collection: in-person interview, checking containers and labels in home, and post hoc review and classification of the information by nutritionists. NHANES has collected information about motivations for DS use since 2007. To our knowledge, this study is the first to examine the detailed DS use information and motivations for DS use by economic indicators.

There are many theories regarding DS use. Some of our results highlight the "inverse supplement hypothesis" that suggests healthier and more health-conscious people with better quality diets are more likely to use DS (30,31), and the Health Belief Model that suggests limited financial resources may be one of the modifying factors that may supersede intentions for DS use (8). Nutrients from DS can contribute substantial amount of nutrients to total nutrient intake and, therefore, may fill the nutrient gaps for those who otherwise would not meet recommended intake targets of some nutrients (40–42). DS may differentially contribute to total nutrient intake by socioeconomic status as shown in previous studies using PIR as a poverty indicator (6,25). However, this argument assumes that the nutrient gaps are filled by the DS taken, which is highly dependent on whether there is a nutrient gap to begin with and whether DS taken contain the deficient nutrient. Future work should estimate total nutrient intakes from foods and DS to identify the proportions of various socioeconomic subpopulations that are not meeting Estimated Average Requirements or exceeding Tolerable Upper Intake Levels and to what extent nutrients from DS contribute to total intakes. At the same time, more investigations on the safety of DS and the efficacy of DS are needed. The practical implementation and behavioral changes necessary for effective supplement use among children in households with limited resources are also unknown. More efforts are warranted to ensure adequate nutrition across all socioeconomic groups, taking into account the complex interplay of socioeconomic, lifestyle, health, and psychological determinants and incorporating diverse actors, including caregivers, health care providers, and society.

In conclusion, DS are used by about a third of U.S. children, with most child DS users using MVM or multivitamins and taking only one product in a 30-d period. DS use was greater among children in families with a higher household income and a higher level of household food security, and was lowest among children living in lower income families who were participating in WIC or SNAP. The most common motivations for DS use were related to health across all subgroups, while children in high-income families were more likely to use DS “to supplement the diet.” The data suggest that there are systematic differences in DS use and types of DS used by family income level, food security level, and federal nutrition assistance program participation status.

3.6. Acknowledgements

RLB, SJ, and AEC conceptualized and designed the study; SJ performed analyses and drafted the initial manuscript; SJ, AEC, and RLB interpreted the data and SJ, AEC, JAT, JJG, JTD, HAE-M., AB, PMG, NP, KWD, and RLB reviewed and revised the manuscript. All authors read and approved the final manuscript.

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CHAPTER 4 . CHILDREN’S DIETARY QUALITY AND MICRONUTRIENT ADEQUACY BY FOOD SECURITY IN THE HOUSEHOLD AND AMONG HOUSEHOLD CHILDREN

Jun S, Zeh MJ, Eicher-Miller HA, and Bailey RL. Children’s dietary quality and micronutrient adequacy by food security in the household and among household children. *Nutrients* 2019; 11(5), 965. doi: 10.3390/nu11050965.

4.1. Abstract

Children’s food-security status has been described largely based on either the classification of food security in the household or among household children, but few studies have investigated the relationship between food security among household children and overall dietary quality. Our goal was to examine children’s dietary quality and micronutrient adequacy by food-security classification for the household and among household children. Data from 5540 children (2–17 years) from the National Health and Nutrition Examination Survey (NHANES) 2011–2014 were analyzed. Food-security status was assessed using the U.S. Household Food Security Survey Module and categorized into high, marginal, low, and very low food security for the households and among household children. Dietary quality and micronutrient adequacy were characterized by the Healthy Eating Index (HEI) 2015 and Mean Adequacy Ratio (MAR; based on total nutrient intakes from diet and dietary supplements), respectively. The HEI 2015 scores did not substantially vary by either food-security classification, but the MAR was greater in high compared to very low food security in households and among household children; a linear relationship was found only among household children. In general, very good agreement was observed between the classifications, but the strength of agreement differed by children’s age, race/Hispanic origin, and family income. In conclusion, micronutrient adequacy, but not dietary quality, significantly differed by food-security status. While the agreement between food security in the household and among household children is very good, classification of food security

among household children may be more sensitive to detecting differences in exposure to nutrients.

4.2. Introduction

Food insecurity occurs when consistent access to enough food for an active and healthy life is limited or uncertain due to lack of resources for food (1,2). Food-security status in the United States (U.S.) has been assessed since 1995 by the U.S. Department of Agriculture (USDA) using the U.S. Household Food Security Survey Module (HFSSM) (3). The USDA classification of food insecurity represents a range of experiences characterizing limited resources for food: high food security is defined as no indication of limits to food access, marginal food security as anxiety about securing food but little indication of changes in diet or food intake, low food security as reduced quality of diet, and very low food security as altered eating patterns and reduced quantity of food intake (2). Food insecurity is quantified for the entire household using the full set of questions in the HFSSM, adults in the household using the 10 adult-specific items in the HFSSM, and children in the household using the eight child-specific items. The ranges of experience for the household or children in the household (i.e., household children) are classified using the Household Food Security Scale or the Child Food Security Scale, respectively. Such a tailored approach to food-security classification recognizes that the experience of children may be different with adults living in the same household. In 2017, household food insecurity (i.e., food insecurity in the household) was estimated at 15.7% among households with children, 11.6% with low food security and 4.1% with very low food security (2). Meanwhile, in 7.7% of households with children, at least one child was food-insecure (i.e., food insecurity among household children), suggesting that children may not have directly experienced food insecurity in about half of food-insecure households with children.

Previous systematic and narrative reviews of U.S. studies showed evidence of adverse associations between food insecurity and dietary outcomes among children that may vary by age, although less consistent when compared to adults (4,5). Among the studies that utilized the HFSSM or its short form, many used the Household Food Security Scale to describe children's food-security status, and a few studies used the Child Food Security Scale to investigate the relationship with dietary intake (4). The choice of food-security scale may impact the resulting relationship discovered between food security and dietary intake. Agreement between the scales has not been evaluated since the development of the Child Food Security Scale (6). Furthermore, most studies focused on individual nutrients and food groups rather than overall dietary quality. Several indices of dietary quality were developed to reflect multiple components of the human diet (7). The Healthy Eating Index (HEI) measures adherence to the Dietary Guidelines for Americans (DGA), primarily based on food intake (8), whereas the Mean Adequacy Ratio (MAR) assesses micronutrient intakes relative to Dietary Reference Intakes (9-11). The objective of this study was to examine children's dietary quality and micronutrient adequacy by food security in the household and among household children using a nationally representative sample of U.S. children from the National Health and Nutrition Examination Survey (NHANES) 2011–2014. Agreement between household food security and child food security was also examined.

4.3. Materials and methods

4.3.1. Study population

The NHANES is a nationally representative, cross-sectional survey that samples the noninstitutionalized, civilian residents of the United States using a complex, stratified, multistage probability cluster-sampling design (12). The NHANES survey protocol was approved by the Research Ethics Review Board at the National Center for Health Statistics, and written informed consent was obtained for all participants or proxies. The NHANES protocol includes an in-home interview of demographics and self-reported health information, and a follow-up health measurement in a Mobile Examination Center for each participant. For survey participants who were under 16 years of age, a proxy provided information. We combined data from the 2011–2012 and 2013–2014 NHANES survey cycles, collected based on the four-year sample design that oversampled non-Hispanic non-Black Asian persons for the first time; these have most up-to-date dietary-supplement intake data because dietary-supplement use information is not yet available from the 2015–2016 cycle. From 2011, NHANES collected food-security information using the HFSSM alone and discontinued implementing several follow-up items on individual-level food security. The analytic sample included children ages 2–17 years with complete food-security information and reliable dietary recall data for at least one day (n = 5540). Children under 2 years were excluded, as Healthy Eating Index (HEI) score estimation is not possible in these ages because the DGA are for the U.S. population ages two and older.

4.3.2. Food security assessment

The HFSSM was administered during the household interview, where an adult responded to the questions for the entire family (3). The Household Food Security Scale was used to classify food security for households with children ages 17 years and younger, and the Child Food Security Scale was used to classify the experience of children in the household (i.e., household children). Based on the number of affirmative responses, household food security was categorized as high (0), marginal (1–2), low (3–7), or very low (8–18) (3). Food security among household children was categorized as high (0), marginal (1), low (2–4), and very low (5–8) per NHANES documentation. Both household food security and food security among household children are reflective of conditions over the last 12 months, the reference period inherent to the HFSSM.

4.3.3. Sociodemographic variables

Sociodemographic characteristics that were linked with food-security status in the previous literature were examined, including individual characteristics (age, sex, race/Hispanic origin, and sibling status) and household characteristics (parental education level, family income, and food-assistance-program participation) (2,13). Self-reported race/Hispanic origin groups as defined in the NHANES were non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic, and other races; the "other" race group was only included in the estimates for the total sample as recommended (12). Household education level, defined as the education level of an adult household member who owns or rents the residence, was categorized as less than high school, high school or equivalent, some college or associate degree, and college graduate or above. The family poverty-to-income ratio (PIR) is the ratio of the annual family income to the poverty guideline established by the Department of Health and Human Services. PIR was categorized as <1, 1–1.3, 1.31–1.85, and >1.85. Families with PIR below 1 are considered "poor" by the Census Bureau (14). PIR of 1.3 is an income eligibility criterion for the Supplemental Nutrition Assistance Program (SNAP), a federally funded food-assistance program that provides cash benefits for food (15,16). A PIR of 1.85 also serves as the income eligibility criterion of other federal food-assistance programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (16). Current household SNAP participation status was categorized as participating, income-eligible but not participating, and income-ineligible and not participating. Lastly, whether a child is a singleton (i.e., an only child) or has one or more siblings was determined based on the information about the number of children in the household. When a child was living in a household with two or more children, the child was considered to have a sibling.

4.3.4. Dietary intake data

Dietary-intake data were collected using the Automated Multiple-Pass Method as part of What We Eat in America using two 24-hour dietary recalls (17). The first 24-hour recall was collected in person in the Mobile Examination Center, and the second recall was collected via phone 3 to 10 days later. During the 24-hour recall interview, information on the types and amounts of dietary supplements consumed during the 24-period prior to the interview was also collected, directly after the collection of food and beverage information. The USDA's Food and Nutrient Database for Dietary Studies and NHANES Dietary Supplement Database were used to convert foods and beverages, and dietary supplements, respectively, to nutrient values.

Children's dietary quality was characterized by the HEI 2015 because the HEI 2015 is based on the latest iteration of the DGA that reflects the most updated evidence on healthy eating. The HEI 2015 is a validated dietary-quality index that measures conformance to the 2015–2020 DGA (8). The HEI 2015 rates densities of consumed food groups and nutrients rather than absolute amounts to evaluate dietary quality rather than dietary quantity. The HEI 2015 represents 13 dietary components with a total score of 100: adequacy components include total fruit (maximum score of 5), whole fruit (5), total vegetables (5), greens and beans (5), whole grains (10), dairy (10), total protein foods (5), seafood and plant proteins (5), and fatty acids (10), and moderation components include refined grains (10), sodium (10), added sugars (10), and saturated fats (10). The HEI 2015 components are similar with those of the HEI 2010 that assesses adherence to the 2010–2015 DGA, except that HEI 2015 includes separate components for 'added sugars' and 'saturated fats' instead of 'empty calories' component, does not include excessive energy from alcohol in any component, and allocates the legumes to all 4 components for vegetables and protein foods (8). The scores were calculated at group level by the population ratio method based on first-day recalls (18,19) using publicly available SAS macros from the National Cancer Institute (20).

The MAR was chosen as an index of micronutrient adequacy. The MAR is calculated at an individual-person level based on nutrient intake from diet alone (i.e., dietary nutrient intake) or based on total nutrient intake from diet and dietary supplements (9,11). Nutrient intake data were derived from the mean of two 24-hour dietary recalls when available, and from the first recall when only one reliable recall is available. Nutrient-adequacy ratio is the ratio of an individual's nutrient intake to the Recommended Dietary Allowance (RDA) or Adequate Intakes (AI) from the Dietary Reference Intakes, truncated at 1.0 (21,22). The MAR is the mean of NAR values for individual nutrients. This analysis included the NAR and MAR for the 9 shortfall micronutrients identified in the DGA: vitamins A, C, D, and E, folate, calcium, magnesium, iron, and potassium (23). Vitamin A and E intakes from dietary supplements are not available in the 2011–2014 NHANES and are not included in this analysis.

The prevalence of dietary-supplement use was estimated using information from a dietary-supplement questionnaire (DSQ) (24). The DSQ was administered during the in-home interview in tandem with a home inventory, and collected information about any dietary-supplement use over the past 30 days to capture both habitual and episodic consumption of dietary supplements. If a child used any dietary supplement during the 30-day period, the child was classified as dietary-supplement user. As mentioned above, dietary-supplement-use information was also collected through 24-hour dietary recalls, and nutrient intake from dietary supplements was determined from 24-hour recall data.

4.3.5. Statistical analysis

All statistical analyses were performed using SAS (version 9.4; SAS Institute, Inc., Cary, NC, USA) and SAS-callable SUDAAN (version 11; RTI International, Research Triangle Park, NC, USA) software. The 2011–2014 NHANES 4-year sample weights were used to account for differential probabilities of selection, nonresponse, and planned oversampling. Sociodemographic characteristics, including sex, age, PIR, race/Hispanic origin, household education level, sibling status, and SNAP participation status, were examined by household food security and food security among household children. The Satterthwaite-adjusted Wald Chi-square test was used to assess differences in the distribution of sociodemographic variables. Mean HEI 2015 score, dietary-supplement-use prevalence, and MAR from diet and from diet and dietary supplements were examined by household food security and food security among household children with pairwise t tests. Statistical significance was determined at a two-sided p-value <0.05.

To examine agreement between classifications of household food security and food security among household children, concordance (i.e., perfect agreement) was examined using the n obtained from Chi-square contingency tables. Raw Kappa agreement was estimated using the agree statement within proc crosstab using the survey design features. Additionally, "weighted" agreement was calculated using a Cichetti and Allison C-statistic for the four categories of food security, representing the relative proximity to each other (25). The weighing of the agreement exerts more influence to observations closer to proximity rather than to perfect agreement alone, and is the preferred method to apply to scales that are ordinal in nature, whereas the unweighted Kappa is traditionally used for nominal scales (26). The C-statistic is interpreted like a correlation coefficient and has been previously used to characterize nutritional indicators in the NHANES (27,28). Statistical differences in C-statistics among sociodemographic subgroups were assessed by the overlap of confidence intervals because survey procedures do not exist for incorporating the NHANES sample weights and complex survey design features. The test of marginal homogeneity was used to test the null hypothesis that the probabilities of all the categories are the same, which would be expected based on random chance.

4.4. Results

In a representative sample of U.S. children in 2011–2014, both household food security and food security among household children were associated with children's age, race/Hispanic origin, family income, household education level, and SNAP participation (**Table 4.1**). Compared to the high food-security category, children with marginal, low, and very low food security were more likely to be Non-Hispanic Black or Hispanic, and were living in families with lower incomes, lower educational attainment, and participating in SNAP.

There were no significant differences observed in children's HEI 2015 scores by household food security; however, specifically among household children, HEI 2015 scores with marginal food security (52.2 ± SE 1.16) were lower compared to those with high food security (55.6 ± SE 0.62), but not different to other groups (**Figure 4.1**). Dietary-supplement use was highest in the high food security category, classified by both household food security (40.4%) and food security among household children (37.3%; **Figure 4.2**). The MAR calculated from diet alone was greater in the high food security category compared to the very low food-security category classed for both household and household children (**Figure 4.3.A**). The MAR from total nutrient intake, inclusive of dietary supplements, was also higher in the high compared to the very low food-security category for both the household and among household children (**Figure 4.3.B**). In addition, only when food security among children was classified was the MAR from total intake of the marginal food-security category lower than that of the high food-security category and higher than that of very low food-security category. These patterns largely remained after adjustment for age, race/Hispanic origin, family income, and household education level, except that a significant difference was observed in the MAR from diet alone between high and marginal food security among household children (data not shown).

Sixty-six percent of children 2–17 years were living in households with high food security, while 12%, 15%, and 7% were in households with marginal, low, and very low food security, respectively (**Table 4.2**). In contrast, 84% of children were living in situations where household children had high food security, followed by 6%, 8%, and 1% having marginal, low, and very low food security, respectively. Overall, 66% of observations were perfectly concordant and, among 28% of discordant observations, almost all were categorized into a higher food security category using the Child Food Security Scale compared to the Household Food Security Scale (data not shown). Based on the unweighted Kappa, fair agreement was observed (Kappa of 0.34) between household food security and food security among household children (data not shown) (29). Analysis of the proximity of agreement in household and household children classifications using the C-statistic was 85%, and the test of marginal homogeneity suggested that the scales agreed beyond what was expected by chance ($p < 0.0001$). No substantial differences existed in the strength of agreement between boys and girls. When stratified by age group, the proximity of agreement was lower in the 2–5-year-olds (C-statistic = 0.84) than the 15–17-year-olds (C-statistic = 0.87). When stratified by race and Hispanic origin, agreement was highest in non-Hispanic Asians (C-statistic = 0.95), followed by non-Hispanic White (C-statistic = 0.89), non-Hispanic Black (C-statistic = 0.84), and Hispanics (C-statistic = 0.81). By family income, the agreement was lower in lower incomes (PIR ≤ 130%; C-statistic = 0.77) compared to higher incomes (PIR > 130%; C-statistic = 0.92); however, agreement did not vary based on singleton and sibling classification.

Table 4.1. Sociodemographic characteristics of U.S. children (2-17 years) by household food security and food security among household children, NHANES 2011-2014[1]

	Household food security (n = 5,540)					Food security among household children (n = 5,531)				
	High (n = 3,196)	**Marginal (n = 847)**	**Low (n = 1,023)**	**Very Low (n = 474)**	**P-value[2]**	**High (n = 4,438)**	**Marginal (n = 425)**	**Low (n = 578)**	**Very Low (n = 90)**	**P-value[2]**
Sex										
Boy	50.8 (1.3)	48.9 (3.0)	50.1 (2.1)	55.6 (3.9)	0.49	50.2 (1.2)	50.2 (3.0)	57.3 (3.0)	46.7 (6.7)	0.14
Girl	49.2 (1.3)	51.1 (3.0)	49.9 (2.1)	44.4 (3.9)		49.2 (1.2)	49.8 (3.0)	42.7 (3.0)	53.3 (6.7)	
Age										
2-5 years	24.3 (1.0)	27.1 (2.3)	25.5 (1.8)	16.8 (2.3)	0.02	24.8 (0.9)	29.1 (3.4)	17.6 (2.4)	9.6 (2.9)	0.01
6-14 years	55.8 (1.7)	57.7 (2.9)	55.6 (2.0)	68.0 (3.6)		56.0 (1.6)	53.4 (3.0)	67.5 (2.9)	61.3 (5.8)	
15-17 years	20.0 (1.5)	15.2 (1.8)	19.0 (1.8)	15.2 (2.7)		19.2 (1.2)	17.4 (3.0)	15.0 (2.1)	29.0 (7.1)	
Race and Hispanic origin										
Non-Hispanic White	61.3 (3.5)	39.7 (4.9)	32.6 (5.6)	37.5 (6.2)	<0.001	55.8 (3.6)	37.1 (7.1)	34.3 (6.1)	32.5 (13.5)	<0.001
Non-Hispanic Black	10.9 (1.7)	20.5 (3.6)	20.5 (2.7)	22.4 (4.3)		12.5 (1.8)	25.5 (4.6)	23.7 (3.7)	21.6 (7.5)	
Non-Hispanic Asian	6.1 (0.6)	3.6 (1.0)	2.5 (1.0)	0.9 (0.4)		5.3 (0.5)	2.7 (0.8)	2.5 (1.1)	0.4 (0.4)	
Hispanic	17.6 (2.6)	29.7 (3.8)	40.2 (4.5)	32.7 (5.7)		22.0 (2.7)	29.4 (5.7)	33.4 (5.0)	41.9 (11.9)	
Family Income										
PIR<1	14.9 (1.8)	43.9 (4.1)	48.0 (3.6)	52.5 (4.8)	<0.001	22.2 (2.3)	48.2 (4.4)	47.8 (4.1)	48.0 (12.9)	<0.001
PIR 1-1.3	7.6 (1.1)	17.4 (3.2)	12.6 (2.3)	20.5 (4.6)		8.8 (1.0)	20.8 (3.6)	16.1 (3.6)	39.3 (14.0)	
PIR 1.31-1.85	10.5 (1.3)	12.4 (1.9)	16.6 (2.9)	13.9 (3.0)		11.3 (1.2)	16.2 (3.4)	15.5 (2.8)	6.9 (3.8)	
PIR >1.85	67.0 (2.5)	26.3 (5.4)	22.8 (3.9)	13.0 (4.7)		57.7 (3.0)	14.8 (2.8)	20.6 (4.9)	5.9 (5.6)	

Household education level										
Less than high school	13.3 (1.6)	31.4 (4.3)	34.8 (3.6)	28.9 (3.7)	<0.001	18.4 (1.5)	27.8 (4.0)	27.7 (3.9)	35.3 (12.0)	<0.001
High school or equivalent	18.1 (1.8)	30.0 (2.8)	31.3 (3.7)	25.0 (3.6)		20.4 (1.7)	33.9 (5.6)	30.5 (4.5)	22.3 (9.5)	
Some college or associate degree	29.9 (2.0)	27.6 (3.7)	26.5 (3.4)	36.1 (4.0)		29.2 (1.7)	32.7 (5.6)	30.2 (3.6)	38.0 (11.8)	
College graduate or above	38.6 (2.4)	11.0 (2.8)	7.4 (1.6)	10.1 (4.3)		32.0 (2.3)	5.6 (2.4)	11.6 (4.2)	4.4 (2.5)	
SNAP										
Participating	16.8 (1.8)	45.9 (4.7)	49.4 (3.4)	54.9 (5.3)	<0.001	23.9 (2.3)	48.7 (5.3)	50.7 (5.0)	61.1 (12.1)	<0.001
Not participating, income-eligible	10.7 (1.3)	20.2 (4.0)	19.9 (2.3)	23.5 (3.3)		12.4 (1.3)	31.9 (3.5)	18.2 (2.7)	29.4 (10.6)	
Income-ineligible	72.5 (2.4)	33.9 (5.2)	30.6 (3.8)	21.6 (4.8)		63.7 (2.8)	19.4 (4.0)	31.2 (5.2)	9.5 (5.8)	

[1] Values are % (SE). Percentages may not sum to 100 owing to missing data and/or rounding. [2] P-vales are from chi-square tests. PIR, family income-to-poverty ratio; SNAP, Supplemental Nutrition Assistance Program.

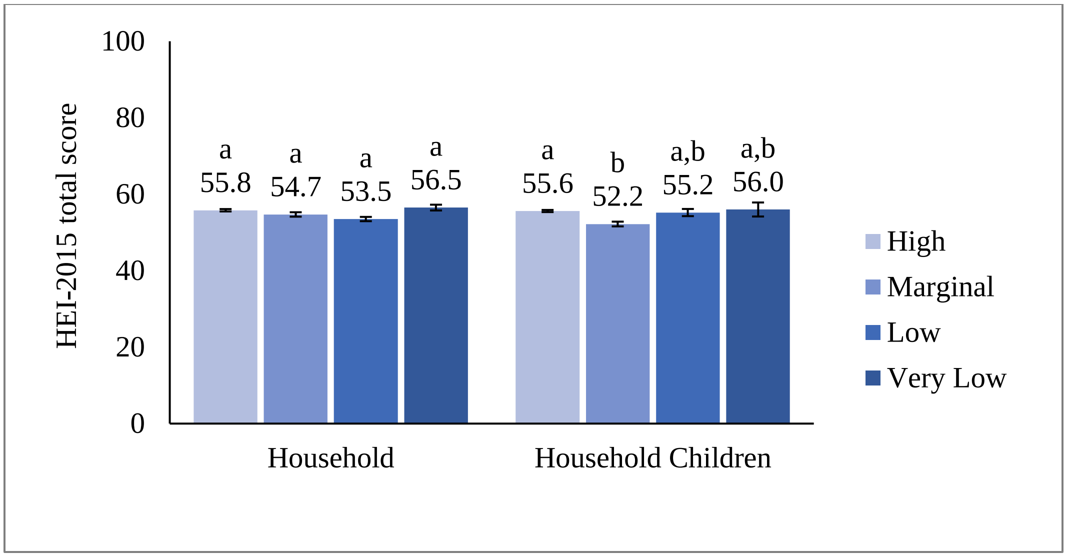

Figure 4.1. Healthy Eating Index (HEI)-2015 score of U.S. children (2-17 years) by household food security and food security among household children, NHANES 2011-2014

Estimates with different alphabet letters are significantly different based on pairwise t-tests within each classification at P-value < 0.05.

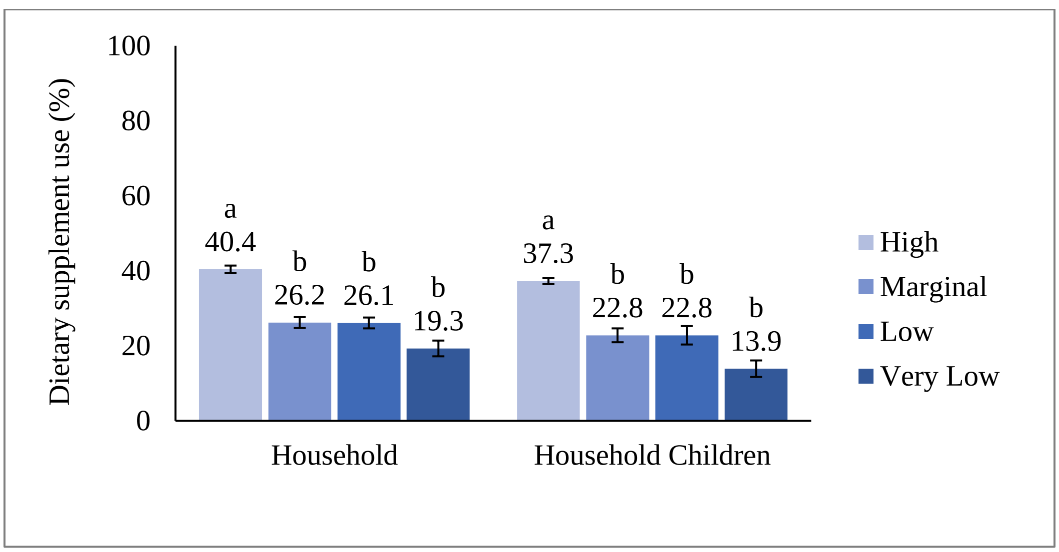

Figure 4.2. Prevalence of dietary supplement use in U.S. children (2-17 years) by household food security and food security among household children, NHANES 2011-2014

Estimates with different alphabet letters are significantly different based on pairwise t-tests within each classification at P-value < 0.05. Percentages may not sum to 100 owing to missing data and/or rounding.

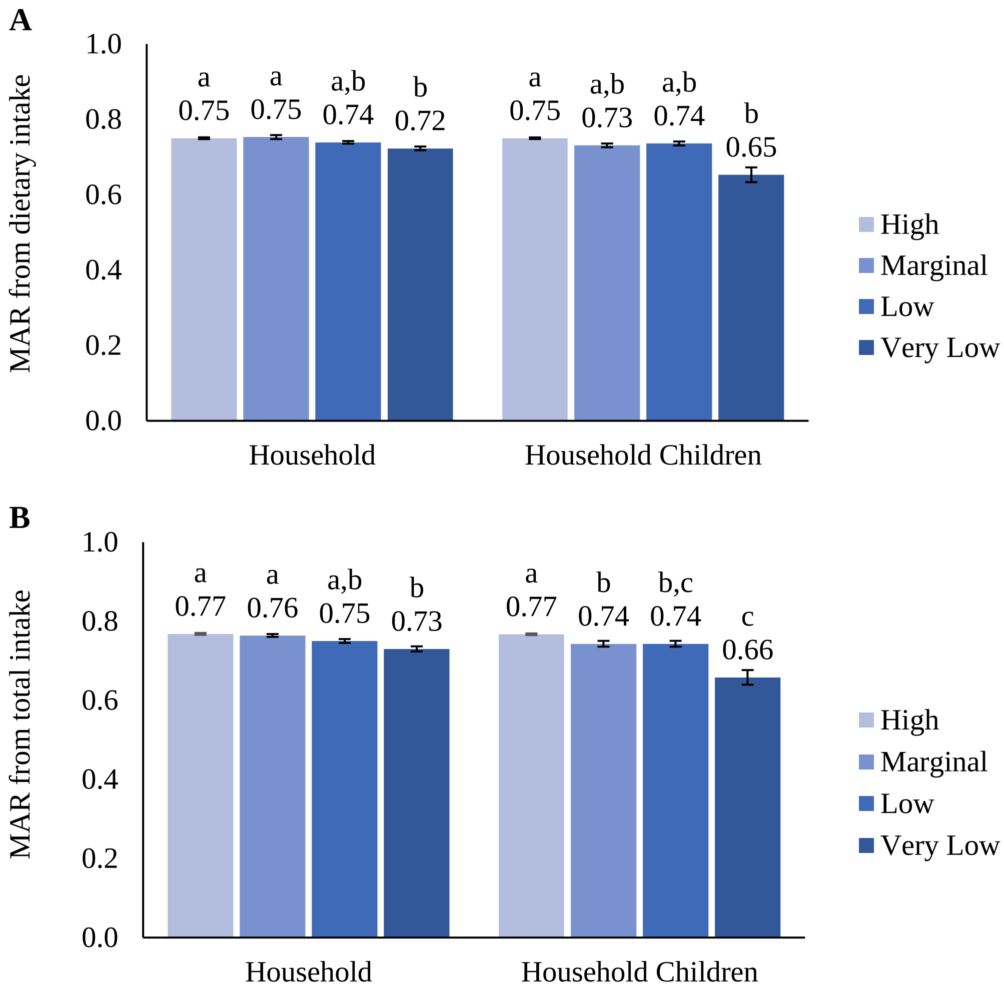

Figure 4.3. Mean Adequacy Ratio (MAR) from (A) dietary nutrient intake and (B) total nutrient intake of U.S. children (2-17 years) by household food security and food security among household children, NHANES 2011-2014

MAR was calculated from intakes of vitamins A, C, D, and E, folate, calcium, magnesium, iron, and potassium. Estimates with different alphabet letters are significantly different based on pairwise t-tests within each scale at P-value < 0.05.

Table 4.2. The agreement between household food security and food security among household children among U.S. children (2-17 years), NHANES 2011-2014[1]

	Household food security % (SE)	Food security among household children % (SE)	Concordance %	C-statistic (95% CI)	Heterogeneity chi-square[2]
All	*n=5,540*	*n=5,531*	66.0	0.851 (0.845, 0.857)	2413.2
High	65.5 (2.3)	84.4 (1.2)			
Marginal	12.0 (1.0)	6.0 (0.5)			
Low	15.2 (1.3)	8.4 (0.9)			
Very Low	7.3 (0.7)	1.3 (0.3)			
Sex: Boys	*n=2,810*	*n=2,805*	65.3	0.848 (0.839, 0.857)	1265.7
High	65.5 (2.5)	83.5 (1.4)			
Marginal	11.5 (1.1)	5.9 (0.6)			
Low	15.0 (1.4)	9.4 (1.1)			
Very Low	8.0 (1.0)	1.2 (0.2)			
Sex: Girls	*n=2,730*	*n=2,726*	66.7	0.854 (0.846, 0.863)	1148.8
High	65.5 (2.4)	85.3 (1.4)			
Marginal	12.5 (1.2)	6.0 (0.7)			
Low	15.4 (1.6)	7.3 (0.9)			
Very Low	6.6 (0.8)	1.4 (0.4)			
Age group: 2-5 years	*n=1,502*	*n=1,501*	64.5	0.840 (0.828, 0.852)	696.8
High	65.6 (2.6)	86.3 (1.4)			
Marginal	13.4 (1.4)	7.2 (0.9)			
Low	16.0 (1.4)	6.1 (0.9)			
Very Low	5.0 (0.8)	0.5 (0.2)			
Age group: 6-14 years	*n=3,144*	*n=3,140*	66.0	0.852 (0.844, 0.860)	1373.6
High	64.2 (2.6)	83.1 (1.6)			
Marginal	12.2 (1.1)	5.6 (0.6)			
Low	14.9 (1.6)	9.9 (1.3)			
Very Low	8.7 (1.0)	1.4 (0.3)			
Age group: 15-17 years	*n=894*	*n=890*	68.6	0.867 (0.852, 0.881)	348.3
High	69.2 (3.1)	85.9 (2.0)			
Marginal	9.6 (1.6)	5.5 (1.1)			
Low	15.3 (1.9)	6.6 (1.2)			
Very Low	5.9 (1.3)	1.9 (0.8)			
Race/Hispanic origin: NH White	*n=1,336*	*n=1,334*	73.5	0.885 (0.874, 0.896)	423.5
High	76.3 (2.2)	89.6 (1.5)			
Marginal	9.0 (1.4)	4.2 (0.7)			
Low	9.4 (1.4)	5.5 (1.1)			
Very Low	5.2 (1.0)	0.8 (0.4)			

Table 4.2 continued

Race/Hispanic origin: NH Black	*n=1,523*	*n=1,520*	60.8	0.836 (0.825, 0.847)	802.4
High	49.8 (2.8)	73.7 (2.3)			
Marginal	17.1 (1.5)	10.6 (1.6)			
Low	21.7 (2.5)	13.8 (1.7)			
Very Low	11.4 (1.5)	1.9 (0.7)			
Race/Hispanic origin: NH Asian	*n=572*	*n=571*	85.8	0.946 (0.935, 0.958)	77.6
High	81.9 (3.8)	92.4 (1.9)			
Marginal	8.9 (1.9)	3.3 (1.0)			
Low	7.9 (2.8)	4.2 (1.8)			
Very Low	1.3 (0.5)	0.1 (0.1)			
Race/Hispanic origin: Hispanic	*n=1,776*	*n=1,774*	57.9	0.805 (0.793, 0.817)	1086.8
High	48.9 (3.6)	78.5 (2.3)			
Marginal	15.1 (1.9)	7.4 (1.3)			
Low	25.9 (2.3)	11.8 (1.4)			
Very Low	10.1 (1.6)	2.2 (0.7)			
Family income: PIR≤1.3	*n=2,494*	*n=2,489*	48.7	0.774 (0.764, 0.784)	2090.3
High	40.2 (2.9)	71.3 (2.1)			
Marginal	19.8 (1.8)	10.7 (0.9)			
Low	25.1 (1.9)	15.1 (1.6)			
Very Low	15.0 (1.4)	2.9 (0.7)			
Family income: PIR>1.3	*n=2,710*	*n=2,707*	81.1	0.917 (0.911, 0.925)	558.3
High	80.1 (1.7)	92.0 (1.0)			
Marginal	7.2 (1.1)	2.8 (0.4)			
Low	9.4 (1.2)	4.9 (0.9)			
Very Low	3.2 (0.7)	0.2 (0.1)			
Sibling: Only child	*n=1,046*	*n=1,040*	70.1	0.863 (0.848, 0.877)	369.2
High	71.0 (2.0)	90.5 (1.0)			
Marginal	11.1 (1.2)	4.3 (0.7)			
Low	13.0 (1.4)	4.5 (0.8)			
Very Low	4.9 (0.8)	0.6 (0.2)			
Sibling: Has sibling	*n=4,494*	*n=4,491*	65.0	0.848 (0.842, 0.855)	2054.6
High	64.1 (2.6)	82.9 (1.4)			
Marginal	12.2 (1.2)	6.4 (0.5)			
Low	15.8 (1.5)	9.3 (1.1)			
Very Low	7.9 (0.8)	1.4 (0.3)			

[1] Percentages may not sum to 100 owing to missing data. Concordance indicates the percentage of concordant observations. C-statistic and heterogeneity are from a weighted kappa approach proposed by Cicchetti and Allison [25]. Concordance, C-statistic, and heterogeneity do not account for the NHANES survey design features or sampling weights, but all other values are survey weighted. PIR, family income-to-poverty ratio. NH, Non-Hispanic [2] All *P*-values were below 0.0001.

4.5. Discussion

Food insecurity can challenge a household's ability to obtain food and make healthy choices, and may negatively influence dietary quality (23). The unfavorable impact of food insecurity on childhood nutrition is especially concerning given the importance of this life stage for optimal growth and development, and the establishment of dietary behaviors that may persist into adulthood. Our findings suggest that both household food insecurity and food insecurity among household children are associated with lower micronutrient adequacy, as assessed by the MAR, and lower dietary-supplement use. A linear relationship was found only for food insecurity among household children in relationship with the MAR from total nutrient intake. Previous studies generally reported few differences in micronutrient intake from diet between food-secure (i.e., high and marginal food security) and food-insecure (i.e., low and very low food security) children, regardless of food-security scale (4,5); however, some adverse associations of calcium and iron intakes with food insecurity among household children in older children were reported (30,31). To the best of our knowledge, no study evaluated a summary measure derived from a group of nutrients (e.g., MAR) that reflects comprehensive nutrient intakes rather than single nutrients (7). Furthermore, few studies have examined children's total nutrient intake from both foods and dietary supplements by food-security status, although dietary-supplement use is known to differ by food security and household income (24). Given that dietary supplements contribute substantial amounts of nutrients to children who use them (32), analysis of food-security comparisons should consider inclusion of nutrients from all sources (33).

The HEI 2015 score did not substantially differ by household food security or food security among children, consistent with many previous studies on food-based dietary-quality indices or food-group intakes (34-38). There was very little variation in overall HEI scores, with all scores in the midrange of 50 out of a total possible 100 points (i.e., perfect adherence to the DGA). However, several other studies have reported lower fruit and vegetable intake, and higher added sugar intake in food-insecure children than in food-secure children, suggesting some possible constraints on specific dimensions of food intake (4,5). It is notable that, in our analysis, the marginal food-security category had lower HEI scores than the high food-security category for classification by food security among children; the difference was largely driven by whole fruit, whole grain, and refined grain components (data not shown). Although the NHANES documentation identifies marginal food security among household children, the USDA has not separately reported the national prevalence estimates on this category due to a lack of expert consensus on language to describe it (39). Given lower HEI 2015 scores and a lower MAR from total nutrient intakes inclusive of DS, marginal food security among household children may also pose a nutritional risk, although less severe, and should not be combined with full food security (40). Further differences in children's MAR across food-security categories were observed when classifying food security among household children compared to household food security. This suggests that food security among household children may be more sensitive to micronutrient adequacy, which was somewhat expected because the Child Food Security Scale was developed as a more specific classification of the experience of children compared with the Household Food Security Scale (6,39). In contrast, two previous studies that conducted sensitivity analyses to compare the classification of household food security and food security among children observed fewer significant differences in micronutrient intake among Canadian children (41) and in food-group intake among U.S. children when using the Child Food Security Scale (36). Inconsistencies with our findings could be due to dichotomization of food-security status, different dietary outcomes of interest (e.g., estimated usual intake of a single nutrient or food group), and different sample characteristics.

There are many federal nutrition-assistance programs to mitigate food insecurity among children, for example, SNAP, the Special Supplemental Nutrition Program for WIC, National School Lunch and Breakfast Programs, and the Summer Food Service Program. While SNAP largely does not limit food choices, WIC, National School Lunch and Breakfast Programs, and Summer Food Service Program require offered foods to be aligned with the DGA. As children with less food security had lower micronutrient adequacy, continuous efforts to improve the nutrient quality of foods provided in these programs are warranted. In addition, more efforts to promote access to available programs and nutritious foods for food-insecure children not participating in federal programs may be needed. In this study, 32%, 18%, and 29% of children living in situations where household children had marginal, low, and very low food security, respectively, were not participating in SNAP. Moreover, 15%, 21%, and 6% of those with marginal, low, and very low food security among household children, respectively, were living in households that are income-ineligible for federal programs (i.e., PIR >1.85), although they may need nutrition assistance.

This analysis of NHANES data confirms the differences in the prevalence estimates of children living in food-insecure household (22.5%) and those with food insecurity among household children (9.7%), which has been reported by the U.S. Census data analysis (2,6). In the current study, fewer children were categorized into the very low food-security category by the Child Food Security Scale compared to the Household Food Security Scale across all age groups. This is congruent with the work of Nord and Bickel (6) for younger children (2–5-year-olds), but different for older children; the previous work found more children to be categorized into "food insecurity with hunger among children" (now called very low food security among children) with the Child Food Security Scale than with the Household Food Security Scale in 6–14-year-olds and 15–17-year-olds. Household food security can differentially impact children when compared to adults within the same household, which is often explained as children being protected from the lack of food resources (42,43). However, we cannot rule out potential bias in parental reporting on children's experiences (44-46). The strength of agreement between the two classification scales was lower in non-Hispanic Black and Hispanic children and those with lower family income; this may be partly due to higher food insecurity in these subgroups, but also highlights a need for special efforts in assessing food insecurity by race and Hispanic origin and family income.

4.5.1. Limitations and strengths

This study uses cross-sectional data, so temporality could not be determined. In addition, the HFSSM captures chronic and episodic experiences of food insecurity over the past 12 months, while dietary recalls collect dietary intakes on one or two days that are 3–10 days apart. Thus, for those inconsistently experiencing food insecurity over time (e.g., summer vacation (47)), food-insecure experiences may not have been picked up in the recall time frame. However, the HEI 2015 scores were calculated using the population ratio method that provides a less biased estimate of the usual HEI score for a group of individuals compared to individual-person-level scores (18). MAR calculation based on two dietary recalls may not reflect usual intakes (48), which would have affected the standard errors, but not the mean estimates; a method for usual intake estimation at individual level is not yet available (33). All dietary data are subject to measurement errors, and it is possible that parents or caregivers reported intakes more favorably due to social-desirability bias (49), but little is known about the extent of reporting bias by food security. The sample size of the very low food-security group was very small and did not allow further stratification by age. Lastly, food-insecurity assessment is challenging. Neither household food security nor food security among children measures an individual child's food insecurity, even though a child report can differ from an adult report (44-46). Nonetheless, most large surveys and studies, including NHANES, interview an adult responsible for household food management about the food-security status of household members using the HFSSM. Nord and Hopwood (39) state that "standards have not yet been specified for the classification of individuals' food-security status based on NHANES items". Further efforts are needed to explore the best method to measure individual child food insecurity in national studies.

The strengths of this study include the use of a nationally representative sample of U.S. children and the estimation of the most updated HEI 2015 score. In addition, agreement between household food security and food security among household children classifications was assessed using the Cicchetti and Allison C-statistic that takes into consideration how far the categories are; for example, one category away (e.g., marginal food security in the household and low food security among household children) is considered a greater level of agreement than two or three categories away. The inclusion of nutrient intake from dietary supplements and parsing out singletons and children with siblings are novel contributions to the literature.

4.5.2. Conclusion

In conclusion, micronutrient adequacy, but not dietary quality, of U.S. children differed significantly by food-security status classed by both household food insecurity and food insecurity among children. While agreement between household food security and food security of household children is very good, classification for food security among children appears to be more sensitive to dietary outcomes. The strength of agreement differed by children's age and race/Hispanic origin, and family income. The findings of this study highlight the need for public health efforts to reduce food insecurity among U.S. children, and also serve to inform future studies of food-security scales in children.

4.6. Acknowledgement

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CHAPTER 5 . TOTAL USUAL NUTRIENT INTAKE AND DIETARY QUALITY BY FOOD SECURITY STATUS AMONG U.S. CHILDREN

The chapter was prepared for submission to *American Journal of Clinical Nutrition* and formatted according to the journal requirements. American Society for Nutrition journals provide the right for authors to include their own articles in their dissertation.

5.1. Abstract

Background: Food insecurity is associated with poorer intakes of nutrients from food sources and lower dietary supplement use, but its association with total usual nutrient intakes among children is unknown.

Objective: We assessed total usual nutrient intakes and scores on the Healthy Eating Index (HEI)-2015 by sex and food security status among U.S. children.

Design: We analyzed data from 9,147 children aged 1-18 y who participated in the 2011-2016 National Health and Nutrition Examination Survey, a nationally representative survey. Energy intake, total usual nutrient intake distributions, and HEI-2015 score were estimated using the National Cancer Institute method.

Results: Food-insecure boys and girls were less likely to take dietary supplements than their food-secure counterparts. Food-insecure boys and girls were at a higher risk of inadequate intakes for vitamins D, E, and magnesium, while food-insecure girls also had a higher risk for inadequate intakes for vitamin A and calcium, compared to their food-secure counterparts. Also, choline intakes of food-insecure children were less likely to exceed the Adequate Intake than their food-secure peers. Food-insecure adolescent girls 14-18 y were at highest risks of micronutrient inadequacies than any other age, sex, and food security subgroups, with 92.8% (SE 3.6%) and 18.6% (SE 2.6%) at risk of inadequate intakes for vitamin D and iron, respectively. Food-insecure children had similar mean energy and macronutrient intakes and mean total HEI-2015 scores (ranging from 52.1 to 53.7) as food-secure children.

Conclusions: Food insecurity was associated with compromised intake of some micronutrients from foods and dietary supplements. Overall diet quality was poor and sodium, added sugar, and saturated fat intakes were higher than recommendations, regardless of food security status. These

results highlight a need for targeted interventions to reduce specific nutrient inadequacies and improve diet quality, especially among food-insecure children.

5.2. Introduction

Food insecurity is the lack of consistent access to adequate and safe foods for an active and healthy life caused by limited resources for food (1). Its risk is associated with many factors, including low income, unemployment, and limited food access (1). Children are less likely to be food-insecure than adults in the same household, perhaps because adults attempt to shield children from the impact of household’s limited resources (2, 3). Even so, food-insecure children are more likely to have developmental delays and poorer physical and mental health than their food secure counterparts (4-9), which may present a risk to life-long health (10).

The concept and measurement of food security are inherently linked to diet quality and quantity, which may partially mediate the association between food insecurity and negative health outcomes. Therefore, many studies have assessed nutrient intakes of food-insecure children in order to identify the gaps between the amounts of nutrients consumed and recommended intakes (i.e., nutrient gaps). Findings to date suggest that a considerable number of nutrient gaps exist among food-insecure adolescents and a smaller but important number of gaps exist among younger children both in food groups and nutrients (e.g., lower vegetable consumption and higher added sugar intake) (11-13). Total usual nutrient intakes from foods and supplements have not yet been assessed among food-secure and food-insecure children. Dietary supplement use is lower among food-insecure children compared with their food-secure counterparts (14), which may further widen the disparities in total nutrient intakes (15).

Therefore, the purpose of this study was to assess total usual nutrient intakes, inclusive of nutrients obtained from dietary supplements, and scores of the Healthy Eating Index (HEI)-2015, a diet quality index, by sex and food security status (food secure and food insecure) among U.S. children aged 1-18 y, using data from the 2011-2016 National Health and Nutrition Examination Survey (NHANES).

5.3. Subjects and methods

The NHANES is a continuous, cross-sectional survey of a nationally representative sample of the resident, civilian, noninstitutionalized U.S. population of all ages (16). All of the survey protocols were approved by the research ethics review board at the National Center for Health Statistics and written informed consent was obtained from the participants or their proxies. This study did not require institutional review board approval because it was a secondary data analysis devoid of personally identifying information. We combined the three most recent survey cycles (i.e., 2011-2012, 2013-2014, and 2015-2016) with food security and dietary data available to obtain reliable estimates across sex and age groups (17). The analytic sample included children aged 1-18 y who had complete food security data (i.e., either household food security or child food security) and at least one reliable 24-hour dietary recall (n=9,147) (**Figure 5.1**).

Data collection in the NHANES consists of an in-home interview, a health examination in the mobile examination center (MEC), and a follow-up telephone interview. During the in-home interview, using the Computer-Assisted Personal Interview system, a proxy provided information for children ≤15 y; and persons ≥16 y answered the questions for themselves. For the dietary interviews, a proxy answered for participants 6 y and younger, participants ages 9-11 y answered for themselves with the assistance of a proxy, and participants ages 12 y or older answered for themselves.

5.3.1. Sociodemographic variables

Age groups were categorized according to the Dietary Reference Intakes: 1-3 y, 4-8 y, 9-13 y, and 14-18 y (18). Self-reported race/Hispanic origin categories were as follows: non-Hispanic white, non-Hispanic black, non-Hispanic Asian, Hispanic, and “other” races. Household education level, defined as the education level of household reference person who owns or rents the residence, was categorized as less than high school, high school graduate or equivalent, some college or associate degree, and college graduate or above. The family income-to-poverty ratio (PIR) is the ratio of the annual family income to the poverty guideline set by the Department of Health and Human Services (19). The PIR has been used an indicator of family income level and as an income eligibility criterion for federal nutrition assistance programs. Four

PIR categories were constructed: <1.30, 1.31-1.85, 1.86-3.5, and >3.5. A PIR of 1.30 indicates potential eligibility for the Supplemental Nutrition Assistance Program (SNAP) that provides cash benefits for foods to low-income households to reduce food insecurity (20). A PIR of 1.85 is an eligibility criterion for the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) that provides tailored food packages, nutrition education, and health referrals to low-income pregnant or lactating women, infants, and young children ≤5 y. A PIR of 3.50 has been used in other studies to differentiate middle-income and high-income families (21, 22). The household's current SNAP and WIC participation status variables were used to categorize these program participants. For children 4 to 18 y, the National School Lunch Program and the National School Breakfast Program (NSLP/BP) provide reduced-cost meals to children in households with PIR of 1.31-1.85 and free meals to those in households with PIR<1.30. Children receiving either reduced-cost or free lunch or breakfast were categorized as NSLP/BP participants (20).

5.3.2. Food security measurement

Food security was measured using the U.S. Household Food Security Survey Module during the in-home interview (23, 24). An adult responded to the 10 items for the entire household and additional 8 items specific to children in the household when there were children ≤17 y in the household. Each question referenced the past 12-month period. The ranges of experience of the entire household or children in the household were classified into 1 of 4 categories of food security (i.e., high, marginal, low, and very low) per NHANES documentation (25). High and marginal food security categories were collapsed to classify food security, and low and very low food security categories were collapsed as food insecurity. Food security of household children was used for children ≤17 y as more direct and sensitive measure tied to the children's experience and dietary intake (15). For children ≤17 y who did not have complete information about food security of household children (n=10) and, for children 18 y, food security of the entire household was used to classify their food security status.

5.3.3. Dietary assessment

Two 24-hour dietary recalls were collected using the USDA's Automated Multiple-Pass Method (26); the first 24-hour recall was administered in person in the MEC, and the second recall was completed via telephone approximately 3 to 10 days later. Right after the collection of food and beverage information, dietary supplement use during the 24-h period prior to the interview was also collected. Additionally, a dietary supplement and prescription medication questionnaire (DSMQ) in tandem with a product inventory was administered during the in-home interview. For each dietary supplement reported, participants were asked to show containers and to report the consumption frequency, the dose, and the duration of use. The time frame for the DSMQ was over the previous 30 days. If a child took any dietary supplement during the 30-day period, the child was classified as dietary supplement user. USDA's Food and Nutrient Database for Dietary Studies and NHANES Dietary Supplement Database were used to calculate daily intakes of energy, nutrients, and food components. Micronutrients of interest were vitamins A, C, D, and E, potassium, choline, magnesium, calcium, and iron that were identified as under-consumed nutrients by the 2015-2020 Dietary Guidelines for Americans (27); and folic acid, zinc, and sodium for which excessive intakes have been of concern in certain age groups (27, 28). Intakes of vitamins A and E from dietary supplements were not available from the NHANES.

Overall diet quality was characterized by the Healthy Eating Index (HEI)-2015 score (29). The HEI-2015 is a measure of overall diet quality in terms of adherence to the 2015–2020 Dietary Guidelines for Americans (27). The HEI-2015 include 13 dietary components, including 9 food group and nutrient adequacy components (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and 4 moderation components (refined grains, sodium, added sugars, and saturated fats). The component scores add up to a maximum score of 100, with a greater score indicating higher diet quality. The HEI-2015 assesses densities (i.e., per unit of energy intake) of consumed food groups and nutrients rather than absolute amount and does not account for nutrients from dietary supplements. Because the 2015-2020 Dietary Guidelines for Americans apply only to the U.S. population ages 2 and older, HEI was only calculated for children 2-18 y.

5.3.4. Biomarker measurement

Blood samples were collected by trained phlebotomists in the MEC. Serum samples were analyzed at the CDC's Laboratory. Serum 25-hydroxyvitamin D [25(OH)D] was quantified using ultra-high-performance liquid chromatography-tandem mass spectrometry (30). Vitamin D inadequacy was determined at <40 nmol/L, which is consistent with the Estimated Average Requirement (EAR) (31). Vitamin D can be produced in the skin by sunlight exposure, so we adjusted vitamin D estimates for the season when the sample was collected: winter (November–March) and summer (April–October), as dichotomized per the NHANES protocol. Serum 25(OH)D data were only available in the 2011-2014 NHANES. Ferritin was analyzed using electrochemiluminescence immunoassay (Roche Diagnostics, IN) (32) and soluble transferrin receptor were analyzed using particle enhanced immunoturbidimetric assay (Roche Diagnostics, IN) (33). Ferritin and soluble transferrin receptor data were only available in the 2015-2016 NHANES and for participants 1-5 y and females 12-18 y. Total body iron was calculated using a formula from Cook and colleagues (34, 35) where soluble transferrin receptor is in mg/L and ferritin is in ng/mL; soluble transferrin receptor values obtained through the current NHANES method were converted to those equivalent to the Flowers method that was used in the development of the formula (36, 37).

$$Total\ body\ iron = -\left\{\log_{10}\left(soluble\ transferrin\ receptor \times \frac{1000}{ferritin}\right) - 2.8229\right\}/0.1207$$

Total body iron < 0 mg/kg was considered as iron deficient (30, 31). Very few children 1-5 y were iron deficient, so estimates were not presented.

5.3.5. Statistical analyses

The Dietary Reference Intakes and the Dietary Guidelines for Americans are intended to be met on average over time; therefore, adherence to these recommendations should be evaluated on the basis of usual intake (i.e., long-term daily average intake). Therefore, several methods have been developed to estimate the distribution of usual intakes from a small number of daily self-reported diet assessments (e.g., 24-hour dietary recalls) per individual on at least a subsample (38, 39). These methods employ statistical modelling to adjust for random measurement error (e.g., day-to-day variation) and approximate the distribution that would be obtained by averaging many repeated 24-hour dietary recalls per individual.

For this analysis, total usual nutrient intake distributions were estimated using an adaptation of National Cancer Institute (NCI) method: "shrink then add" (21). This adapted NCI method incorporates nutrient intake from dietary supplements reported on the DSMQ to estimate distributions of total usual nutrient intake (i.e., nutrient intake from foods and dietary supplements); in brief, nutrient intake from dietary supplements was added to the adjusted usual nutrient intake from foods. Covariates were included for day of the recall day (Monday-Thursday vs. Friday-Sunday), sequence of the recall (first vs. second), dietary supplement use (yes vs. no), age group (when age groups are combined), and race/Hispanic origin. For sensitivity analyses, whether a child was participating in SNAP, WIC, or NSLP/BP was added as covariates to examine if federal nutrition program participation explains a fraction of variation in dietary intakes; however, the addition of federal nutrition program participation had little impact on usual intake estimates (data not shown). A balanced repeated replication technique was performed to estimate standard errors. Balanced repeated replication weights were constructed with Fay adjustment factor F = 0.3 (perturbation factor, 0.7) and post-stratified to match the original sample weights within specific age, sex, and race/Hispanic origin groupings (40).

This adapted NCI macro produces means and percentiles of usual intake, and proportions of the group with intakes below the EAR or above the Adequate Intake (AI) and Tolerable Upper Intake Level (UL). The percentage of intakes below the EAR was used as an indicator of the percentage at risk of inadequate intakes (i.e., the EAR cut-point method) for all nutrients except iron, as recommended (41). Due to menstrual iron loss among females of reproductive age, the iron requirement distributions are not symmetrical for all sex and life stage groups, which makes the EAR cut-point method inappropriate. Therefore, we calculated the prevalence of inadequate iron intake using the full probability approach as recommended (42). The Dietary Reference Intake report on iron provides the probability of inadequacy at various ranges of usual intake based on the assumption of 18% iron bioavailability; for adolescent girls 14-18y, we used the mixed adolescent population distribution that assumes all were menstruating and that 17% were using oral contraceptives (42). For nutrients with only an AI, the percentage above the AI was calculated to estimate the proportion of children "at low risk of inadequacy". The percentage above the UL indicated the percentage of the population who are potentially at risk of adverse effects from excess nutrient intake. The estimated percentage above the UL was presented only for folic acid and zinc because the percentage above the UL was below 5% for other nutrients. Also, note that the ULs for folate only apply to synthetic forms from dietary supplements and fortified foods (i.e., folic acid) (43). For sodium, the percentage above the Chronic Disease Risk Reduction Intake (CDRR) was calculated to represent those who were deemed to need reductions in sodium intake to reduce chronic disease risk (44). Lastly, the percentage above the recommended limit for added sugars or saturated fat (i.e., 10% of total energy intake) from the 2015-2020 Dietary Guidelines was estimated (27).

The contribution of dietary supplements to total usual nutrient intake was calculated by dividing mean intake from dietary supplements by mean intake from foods and dietary supplements for each sex and food security subgroup (45).

Distributions of the HEI-2015 component and total scores were estimated by using the multivariate Markov Chain Monte Carlo approach. The Markov Chain Monte Carlo method has been described in detail elsewhere (46), and SAS macros from the NCI are publicly available (47). Briefly, it is an extension of the NCI method that enables estimation of distributions of usual intakes of episodically and non-episodically consumed dietary components and simultaneous modeling of multiple components. Covariates were included for day of the recall (Monday-Thursday vs. Friday-Sunday), sequence of the recall (first vs. second), age group, and race/Hispanic origin. Balanced repeated replication variance estimation was performed to obtain standard errors.

All statistical analyses were performed using SAS (version 9.4; SAS Institute, Inc., Cary, NC, USA) and SAS-callable SUDAAN (version 11; RTI International, Research Triangle Park, NC, USA) software. Design-based statistical methods were used to account for a complex, four-stage sampling design (48). Estimates with a relative standard error (SE) of greater than 40% were considered unreliable and, thus, are not displayed per the National Center for Health Statistics analytical guidelines. Estimates between food-secure and food-insecure groups were compared within sex using t tests as recommended by National Center for Health Statistics (49). Statistical significance was determined at a two-sided p-value <0.05.

5.4. Results

In 2011-2016, 11.9% of boys and 10.8% of girls aged 1-19 y in the U.S. were food-insecure (**Table 5.1**). Compared to food-secure boys and girls, food-insecure boys and girls were more likely to be older, be non-Hispanic black or Hispanic, live in a lower-income family (i.e., PIR≤1.30), live in a household with lower education level (i.e., less than high school), live in a household participating in SNAP, and participate in WIC (for 1-4y) or NSLP/BP (for 4-18y); and were less likely to take dietary supplements.

Few differences in estimated mean intakes of energy and macronutrients were observed between food-secure and food-insecure groups (**Table 5.2**). Regardless of food security status, mean energy intake was a little over 2,000 kcal/d among boys and about 1,700 kcal/d among girls; 53-54%, 33%, and 14-15% of energy were from carbohydrates, fats, and proteins, respectively. Over 75% of boys and of girls exceeded the recommendations for added sugars and saturated fat; whereas only 1~2% met the AI for fiber. Total HEI-2015 scores were not statistically different between food-secure and food-insecure groups within each sex, ranging from 52 to 54 (**Table 5.3**). Among girls, the whole grain component score was significantly lower in the food-insecure than in the food-secure group, but no other differences in HEI-2015 component scores were observed.

When nutrient intakes from food sources alone were examined, food-insecure girls were at higher risk of inadequate intakes (i.e., %<EAR) for vitamins A, D, and E, calcium, and magnesium compared to food-secure girls (**Table 5.4**). Food-insecure boys were at higher risk of inadequate intakes for vitamin E, calcium, and magnesium, compared to food-secure boys. Similar patterns were noted when total intakes were examined; however, after including dietary supplements, the magnitude of difference between food-secure and food-insecure groups in the prevalence of inadequate vitamin D intake was much larger among both boys and girls. Food insecure boys and girls were less likely to have a total usual intake above the AI for choline compared to their food-secure counterparts.

The percentage of those at risk of inadequate intake was lower for folate, vitamins C and D, calcium, iron, magnesium, and zinc when total intakes that included dietary supplements were examined compared with intakes from foods alone (**Table 5.4**). At the same time, nutrient intakes from dietary supplements increased the risk of potentially excessive intakes (i.e., %>UL) for zinc (**Table 5.5**). Over 90% of boys and girls exceeded the CDRR for sodium from intakes from foods alone. The contribution of dietary supplements to total nutrient intakes varied widely: <3% for sodium, potassium, choline, calcium, and magnesium (all sex and food security subgroups) and >30% for vitamins C and D (only in food-secure girls) (**Table 5.6**).

When stratified by age group, older children were at greater risk of inadequate total nutrient intakes but at less risk of excessive intakes (**Table 5.7 and 5.8**). Specifically, adolescent boys and girls (14-18 y) had the highest prevalence of nutrient inadequacy for the micronutrients examined, but no differences were noted between food-secure and food-insecure adolescent boys (**Table 5.9**). Food-insecure adolescent girls had a higher risk of inadequate vitamin D intake compared to their food-secure peers. Based on serum 25(OH)D, 8.4% of food-secure and 15.1% of food-insecure girls 1-18 y, respectively, had serum 25(OH)D concentrations <40 nmol/L; the difference was marginally different (P=0.058). Among girls 12-18 y, 12.7% and 12.0% of food-secure and food-insecure girls, respectively, were iron deficient based on total body iron (**Figure 5.2**).

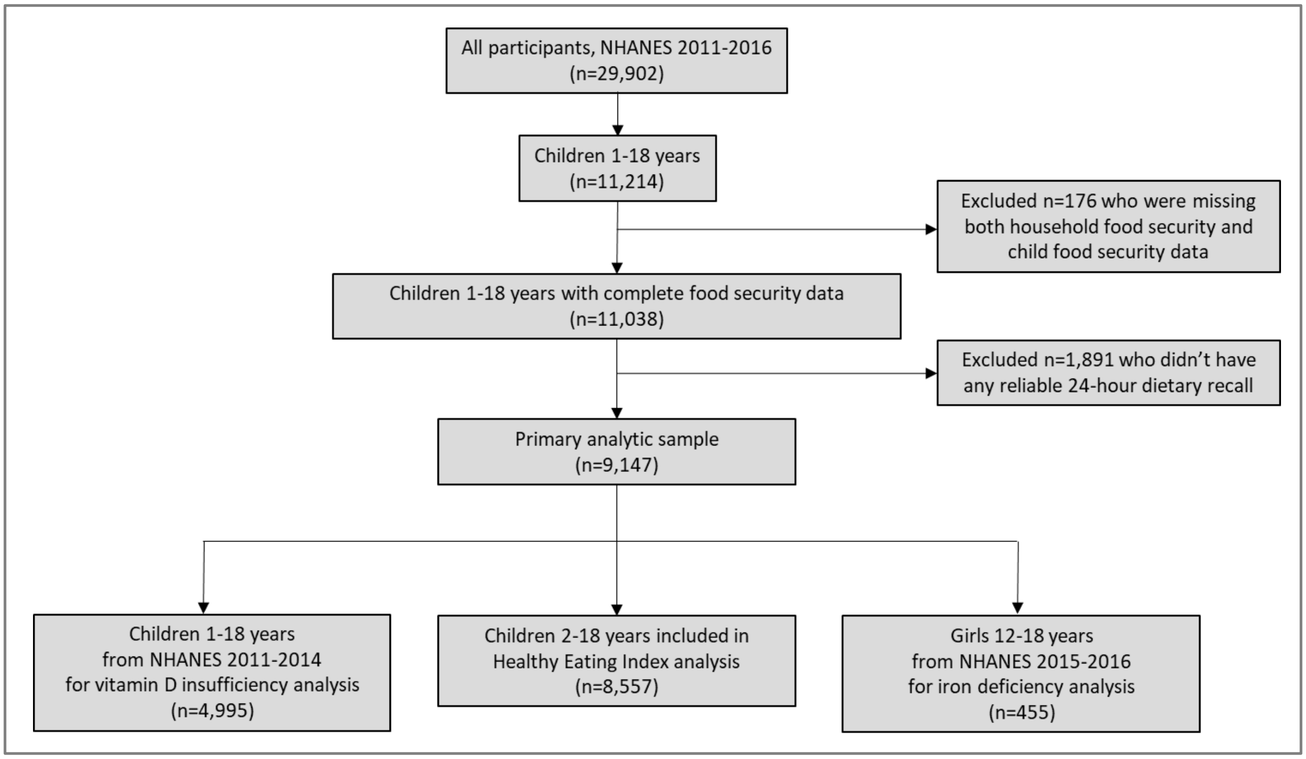

Figure 5.1. Flow chart showing sample identification in the current investigation using data from the NHANES 2011-2016

Table 5.1. Characteristics of U.S. children (1-18 y) by sex and food security, NHANES 2011-2016[1]

Component	Boys		Girls	
	Food secure (n=3,981)	**Food insecure (n=646)**	**Food secure (n=3,940)**	**Food insecure (n=580)**
%	88.1 ± 0.8	11.9 ± 0.8	89.2 ± 0.8	10.8 ± 0.8
Age group				
1-3 y	16.7 ± 0.8	9.2 ± 1.3*	17.8 ± 0.8	7.3 ± 1.1*
4-8 y	29.7 ± 1.3	23.7 ± 2.3*	26.5 ± 1.1	24.9 ± 2.4
9-13 y	25.8 ± 0.8	35.4 ± 3.1*	27.7 ± 1.2	28.9 ± 2.3
14-18 y	27.7 ± 1.3	31.7 ± 2.3	28.1 ± 1.1	38.9 ± 2.6*
Race and Hispanic origin				
Non-Hispanic white	55.4 ± 3.0	33.6 ± 4.1*	53.5 ± 3.3	39.4 ± 5.6*
Non-Hispanic black	13.0 ± 1.6	23.0 ± 3.1*	13.6 ± 1.7	19.5 ± 2.8*
Hispanic	22.7 ± 2.4	32.9 ± 3.7*	22.5 ± 2.3	34.2 ± 5.2*
Non-Hispanic Asian	4.9 ± 0.6	1.5 ± 0.6*[,2]	5.0 ± 0.5	2.5 ± 0.8*[,2]
Family Income level				
PIR ≤1.3	30.8 ± 2.0	61.2 ± 3.9*	32.0 ± 2.5	69.9 ± 4.5*
PIR >1.3-≤1.85	10.9 ± 1.0	17.3 ± 2.6*	12.8 ± 1.2	14.0 ± 2.3
PIR >1.85-≤3.5	27.3 ± 1.6	19.2 ± 3.6*	25.0 ± 1.7	14.5 ± 3.1*
PIR >3.5	31.0 ± 2.2	2.2 ± 0.8*[,2]	30.2 ± 2.4	—*
Household’s education level[3]				
Less than high school	17.7 ± 1.4	32.7 ± 3.8*	18.6 ± 1.4	32.8 ± 4.3*
High school graduate or equivalent	21.0 ± 1.6	26.5 ± 3.8	19.9 ± 1.3	21.6 ± 2.9
Some college or associate degree	30.9 ± 1.4	30.3 ± 2.9	30.9 ± 1.6	37.5 ± 4.8
College graduate or above	30.4 ± 1.9	10.5 ± 3.1*	30.7 ± 2.3	8.1 ± 1.9*
SNAP participating[4]	25.7 ± 1.8	56.0 ± 4.0*	26.8 ± 2.2	62.9 ± 4.4*
WIC participating[5]	22.2 ± 2.0	36.5 ± 4.9*	23.6 ± 2.2	43.6 ± 5.1*
NSLP/BP participating[6]	44.1 ± 2.6	77.1 ± 2.9*	46.4 ± 3.0	75.5 ± 3.2*
Dietary supplement use	34.8 ± 1.4	21.0 ± 2.8*	35.2 ± 1.6	23.6 ± 3.5*
Weight status[7]				
Underweight	3.3 ± 0.5	2.5 ± 0.8	3.7 ± 0.6	1.9 ± 0.8
Normal weight	62.8 ± 1.2	55.9 ± 2.6*	64.6 ± 1.4	59.9 ± 2.7
Overweight	16.9 ± 0.9	13.1 ± 1.3*	15.1 ± 0.8	18.1 ± 2.4
Obese	17.1 ± 1.1	28.5 ± 2.8*	16.6 ± 1.0	20.1 ± 2.3

[1]Values are percentages ± SEs. Percentages may not add up to 100% due to rounding. *significantly different from food-secure group within sex based on *t*-test, P<0.05. NSLP/BP, National School Lunch Program and Breakfast Program; PIR, family income-to-poverty ratio (n=568 missing); SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; —, relative SE >40% (data not shown).

[2] The relative SE is >30% but ≤40% and may be statistically unreliable.

[3] Education level of household reference person who owns or rents the residence (n=245 missing).

[4] Household-level participation (SNAP, n=24 missing)

[5] Among 1-5 y (n=2,740)

[6] Among 4-18 y (n=6,618)

[7] Measured by the trained health technicians (n=711 missing)

Table 5.2. Usual intakes of energy and macronutrients from foods alone among U.S. children (1-18 y) by sex and food security, NHANES 2011-2016[1]

Component	Boys		Girls	
	Food secure (n=3,981)	**Food insecure (n=646)**	**Food secure (n=3,940)**	**Food insecure (n=580)**
Energy (kcal/d)	2014.3 ± 19.7	2007.1 ± 52.9	1683.5 ± 15.3	1703.3 ± 46.5
Carbohydrate (% kcal)	53.2 ± 0.3	53.6 ± 0.7	53.6 ± 0.3	52.7 ± 0.6
Added sugars (% kcal)	13.9 ± 0.2	14.9 ± 0.5	13.8 ± 0.3	14.2 ± 0.7
%> 10% of total energy	78.0 ± 1.4	84.5 ± 3.4	81.1 ± 3.4	76.1 ± 3.8
Total fat (% kcal)	33.1 ± 0.2	33.0 ± 0.5	33.4 ± 0.2	33.8 ± 0.5
Saturated fat (% kcal)	11.8 ± 0.1	11.4 ± 0.2	11.7 ± 0.1	11.8 ± 0.2
%> 10% of total energy	82.5 ± 1.9	82.1 ± 5.0	81.7 ± 2.4	90.8 ± 5.0
Protein (% kcal)	14.8 ± 0.1	14.7 ± 0.3	14.4 ± 0.1	14.8 ± 0.3
Fiber (g/d)	14.8 ± 0.2	15.4 ± 0.5	12.9 ± 0.2	12.5 ± 0.4
%> AI	1.4 ± 0.3	1.8 ± 0.9[2]	1.1 ± 0.3	─

[1]Values are % ± SEs unless otherwise noted. AI, adequate intake; ─, relative SE >40% (data not shown).
[2]The relative SE is >30% but ≤40% and may be statistically unreliable.

Table 5.3. Healthy Eating Index-2015 scores among U.S. children (2-18 y) by sex and food security, NHANES 2011-2016[1]

	Boys		Girls	
Component (maximum points)	**Food secure (n=3,699)**	**Food insecure (n=620)**	**Food secure (n=3,671)**	**Food insecure (n=567)**
Total fruits (5)	3.2 ± 0.1	3.2 ± 0.4	3.4 ± 0.1	3.3 ± 0.4
Whole fruits (5)	3.5 ± 0.1	3.4 ± 0.2	3.7 ± 0.1	3.6 ± 0.2
Total vegetables (5)	2.2 ± 0.1	2.7 ± 0.5	2.5 ± 0.1	2.4 ± 0.7
Greens and beans (5)	1.5 ± 0.1	2.5 ± 0.6	1.8 ± 0.1	─
Whole grains (10)	3.1 ± 0.1	2.6 ± 0.4	3.1 ± 0.1	2.5 ± 0.3*
Dairy (10)	8.0 ± 0.1	8.0 ± 0.2	7.9 ± 0.1	8.0 ± 0.4
Total protein foods (5)	4.2 ± 0.1	4.5 ± 0.1	4.2 ± 0.1	4.5 ± 0.2
Seafood and plant proteins (5)	2.7 ± 0.2	3.4 ± 0.5	3.0 ± 0.1	3.0 ± 0.8
Fatty acids (10)	3.1 ± 0.1	3.7 ± 0.6	3.4 ± 0.1	3.1 ± 0.4
Refined grains (10)	4.8 ± 0.1	4.4 ± 0.3	4.9 ± 0.2	4.4 ± 0.4
Sodium (10)	4.7 ± 0.1	4.1 ± 0.4	4.8 ± 0.1	4.4 ± 0.5
Added sugars (10)	6.0 ± 0.1	5.7 ± 0.2	6.1 ± 0.1	5.8 ± 0.5
Saturated fats (10)	5.2 ± 0.1	5.6 ± 0.6	5.1 ± 0.1	4.7 ± 0.9
Total score (100)	52.3 ± 0.6	53.7 ± 1.8	53.7 ± 0.5	52.1 ± 2.5

[1] Values are means ± SEs. Component scores may not add up to 100% due to rounding. *significantly different from food-secure group within sex based on *t*-test, P<0.05. ─, relative SE >40% (data not shown).

Table 5.4. Prevalence of usual intakes less than the EAR or above the AI among U.S. children (1-18 y) by sex and food security, NHANES 2011-2016[1]

	Boy		Girl	
	Food secure (n=3,981)	**Food insecure (n=646)**	**Food secure (n=3,940)**	**Food insecure (n=580)**
Foods alone				
Vitamin A (EAR)	20.0 ± 1.7	21.0 ± 4.2	24.0 ± 2.0	32.9 ± 3.5*
Folate (EAR)	─	─	6.0 ± 1.3	11.1 ± 3.1
Vitamin C (EAR)	17.9 ± 1.8	22.3 ± 2.8	21.8 ± 1.5	25.8 ± 5.5
Vitamin D (EAR)	88.3 ± 1.3	90.8 ± 2.2	94.8 ± 0.6	97.8 ± 1.1*
Vitamin E (EAR)	60.6 ± 1.4	74.3 ± 4.4*	72.8 ± 1.4	80.9 ± 3.9*
Choline (AI)	28.1 ± 1.2	19.4 ± 2.2*	18.1 ± 1.1	11.7 ± 2.6*
Calcium (EAR)	32.0 ± 1.7	42.0 ± 4.5*	52.0 ± 1.4	64.0 ± 4.2*
Iron[2]	0.8 ± 0.2	─	5.2 ± 0.7	6.3 ± 1.9
Magnesium (EAR)	27.4 ± 1.1	34.9 ± 2.3*	37.4 ± 0.9	50.3 ± 3.0*
Potassium (AI)	38.0 ± 1.6	34.0 ± 4.2	25.0 ± 1.5	20.0 ± 3.9
Zinc (EAR)	4.7 ± 1.0	4.7 ± 2.4[3]	13.8 ± 1.9	15.0 ± 3.1
Total				
Folate (EAR)	─	─	5.0 ± 1.2	9.0 ± 2.9
Vitamin C (EAR)	15.4 ± 1.5	21.1 ± 2.7	18.0 ± 1.3	23.2 ± 5.4
Vitamin D (EAR)	71.4 ± 1.3	80.2 ± 2.8*	76.2 ± 1.2	86.8 ± 2.3*
Choline (AI)	28.7 ± 1.2	19.7 ± 2.2*	18.6 ± 1.1	12.0 ± 2.5*
Calcium (EAR)	31.0 ± 1.6	40.0 ± 4.4	51.0 ± 1.3	63.0 ± 4.2*
Iron[2]	0.7 ± 0.2	─	4.9 ± 0.7	6.1 ± 1.8
Magnesium (EAR)	26.5 ± 0.1	34.6 ± 2.3*	36.3 ± 0.9	49.5 ± 2.5*
Potassium (AI)	38.0 ± 1.6	34.0 ± 4.2	25.0 ± 1.5	20.0 ± 3.9
Zinc (EAR)	4.1 ± 0.9	3.9 ± 2.3[3]	12.4 ± 1.7	14.2 ± 3.0

[1] Values are means ± SEs. *significantly different from food-secure group within sex based on *t*-test, P<0.05. AI, adequate intake; EAR, estimated average requirement; NA, not applicable; ─, relative SE >40% (data not shown).
[2] Estimated using the probability approach
[3] The relative SE is >30% but ≤40% and may be statistically unreliable.

Table 5.5. Prevalence of usual intakes above the UL or CDRR among U.S. children (1-18 y) by sex and food security, NHANES 2011-2016[1]

	Boys		**Girls**	
	Food secure (n=3,981)	**Food insecure (n=646)**	**Food secure (n=3,940)**	**Food insecure (n=580)**
Foods alone				
Folic acid (UL)	1.7 ± 0.5	–	1.5 ± 0.4	–
Zinc (UL)	17.3 ± 0.8	11.5 ± 1.7*	14.0 ± 0.7	7.9 ± 1.3*
Sodium (CDRR)	98.0 ± 0.4	99.0 ± 1.3	93.0 ± 1.3	90.0 ± 4.0
Total				
Folic acid (UL)	7.8 ± 0.7	5.3 ± 1.5	6.9 ± 0.8	4.3 ± 1.1*
Zinc (UL)	21.9 ± 0.8	14.0 ± 1.8*	12.4 ± 1.7	14.2 ± 3.0*
Sodium (CDRR)	98.0 ± 0.4	99.0 ± 1.3	93.0 ± 1.3	90.0 ± 4.0

[1] Values are percentages ± SEs. *significantly different from food-secure group within sex based on *t*-test, P<0.05. CDRR, Chronic Disease Risk Reduction Intake; UL, Tolerable Upper Intake Level.

Table 5.6. Usual intakes and contribution of dietary supplements among U.S. children (1-18 y) by food security, NHANES 2011-2016[1]

	Food secure			Food insecure		
	Foods alone	**Total**	**% from DS**	**Foods alone**	**Total**	**% from DS**
Boys						
Vitamin A (µg RAE)	643.1 ± 11.0	NA	NA	653.3 ± 37.4	NA	NA
Folate (µg DFE)	535.1 ± 9.3	612.9 ± 9.8	12.7%	573.9 ± 25.9	618.6 ± 27.6	7.2%
Vitamin C (mg)	78.6 ± 2.8	99.8 ± 3.9	21.2%	80.9 ± 4.7	95.7 ± 7.1	15.5%
Vitamin D (µg)	6.3 ± 0.1	8.8 ± 0.2	27.9%	6.1 ± 0.3	7.8 ± 0.4	21.3%
Vitamin E (mg ATE)	7.5 ± 0.1	NA	NA	7.1 ± 0.3	NA	NA
Choline	274.2 ± 3.7	275.8 ± 3.7	0.6%	269.7 ± 8.6	270.3 ± 8.7	0.2%
Calcium (mg)	1121.8 ± 15.4	1135.6 ± 15.8	1.2%	1074.7 ± 40.2	1092.5 ± 40.9	1.6%
Iron (mg)	14.9 ± 0.2	15.6 ± 0.2	4.5%	15.7 ± 0.6	16.1 ± 0.6	2.5%
Magnesium (mg)	249.9 ± 2.8	253.1 ± 3.1	1.3%	250.9 ± 8.3	252.8 ± 8.4	0.8%
Potassium (mg)	2336.0 ± 27.4	2336.9 ± 27.4	0.04%	2333.3 ± 71.5	2334.0 ± 71.5	0.03%
Sodium (mg)	3183.3 ± 44.8	3184.2 ± 44.8	0.03%	3278.7 ± 95.4	3279.0 ± 95.4	0.01%
Zinc (mg)	10.8 ± 0.2	11.8 ± 0.2	8.5%	10.9 ± 0.4	11.4 ± 0.4	4.4%
Girls						
Vitamin A (µg RAE)	549.9 ± 9.7	NA	NA	507.2 ± 22.4	NA	NA
Folate (µg DFE)	457.9 ± 7.9	535.0 ± 9.7	14.4%	458.7 ± 14.4	504.4 ± 20.1	9.0%
Vitamin C (mg)	69.7 ± 1.7	101.3 ± 7.3	31.2%	67.7 ± 4.3	78.7 ± 5.8	14.0%
Vitamin D (µg)	5.1 ± 0.1	8.7 ± 0.6	42.0%	4.8 ± 0.2	6.3 ± 0.4	23.8%
Vitamin E (mg ATE)	6.4 ± 0.1	NA	NA	6.5 ± 0.3	NA	NA
Choline	221.2 ± 3.1	222.7 ± 3.1	0.7%	227.3 ± 7.8	227.8 ± 7.8	0.2%
Calcium (mg)	932.7 ± 11.8	947.4 ± 11.3	1.6%	898.1 ± 41.5	908.5 ± 42.2	1.1%
Iron (mg)	12.4 ± 0.2	13.4 ± 0.2	7.5%	12.9 ± 0.4	13.7 ± 0.6	5.8%
Magnesium (mg)	212.4 ± 1.9	215.8 ± 2.0	1.6%	209.1 ± 5.8	210.9 ± 6.1	0.8%
Potassium (mg)	1956.9 ± 20.4	1957.5 ± 20.4	0.03%	1909.8 ± 47.3	1910.1 ± 47.4	0.02%
Sodium (mg)	2640.4 ± 31.5	2641.2 ± 31.5	0.05%	2732.0 ± 88.5	2732.3 ± 88.5	0.01%
Zinc (mg)	8.7 ± 0.1	9.6 ± 0.2	9.4%	9.1 ± 0.2	9.6 ± 0.3	5.2%

[1] Values are means ± SEs unless otherwise noted. DS, dietary supplements; NA, not applicable because information about supplemental intakes of vitamins A and E is not available in the 2011-2016 NHANES.

Table 5.7. Prevalence of total usual intakes less than the EAR or above the AI among U.S. children (1-13y) by age group and food security, NHANES 2011-2016[1]

	1-3y		**4-8y**		**9-13y boys**		**9-13y girls**	
	Food secure (n=1,628)	**Food insecure (n=151)**	**Food secure (n=2,294)**	**Food insecure (n=327)**	**Food secure (n=1,042)**	**Food insecure (n=199)**	**Food secure (n=1,074)**	**Food insecure (n=162)**
Vitamin A (EAR)[2]	─	─	2.0 ± 0.6	0.2 ± 0.8	16.0 ± 4.2	─	25.0 ± 3.4	25.0 ± 9.8[3]
Folate (EAR)	0	─	0	0	0	0	─	─
Vitamin C (EAR)	─	0	─	─	13.1 ± 2.2	─	15.5 ± 4.0	─
Vitamin D (EAR)	65.5 ± 1.5	74.9 ± 3.7*	69.7 ± 1.6	79.3 ± 5.0	76.0 ± 2.3	84.3 ± 4.3	80.1 ± 2.4	84.5 ± 3.7
Vitamin E (EAR)[2]	54.0 ± 2.2	66.1 ± 7.5	38.8 ± 2.8	59.6 ± 10.3	72.7 ± 4.4	90.4 ± 11.1	89.5 ± 5.8	84.0 ± 8.3
Choline (AI)	55.0 ± 2.3	55.0 ± 9.6	32.9 ± 1.8	24.6 ± 7.8[3]	13.2 ± 2.3	─	─	─
Calcium (EAR)	3.0 ± 0.9[3]	─	23.0 ± 2.1	30.0 ± 7.1	51.0 ± 3.0	55.0 ± 9.2	71.0 ± 2.8	71.0 ± 6.9
Iron (EAR)	1.5 ± 0.3	─	7.1 ± 1.6	─	0	─	─	0
Magnesium (EAR)	0	0	0.4 ± 0.1	─	15.7 ± 2.9	25.5 ± 9.8[3]	31.3 ± 3.9	40.8 ± 8.1
Potassium (AI)	38.0 ± 2.2	36.0 ± 6.2	29.0 ± 2.1	29.0 ± 5.3	38.0 ± 3.1	38.0 ± 9.3	30.0 ± 3.5	19.0 ± 7.3[3]
Zinc (EAR)	0	0	0	─	─	─	14.1 ± 3.9	─

[1] Values are percentages ± SEs. *significantly different from food-secure group based on *t*-test, P<0.05. AI, adequate intake; EAR, estimated average requirement; ─, relative SE >40% (data not shown).

[2] From food sources alone because information about supplemental intakes of vitamins A and E is not available in the 2011-2016 NHANES.

[3] The relative SE is >30% but ≤40% and may be statistically unreliable.

Table 5.8. Prevalence of total intakes above the UL or CDRR among U.S. children (1-18 y) by age group and food security, NHANES 2011-2016[1]

	1-3y		**4-8y**		**9-13y boys**		**9-13y girls**		**14-18y boys**		**14-18y girls**	
	Food secure (n=1,628)	**Food insecure (n=151)**	**Food secure (n=2,294)**	**Food insecure (n=327)**	**Food secure (n=1,042)**	**Food insecure (n=199)**	**Food secure (n=1,074)**	**Food insecure (n=162)**	**Food secure (n=947)**	**Food insecure (n=185)**	**Food secure (n=936)**	**Food insecure (n=202)**
Folic acid (UL)	12.8 ± 1.4	13.4 ± 3.9	11.2 ± 1.6	5.8 ± 1.7*	3.4 ± 1.0[2]	—	1.9 ± 0.7[2]	—	—	—	0.8 ± 0.3[2]	—
Zinc (UL)	64.0 ± 1.9	59.9 ± 7.3	20.0 ± 2.0	19.9 ± 4.3	2.7 ± 0.8[2]	0.9 ± 0.3	1.3 ± 0.5[2]	—	2.0 ± 0.7[2]	—	—	—
Sodium (CDRR)	93.0 ± 1.5	92.0 ± 5.8	99.0 ± 0.3	95.0 ± 2.7	100.0	99.0 ± 1.2	99.0 ± 0.8	95.0 ± 3.5	96.0 ± 1.5	98.0 ± 2.3	79.0 ± 4.1	87.0 ± 10.5

[1] Values are percentages ± SEs. *significantly different from food-secure group based on t-test, P<0.05. CDRR, Chronic Disease Risk Reduction Intake; UL, Tolerable Upper Intake Level; —, relative SE >40% (data not shown).
[2] The relative SE is >30% but ≤40% and may be statistically unreliable.

Table 5.9. Prevalence of total usual intakes less than the EAR or above the AI among U.S. adolescents (14-18 years) by food security, NHANES 2011-2016[1]

	Boys		Girls	
	Food secure (n=947)	**Food insecure (n=185)**	**Food secure (n=936)**	**Food insecure (n=202)**
Vitamin A (EAR)[2]	52.0 ± 2.5	42.0 ± 15.5[4]	49.0 ± 5.3	60.1 ± 8.5
Folate (EAR)	7.0 ± 2.5[4]	─	19.0 ± 4.9	27.0 ± 5.3
Vitamin C (EAR)	34.7 ± 9.1	46.3 ± 5.8	45.0 ± 4.0	46.5 ± 8.4
Vitamin D (EAR)	75.2 ± 2.6	81.0 ± 6.8	83.1 ± 1.8	92.8 ± 3.6*
Vitamin E (EAR)[2]	78.1 ± 3.8	91.2 ± 5.5	97.3 ± 2.0	95.8 ± 4.2
Choline (AI)	5.4 ± 1.8[4]	─	1.1 ± 1.0[4]	─
Calcium (EAR)	42.0 ± 2.6	45.0 ± 8.7	72.0 ± 2.8	79.0 ± 7.2
Iron (EAR)[3]	3.3 ± 1.3	0.8 ± 1.4	16.4 ± 2.2	18.6 ± 2.6
Magnesium (EAR)	67.9 ± 2.4	77.1 ± 5.0	87.4 ± 2.3	88.3 ± 4.5
Potassium (AI)	32.0 ± 2.8	22.0 ± 5.3	23.0 ± 3.2	24.0 ± 5.7
Zinc (EAR)	14.7 ± 2.7	6.2 ± 6.2[4]	26.7 ± 4.1	26.3 ± 5.2

[1] Values are percentages ± SEs. *significantly different from food-secure group within sex based on *t*-test, P<0.05. AI, adequate intake; EAR, estimated average requirement; NA, not applicable; ─, relative SE >40% (data not shown).
[2] From food sources alone because information about supplemental intakes of vitamins A and E is not available in the 2011-2016 NHANES.
[3] Estimated using the probability approach
[4] The relative SE is >30% but ≤40% and may be statistically unreliable.

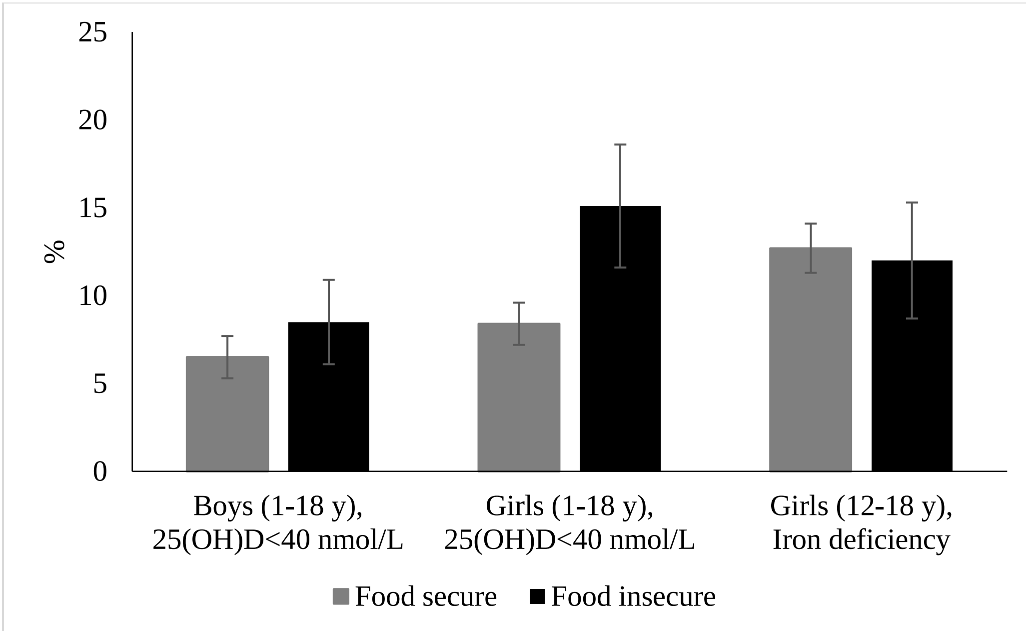

Figure 5.2. Estimated prevalence of vitamin D inadequacy and iron deficiency among U.S. children by sex and food security, NHANES 2011-2016

Values are percentages ± SEs. Serum 25(OH)D data were only available in the 2011-2014 NHANES and were adjusted for season (winter vs. summer): food-secure boys 1-18 y (n=2,192), food-insecure boys 1-18 y (n=370), food-secure girls 1-18 y (n=2,134), and food-insecure girls 1-18 y (n=299). Serum ferritin and soluble transferrin data were only available in the 2015-2016 NHANES and iron deficiency was defined as total body iron <0 mg/kg: food-secure girls 12-18 y (n=368) and food-insecure girls 12-18 y (n=87). 25(OH)D, 25-hydroxyvitamin D; NHANES, National Health and Nutrition Examination Survey.

5.5. Discussion

Food-insecure and food-secure children had similar energy and macronutrient intakes and total HEI-2015 scores, but the food insecure were at higher risk of inadequacy for several micronutrients, including vitamins D and E, magnesium among boys and girls and vitamin A and calcium among girls. Adolescent girls, especially those with food-insecurity, were at greatest risk of micronutrient inadequacy for most nutrients examined, compared to other age and sex subgroups. Our findings, based on rigorous methods of usual dietary intake estimation and a nationally representative sample of U.S. children, contribute to the evidence that food insecurity is associated with compromised intake of some micronutrients among children and the associations are age- and sex-specific (11, 15).

Earlier U.S. and Canadian studies have shown that young children's dietary intakes are less likely to be influenced by the negative impact of food insecurity compared to adults and adolescents (12, 50). Qualitative studies have suggested that adults prioritize young children over other members of the household in terms of food distribution (3). In addition, WIC, which serves almost half of infants and a third of children 1-5 y in the U.S, has successfully reduced disparities in dietary intakes among the youngest children (51). Lastly, some fortified foods, such as ready-to-eat cereals, are widely consumed by young children, regardless of income, and contribute to total micronutrient intakes of both food-secure and food-insecure populations (52). We found that with the exceptions of vitamins D and E, and potassium, younger children are more much more likely to meet EAR or AI than older children. It should be noted that clinical signs of overt vitamin E deficiency is very rare despite high prevalence of inadequate vitamin E intake and there have been calls for the EAR for vitamin E to be revised (53, 54).

Little evidence is available about food-insecure adolescents' diets, but a recent review highlighted adolescence as the stage where food insecurity may have the largest impact on dietary intakes (11). Adolescence is a critical time for establishing adult dietary patterns and health, and yet this age group has the poorest diet quality as well as the lowest dietary supplement use among all other age groups (55, 56). Even when dietary supplements were considered, we found that adolescents 14-18 y were at high risk (>30%) of inadequate intakes for vitamins C, D, and E, calcium, and magnesium. They were also at high risk of inadequacy for vitamins A and E based on intakes from food sources. Moreover, very few (≤5%) had intakes exceeding the AI for choline. These patterns in adolescence may track towards adulthood since the same nutrients were also identified to be under-consumed among adults, even with dietary supplements, in a NHANES 2011-2014 analysis (45). Among adults, disparities in total nutrient intakes by food security status are even greater than they are among children (45).

Among adolescents, some nutrient needs differ by sex. Adolescent girls who are menstruating require more iron to compensate for menstrual losses. Therefore, it is not surprising that the percentage of the population at risk of inadequate iron intake was almost zero in adolescent boys but 16.4% in food-secure and 18.6% in food-insecure adolescent girls (14-18 y). Iron deficiency based on serum ferritin and transferrin receptor was also found in 12.7% of food-secure and 12.0% of food-insecure girls aged 12-18 y. In 1999-2004, 8.4% of food-secure and 10.8% of food-insecure children aged 12-15 y and 12.4% of food-secure and 11.9% of food-insecure children aged 16-19 y were iron deficient when both sexes were combined (7). In this study, iron deficiency was defined as 2 or more abnormal values for serum ferritin, transferrin saturation, and free erythrocyte protoporphyrin (7). Inadequate iron intakes among adolescent girls are of particular concern due to associated risks of iron deficiency anemia as well as possible impact on future pregnancy outcomes (57).

Mean HEI-2015 scores were slightly above 50 on average for the children, out of 100 possible points, indicating that, regardless of sex and food security status, overall diet quality of children was poor. The association between food insecurity and overall diet quality has been weak in previous U.S. studies (12, 15). However, we noted that HEI-2015 scores for the whole grain component were lower in the food-insecure compared to food-secure girls, although difference in boys did not reach statistical significance. Another NHANES analysis that estimated children's usual dietary intakes by food security status also reported lower intakes of whole grains and higher intakes of solid fats and added sugars in the very low food security compared to the high food security subgroup (58). In our study, we did not find significant differences in energy and macronutrient intakes between food-secure and food-insecure boys and girls.

Food-insecure children are less likely to use dietary supplements than the food-secure (14). As a result, with vitamin D, for which the contribution of dietary supplements to total intake was substantial, differences by food security status widened after including dietary supplements. We previously reported that differences in the mean adequacy ratio by food security status widened when dietary supplements were included (15). An earlier study on U.S. adults that estimated total usual nutrient intakes found that dietary supplements contributed more micronutrients to total usual nutrient intakes of higher-income than lower-income subgroups (59). However, to our knowledge, no prior studies have assessed total usual nutrient intake distributions by food security status among U.S. children.

Our study analyzed data from a nationally representative sample of U.S. children. Although measurement errors are inherent in dietary assessment data, we accounted for random measurement error by estimating total usual intakes from two 24-hour dietary recalls and the frequency-based questionnaire for dietary supplement use. Nevertheless, systematic measurement error that is associated with socioeconomic status remains as a potential source of bias in the comparison of food security subgroups; although little is known about the extent of reporting bias specifically by food security status (60). Moreover, reliance on proxy reporters for young children and self-reports for adolescents may pose additional challenges (61). We presented available biomarker data to complement self-reported dietary intake data, but the concentration biomarkers examined can be affected by many factors other than dietary intakes. Another limitation is that our food security classification may not fully reflect children's experience because their caregivers may not be fully aware of children's perceptions, especially those of older children (2). Food security classification based on child self-reports may better characterize experiences of older children (62), but is not currently available in the NHANES or other national surveys possibly due to cost and participant burden. Moreover, a dichotomous classification of four food security status categories was used due to limitations of sample size. Future studies are needed to examine if any potential "dose-response" associations exist by classifying food security in four groups. Lastly, the NHANES is a cross-sectional survey, so temporality and causation cannot be inferred from this analysis.

In conclusion, food insecurity was associated with lower intakes of some micronutrients and whole grains, but not with energy or macronutrient intakes among U.S. children. Among all children, overall diet quality was poor and sodium, added sugar, and saturated fat intakes were much higher than the recommended intakes. The adverse association between food insecurity and children's intakes of some micronutrients is concerning given the importance of childhood for optimal growth and development that can affect life-long health. The constellation of dietary risks in adolescent girls is especially alarming. Interventions to improve the availability of and access to nutrient-dense foods are critical to reduce the negative impact of food insecurity on nutrient adequacy among children.

5.6. Acknowledgements

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CHAPTER 6 . CONCLUSION AND FUTURE DIRECTIONS

6.1. Conclusion

The aim of research in this dissertation was to identify nutrition risk of U.S. infants and children in settings with low income or food insecurity, or who were participating in federal nutrition assistance programs using data from nationally representative surveys, including National Health and Nutrition Examination Survey (NHANES) and Feeding Infants and Toddlers Study (FITS) 2016. In order to mosto accurately and comprehensively capture dietary exposures, usual or habitual intakes were estimated by adjusting for within-person variation from single day assessment methods, and this work included nutrients obtained from dietary supplements,when relevant.

Among U.S. infants and young children, especially those in low-income households, low intakes of iron and vitamin D for infants 6-to 12-months-old; iron, vitamin D, fiber, and potassium for toddlers 12-to 24-months old; and calcium, iron, vitamin D, fiber, and potassium for 24-to 48-months old were of concern. The analysis of FITS 2016 data suggested that participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is beneficial in improving dietary intakes that may be inadequate due to limited financial resources. Infants participating in WIC had higher intakes of many nutrients than lower-income or higher-income nonparticipants. WIC participants had lower risks of inadequate intakes for iron (in 6-24 months-old), saturated fat (in 24-48 months-old), and vitamin D (12-48 months-old) than lower-income nonparticipants. However, WIC participants were more likely to exceed the recommended limits for sodium and energy from added sugars compared to higher-income nonparticipants. Moreover, dietary supplement use was greater in higher-income WIC nonparticipants compared to both participants and lower-income nonparticipants, which can impact total nutrient intake.

The analysis of data from a nationally representative sample of children aged 18 years and younger from the NHANES 2011-2014 showed clear patterns of lower dietary supplement use among children who were in low-income or food-insecure families. Even among low-income children, those participating in WIC and those in households participating in the Supplemental Nutrition Assistance Program (SNAP) were less likely to use dietary supplements. While the most common type of dietary supplements used is multivitamin-minerals, only 15% of multivitamin-mineral users took the product based on health practitioners' recommendations, and SNAP and WIC participants were even less likely to take multivitamin-minerals based on the recommendations of a health practitioner compared to lower-income as well as higher-income nonparticipants.

The difference in dietary supplement use by food security status may widen disparities in total nutrient intakes for those at risk. Indeed, from the analysis of the 2011-2014 NHANES data, the dose-response relationship between food security and mean adequacy ratio was only evident when nutrient intakes from dietary supplements were included and food security status was classified using the Child Food Security Scale. When total usual nutrient intake, a long-term intake inclusive of the contributions of dietary supplements, was estimated by adjusting for random measurement error (i.e. within-person variation) in dietary recall data from the 2011-2016 NHANES, food insecurity was associated with a higher risk of inadequate intakes for some nutrients, such as vitamins D and E, and magnesium. Poor overall dietary quality and excessive sodium, added sugar, and saturated fat intakes were of concern among U.S. children, regardless of food security status. By sex and age, adolescent girls were at considerable nutrition risk because of the large number of nutrients idetifiied in this analysis.

The results from the studies in this dissertation contribute evidence of the association between lower economic status and lower dietary supplement use and suggest that nutrient intake from dietary supplements may rather widen the disparity in nutrition risk. The research findings also highlight unique nutrition risk of U.S. children with lower economic status that should be considered by policymakers and public health professionals when planning nutrition interventions, given that poor dietary intakes during childhood can influence health throughout the life course (e.g., low vitamin D and calcium intakes early in life and life-long bone health).

6.2. Future directions

Future research should establish the temporality of low income or food insecurity proceeding poor dietary behaviors and compromised dietary intakes, using longitudinal data. In addition, longitudinal study design would be beneficial to understand the pathways through which low income and food insecurity impacts diet and health outcomes and to identify the protective factors that shield children's diets from economic disadvantage. At the same time, what protects children's diet from disadvantage should be further investigated. Evidence on the risk factors and protective factors will help policymakers and community workers developing effective intervention strategies. Especially, the impact of federal nutrition assistance programs such as SNAP, WIC, National School Lunch or Breakfast Programs on dietary behaviors, dietary intakes, and mental and physical health should be elucidated, which will justify the need for continued funding and help to improve the programs. Intervention strategies may also consider incorporating diverse actors, including caregivers, health care providers, schools, and society.

To accurately demonstrate the impact of economic status on children's dietary intake, appropriate measures of exposures and outcomes are essential. Self-reported dietary data are prone to measurement errors associated with the day-to-day variation, memory, difficulty in quantifying the amount, personal characteristics such as age and social desirability, reliance on a proxy, and mode of administration. When using a limited number of short-term dietary assessment methods such as 24-hour recall, statistical modeling methods can be used to estimate the usual intake distribution by accounting for the day-to-day variance; but, these methods do not mitigate systematic measurement error, such as energy underreporting. Furthermore, little is known about the measurement error structure of dietary supplement use assessment methods. Therefore, future research needs to identify the measurement error structure of nutrient intakes from dietary supplements, and improve the methods to estimate total usual nutrient intake distribution. Nutritional biomarkers may complement dietary assessment and provide more objective information compared to self-reported dietary intakes, but validated and cost-efficient biomarkers are limited in the nutrition context. Biomarkers are also subject to measurement error and misclassification issues. For example, biomarker estimates can vary substantially by the analtyical method used, and the cutoffs used to define status for particular nutrients (e.g., serum 25-hydroxy vitamin D). Another future research area is the improvement of income and food security measurement and classification. The current official poverty measure does not account for government benefits, taxes, or geography. The new Supplemental Poverty Measure proposed by the Census Bureau may complement the traditional family income measure. In addition, most food security studies measure household-level experience rather than an individual child-level experience. More direct measures of child food security through in-depth interviews with children may be more comparable to their dietary intakes.

Lastly, a growing body of scientific literature suggests that childhood poverty is associated with an increased risk of chronic diseases later in life. Further investigation on the complex relationships between childhood poverty, childhood dietary intakes, dietary intakes throughout the life-course, and adult health will inform potential targets for effective and efficient intervention to prevent development and progression of chronic diseases.

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EDUCATION

Ph.D. **Purdue University, Dual-title in Nutrition Sciences and Gerontology** **2016-2020**
Mentor: Regan L. Bailey, Ph.D., R.D.
Dissertation: Identifying nutrition risk among U.S. infants and children with limited financial resources

M.P.H. **Seoul National University, Public Health Sciences** **2014-2016**
Concentration in Nutritional Epidemiology
Mentor: Hyojee Joung, Ph.D.
Thesis: Development of Flavonoid Database for Common Korean Foods, and Estimation of Intake and Antioxidant Capacity of Flavonoids among Korean Adults.

B.S. **Seoul National University, Food and Nutrition** **2009-2014**
Thesis: Dietary Supplement Use and its Effect on Calcium Intake in Korean Population in the Fourth Korea National Health and Nutrition Examination Survey (2007-2009) Data.

B.A. **Seoul National University, International Relations** **2009-2014**
Thesis: Domestic Adoption of International Norms: Air-Ticket Solidarity Levy in the Republic of Korea.

RESEARCH EXPERIENCE

Purdue University, Interdepartmental Nutrition Program **2016-Present**
Graduate Research Assistant
Advisor: Regan L. Bailey, Ph.D.

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TEACHING EXPERIENCE

Purdue University, Department of Nutrition Science **Fall 2017**

Teaching Assistant

Communication Techniques in Foods and Nutrition (NUTR 424); Evaluation 4.7/5

Instructor: Heather J. Leidy, Ph.D.

Seoul National University, Graduate School of Public Health **Fall 2014**

Teaching Assistant

Obesity and Health Management

Instructor: Hyojee Joung, Ph.D.

HONORS AND SCHOLARSHIPS

- **Outstanding Doctoral Student Award in Nutrition Science**, Purdue University, 2020.
- **Mary E. Fuqua Graduate Scholarship**, Purdue University, Fall 2016, Spring 2017, Fall 2019, Spring 2020 ($150 each time).
- **Richard Family Graduate Nutrition Support**, Purdue University, 2019 ($4,000).
- **Featured on the Office of Interdisciplinary Graduate Programs' website** as a representative of the gerontology program: https://www.purdue.edu/gradschool/oigp/student-profiles/gerontology/jun.html.
- **Poster Presentation Winner**, Interdisciplinary Nutrition Program, Purdue University, 2019 ($500).
- **Travel award**, Third short course on strengthening causal inference in behavioral obesity research, The University of Alabama at Birmingham, 2017 ($1,500).
- **Ross Fellowship**, Purdue University, 2016 (one-year tuition and stipend).
- **Graduated with highest honors**, Master's degree, Seoul National University, South Korea, 2016.
- Seoul National University Graduate School of Public Health **Alumni Scholarship**, Kwanak Corporation, South Korea, 2015.
- **Graduated *Cum Laude***, Bachelor's degree, Seoul National University, South Korea, 2014.

PEER-REVIEWED PUBLICATIONS

1. Bailey RL, **Jun S**, Murphy L, Green R, Gahche JJ, Dwyer JT, Potischman N, Miller JW. High folic acid and folate and low vitamin B12 status: potential but inconsistent interactions with cognitive function in a nationally-representative, cross-sectional study of U.S. older adults. *American Journal of Clinical Nutrition* 2020 (*In press*).
2. **Jun S**, Cowan AE, Bhadra A, Dodd KW, Dwyer JT, Eicher-Miller HA, Gahche JJ, Guenther PM, Potischman N, Tooze JA, Bailey RL. Nutritional status of older adults who are overweight or obese compared to those with a healthy weight, NHANES 2011-2014. *Public Health Nutrition* 2020. doi: 10.1017/S1368980020000257 *(Online ahead of print; Highlighted by the Editorial Board)*.
3. Wallace TC, **Jun S**, Zou P, McCabe GP, Craig BA, Cauley JA, Weaver CM, Bailey RL. Dairy intake is not associated with improvements in bone mineral density or risk of fractures across the menopause transition: Data from the Study of Women's Health Across the Nation (SWAN). *Menopause* 2020. doi: 10.1097/GME.0000000000001555 *(Online ahead of print)*.
4. **Jun S**, Gahche JJ, Potischman N, Dwyer JT, Guenther PM, Sauder KA, Bailey RL. Dietary supplement use and its micronutrient contribution during pregnancy and lactation in the United States. *Obstetrics & Gynecology* 2020; 135(3): 623-633.
5. Kim SA, Kim J, **Jun S**, Wie GA, Shin S, Joung H. Association between dietary flavonoid intake and obesity among adults in Korea. *Applied Physiology, Nutrition, and Metabolism* 2020; 45: 203–212.
6. Bergia RE, **Jun S**, Byers AW, Savaiano DA. Overhauling nutrition assistance programs to provide nutrition support for older adults. *Nutrition Today* 2020; 55(1): 30-37.
7. Cowan AE, **Jun S**, Tooze JA, Dodd KW, Gahche JJ, Eicher-Miller, HA, Guenther PM, Dwyer JT, Moshfegh AJ, Rhodes DG, Bhadra A, Bailey RL. Comparison of four methods to assess the prevalence of use and estimates of nutrient intakes from dietary supplements among U.S. adults. *The Journal of Nutrition* 2020; 150(4):884-893. doi:10.1093/jn/nxz306.
8. Bailey RL, Zou P, Wallace TC, McCabe GP, Graig BA, **Jun S**, Cauley JA, Weaver CM. Calcium supplement use is associated with less bone mineral density loss but does not lessen the risk of bone fracture across the menopausal transition: data from the Study of Women's Health Across the Nation. *JBMR Plus* 2020; 4(1): e10246.
9. Ahn S, **Jun S**, Joung H. Association of total flavonoid intake with hypo-HDL-cholesterolemia among Korean adults: effect modification by polyunsaturated fatty acid intake. *Nutrients* 2020; 12(1), 195. doi:10.3390/nu12010195.
10. Cowan AE, **Jun S**, Tooze JA, Eicher-Miller HA, Dodd KW, Gahche JJ, Guenther PM, Dwyer JT, Potischman N, Bhadra A, Bailey RL. Total usual micronutrient intakes compared to the Dietary

Reference Intakes among U.S. adults by food security status. *Nutrients* 2019; 12(1), 39. doi:10.3390/nu12010038.

11. Ham DW, **Jun S**, Kang M, Paik HY, Joung H, Shin S. Consumption of Korean Foods with High Flavonoid Contents Reduces the Likelihood of Having Elevated C-Reactive Protein Levels: Data from the 2015–2017 Korea National Health and Nutrition Examination Survey. *Nutrients* 2019; 11(10), 2370. doi:10.3390/nu11102370.
12. **Jun S**, Zeh MJ, Eicher-Miller HA, Bailey RL. Children's Dietary Quality and Micronutrient Adequacy by Food Security in the Household and among Household Children. *Nutrients* 2019; 11(5), 965. doi: 10.3390/nu11050965.
13. Bailey RL, Dodd KW, Gahche JJ, Dwyer JT, Cowan AE, **Jun S**, Eicher-Miller HA, Guenther PM, Bhadra A, Thomas PR, Potischman N, Carroll RJ, Tooze JA. Best practices for dietary supplement assessment and estimation of total usual nutrient intakes in population-level research and monitoring. *The Journal of Nutrition* 2019; 149(2): 181-197.
14. **Jun S**, Cowan AE, Tooze JA, Gahche JJ, Dwyer JT, Eicher-Miller HA, Bhadra A, Guenther PM, Potischman N, Dodd KW, Bailey RL. Dietary supplement use among U.S. children by family income, food security level, and nutrition assistance program participation status in 2011–2014. *Nutrients* 2018; *10*(9), 1212. doi: 10.3390/nu10091212.
15. Cowan AE, **Jun S**, Gahche JJ, Tooze JA, Dwyer JT, Eicher-Miller HA, Bhadra A, Guenther PM, Potischman N, Dodd KW, Bailey RL. Dietary supplement use differs by socioeconomic and health-related characteristics among U.S. adults, NHANES 2011-2014. *Nutrients* 2018; 10(8), 1114. doi: 10.3390/nu10081114.
16. **Jun S**, Catellier D, Eldridge AL, Dwyer JT, Eicher-Miller HA, Bailey RL. Usual nutrient intakes from the diets of U.S. children by WIC participation and income: findings from the Feeding Infants and Toddlers Study (FITS) 2016. *The Journal of Nutrition* 2018; 148 (9S) 1567S-1574S. doi:10.1093/jn/nxy059.
17. Bailey RL, Catellier D, **Jun S**, Dwyer JT, Jacquier EF, Eldridge AL. Total usual nutrient intakes of US children (under 48 months): findings from the Feeding Infants and Toddlers Study (FITS) 2016. *The Journal of Nutrition* 2018; 148 (9S) 1557S-1566S. doi:10.1093/jn/nxy042.
18. **Jun S**, Thuppal SV, Maulding MK, Eicher-Miller HA, Savaiano DA, Bailey RL. Poor Dietary Guidelines compliance among low-income women eligible for Supplemental Nutrition Assistance Program-Education (SNAP-Ed). *Nutrients* 2018; 10, 327. doi:10.3390/nu10030327.

19. **Jun S**, Chun OK, Joung H. Estimation of dietary total antioxidant capacity of Korean adults. *European Journal of Nutrition* 2018; 57(4): 1615-1625. doi: 10.1007/s00394-017-1447-6.
20. Thuppal SV, **Jun S**, Cowan AE, Bailey RL. The Nutritional Status of U.S. Adults with HIV. *Current Developments in Nutrition* 2017; 1(10), e001636. doi:10.3945/cdn.117.001636.
21. Quansah DY, Ha K, **Jun S**, Kim S, Shin S, Wie G, Joung H. Associations of dietary antioxidants and risk of type 2 diabetes: data from the 2007-2012 Korea National Health and Nutrition Examination Survey. *Molecules* 2017; 22(10), 1664. doi:10.3390/molecules22101664.
22. Kim S, Song Y, Lee JE, **Jun S**, Shin S, Wie G, Cho YH, Joung H. Total antioxidant capacity from dietary supplement decreases the likelihood of having metabolic syndrome in Korean adults. *Nutrients* 2017; 9 (10): 1055. doi:10.3390/nu9101055.
23. Kim SY, Wie G, Cho Y, Kang H, Ryu K, Yoo M, **Jun S**, Kim S, Ha K, Kim J, Cho YH, Shin S, Joung H. The role of red meat and flavonoid consumption on cancer prevention: the Korean Cancer Screening Examination Cohort. *Nutrients* 2017; 9 (9): 938. doi:10.3390/nu9090938.
24. **Jun S**, Ha K, Chung S, Joung H. Meat and milk in the rice-based Korean diet: impact on cancer and metabolic syndrome. *Proceedings of the Nutrition Society* 2016; 75(3): 374-384.
25. **Jun S**, Shin SA, Joung H. Estimation of dietary flavonoid intake and major food sources of Korean adults. *British Journal of Nutrition* 2016; 115: 480-489.

BOOK CHAPTERS AND NON-ACADEMIC PUBLICATIONS

- Bailey RL, **Jun S**, Eldridge AL. The 2016 Feeding Infants and Toddlers Study (FITS): Dietary Intakes and Practices of Children in the United States from Birth to 48 Months. *Nestle Nutrition Institute workshop series*. 2019; 91: 99-109.
- **Jun S**. Benefits of blueberries for optimal aging. Aging Exchange-The Newsletter of the Center on Aging and the Life Course at Purdue University. Spring 2020.

PRESENTATIONS at NATIONAL MEETINGS

- **Jun S**, Cowan AE, Gahche JJ, Tooze JA, Dodd KW, Eicher-Miller HA, Guenther PM, Dwyer JT, Potischman N, Bailey RL. Comparison of four methods to estimate the prevalence of dietary supplement use among U.S. children. *Nutrition 2020* (Virtual abstract presentation).
- **Jun S**, Cowan AE, Bhadra A, Dodd KW, Dwyer JT, Eicher-Miller HA, Gahche JJ, Guenther PM, Potischman N, Tooze JA, Bailey RL. Nutritional status of older adults who are overweight or obese compared to those with a healthy weight, NHANES 2011-2014. *Nutrition 2019*. Baltimore, U.S., June 8-11, 2019 (Poster).

- **Jun S**, Cowan AE, Tooze JA, Eicher-Miller HA, Bhadra A, Guenther PM, Gahche JJ, Potischman N, Dwyer JT, Bailey RL. Dietary supplement use is higher among US children in higher income households compared to children in lower income households. *Nutrition 2018*. Boston, U.S., June 9-12, 2018 (Poster).
- **Jun S**, Chun OK, Quansah DY, Hei Y, Joung H. Estimation of dietary total antioxidant capacity of Korean adults. *2016 Experimental Biology Meeting*. San Diego, U.S., April 2-6, 2016 (Poster).
- **Jun S**, Shin SA, Joung H. Estimation of dietary flavonoid intake and major food sources of Korean adults. *2015 Experimental Biology Meeting*. Boston, U.S., March 28-April 1, 2015 (Poster).

SELECTED PRESENTATIONS at UNIVERSITY

- **Jun S**, Gahche JJ, Potischman N, Dwyer JT, Guenther PM, Sauder, KA, Bailey R. Dietary supplement use and its micronutrient contribution among U.S. pregnant and lactating women. *Women's Health Symposium*. Nov 1, 2019 (Poster).
- **Jun S,** Cowan AE, Bhadra A, Dodd KW, Dwyer JT, Eicher-Miller HA, Gahche JJ, Guenther PM, Potischman N, Tooze JA, Bailey RL. Nutritional status of older adults who are overweight or obese compared to those with a healthy weight. *Center on Aging and the Life Course at Purdue University-Scholars in Spotlight*. March 28, 2019 (Podium).
- **Jun S**, Cowan AE, Bhadra A, Dodd KW, Dwyer JT, Eicher-Miller HA, Gahche JJ, Guenther PM, Potischman N, Tooze JA, Bailey RL. Nutritional status of older adults who are overweight or obese compared to those with a healthy weight, NHANES 2011-2014. *Purdue Interdepartmental Nutrition Program Poster Session*. February 1, 2019 (Poster; Selected as *Winner*).
- **Jun S**, Cowan AE, Tooze JA, Eicher-Miller HA, Bhadra A, Guenther PM, Gahche JJ, Potischman N, Dwyer JT, Bailey RL. Dietary supplement use is higher among US children in higher income households compared to children in lower income households. *Purdue College of Health and Human Sciences Fall Research Day*. October 17, 2018 (Poster).
- **Jun S**, Eldridge AL, Bailey RL. Characterizing the dietary practices and nutritional exposures of US children (birth-48 months): Data from the Feeding Infants and Toddlers Study (FITS), 2016. *Purdue Office of Interdisciplinary Graduate Program Spring Reception*. May 2, 2018 (Poster).
- **Jun S**, Thuppal SV, Maulding MK, Eicher-Miller HA, Savaiano DA, Bailey RL. Poor Dietary Guidelines compliance among low-income women eligible for Supplemental Nutrition Assistance Program-Education (SNAP-Ed). *Purdue Interdisciplinary Nutrition Program Poster Session*. February 23, 2018 (Poster).

- **Jun S**, Thuppal SV, Maulding MK, Eicher-Miller HA, Savaiano DA, Bailey RL. Comparison of baseline characteristics between Indiana SNAP-Ed and NHANES women. *Purdue College of Health and Human Sciences Fall Research Day*. November 8, 2017 (Poster).

UNIVERSITY SERVICE ACTIVITIES

- Volunteer. Senior Grocery Program (providing a bag of groceries to low-income older adults). Center on Aging and the Life Course at Purdue University. Spring 2019.
- Volunteer. Tech Team (helping older adults in assisted living with their tech issues). Center on Aging and the Life Course at Purdue University. Fall 2017, Fall 2018.
- Social committee member. Nutrition Graduate Student Organization. Purdue University. Summer 2018-Spring 2019.
- Liaison to the Interdisciplinary Graduate Program Students. Center on Aging and the Life Course at Purdue University. Fall 2017-Spring 2019.

PROFESSIONAL MEMBERSHIPS AND ACTIVITIES

- American Society of Nutrition, 2017-Present.
- Reviewer of research articles for journals: *British Journal of Nutrition, Public Health Nutrition, Nutrition Journal, Journal of the American College of Nutrition*

SKILLS AND LANGUAGES

- **Certified Dietitian**, Ministry of Health and Welfare, Korea, 2015.
- Statistical Software: SAS, SUDAAN
- Languages: Korean, English