PERSPECTIVES AND OPINIONS

CURRENT DEVELOPMENTS IN NUTRITION

Maternal and Pediatric Nutrition

Iron-Rich Complementary Foods: Imperative for All Infants

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ABSTRACT

Nearly 1 in 5 (18%) infants in the United States is not consuming sufficient iron. A deficiency of iron during early life may be associated with long-term neurodevelopmental consequence(s). The 2020–2025 Dietary Guidelines for Americans (DGA) are the first DGA to address recommendations for children under 2 y of age. The 2020 Dietary Guidelines Advisory Committee scientific report includes food-group combinations emphasizing iron-rich foods for 6–12-mo-old infants, but these examples did not meet criteria to establish DGA recommended dietary patterns; consequently, iron-rich dietary patterns for ages 6–12 mo are not provided in the 2020–2025 DGA. The 2020–2025 DGA encourage iron-rich foods by 6 mo of age while emphasizing the importance "particularly for infants fed human milk." Early feeding transitions are dynamic and milk feeding groups are rarely static or exclusive such that emphasizing milk feeding groups may become confusing. Risk-to-benefit favors iron-rich complementary feeding for all infants. *Curr Dev Nutr* 2021;5:nzab117.

Keywords: infants, older infants, complementary feeding, dietary guidelines, infant formula, breast milk, human milk, heme iron, nonheme iron, iron deficiency

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Abbreviations used: DGA, Dietary Guidelines for Americans; DGAC, Dietary Guidelines Advisory Committee; EAR, Estimated Average Requirement; ESPGHAN, European Society for Paediatric Gastroenterology, Hepatology, and Nutrition European; FITS, Feeding Infants and Toddlers Study; NESR, Nutrition Evidence Systematic Review; SR, systematic review; UL, Tolerable Upper Intake Level; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

Introduction

Nutritional surveys, such as the Feeding Infants and Toddlers Study (FITS) and NHANES, show that among 6–12-mo-olds, iron intake is low and has fallen over the past two decades (1, 2). With iron needed to support development of the nervous system, erythropoiesis, and other critical aspects of growth and development, iron requirements for 6–12-mo-old infants are the highest in life, at 1 mg/kg per day (3). Iron deficiency is the most common nutrient deficiency among children in developing countries (4). In the United States, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) was established in 1975 to address iron insufficiency and other nutrient concerns among those at risk for poor nutrition (5). Today, over half the newborns in the United States are WIC eligible due to poverty or nutritional risk (6); yet, despite recent revisions to the WIC feeding package, data show that nearly 1 in 5 US infants is still consuming insufficient iron in their diets (7). The American Academy of Pediatrics has noted that a deficiency of iron during the first 1000 days of life may be associated with long-term neurodevelopmental consequence(s) (8).

The 2020–2025 Dietary Guidelines for Americans (DGA) is the first edition of the DGA to directly address food and nutrient needs from birth to 24 mo (9). To address this critical dietary period, the 2020 Dietary Guidelines Advisory Committee (DGAC) relied on 3 approaches to evidence analysis including data analysis, food pattern modeling, and systematic review (SR) conducted by the Nutrition Evidence Systematic Review (NESR) team of the USDA (10). The conclusions of a NESR SR suggest that consuming iron-rich complementary foods will support the micronutrient status of those infants, especially those exclusively breastfed or with known iron insufficiency (11). Specifically, NESR concluded that "Strong evidence suggests that consuming complementary foods and beverages that contain substantial amounts of iron, such as meats or iron-fortified cereal, helps maintain adequate iron status or prevent iron deficiency during the first year of life among infants with insufficient iron stores or breastfed infants who are not receiving adequate iron from another source. However, the benefit of these types of complementary foods and beverages for infants with sufficient iron stores, such as those consuming iron-fortified infant formula, is less evident" (11). Evidence from the NESR SR informed the DGAC scientific report and the 2020–2025 DGA, which also emphasize iron-rich complementary food

TABLE 1 Advice regarding iron-rich food intake during early complementary feeding of infants as provided by the 2020–2025 Dietary Guidelines for Americans

DGA statement/recommendation (9)	DGA location
"Guideline 1—At about 6 months, introduce infants to nutrient-dense complementary foods. Introduce infants to potentially allergenic foods along with other complementary foods. Encourage infants and toddlers to consume a variety of foods from all food groups. Include foods rich in iron and zinc, particularly for infants fed human milk."	Pages ix and 18
"Encourage infants and toddlers to consume a variety of foods from all food groups. Include foods rich in iron and zinc, particularly for infants fed human milk."	Page 53
"For infants fed human milk, it is particularly important to include complementary foods that are rich in iron and zinc when starting complementary foods (see Appendix 1: Nutritional Goals for Age-Sex Groups)."	Page 56
"Iron is a dietary component of public health concern for under consumption among older infants ages 6 through 11 months who are fed primarily human milk and consume inadequate iron from complementary foods."	Page 59
Introduce iron-rich foods to infants starting at about 6 months old	
"Iron-rich foods (e.g., meats and seafood rich in heme iron and iron-fortified infant cereals) are important components of the infant's diet from age 6 through 11 months to maintain adequate iron status, which supports neurologic development and immune function. Infants are typically born with body stores of iron adequate for about the first 6 months of life, depending on gestational age, maternal iron status, and timing of umbilical cord clamping. By age 6 months, however, infants require an external source of iron apart from human milk. Caregivers of infants exclusively fed human milk should talk with their pediatric care provider about whether there may be a need for infants supplementation with iron before age 6 months. A complementary food source of iron beginning at about 6 months is particularly important for infants fed human milk because the iron content of human milk is low and maternal iron intake during lactation does not increase its content. In the United States, an estimated 77 percent of infants fed human milk have inadequate iron intake during the second half of infancy, highlighting the importance of introducing iron-rich foods starting at age 6 months."	Page 59
"Infants receiving most of their milk feeds as iron fortified infant formula are likely to need less iron from complementary foods beginning at 6 months of age. After age 12 months, children have a lower iron requirement, but good food sources of iron are still needed to maintain adequate iron status and prevent deficiency."	Page 59/60
"Protein foods[1], including meats, poultry, eggs, seafood, nuts, seeds, and soy products, are important sources of iron, zinc, protein, choline, and long chain polyunsaturated fatty acids."	Page 60
"Grains, including iron-fortified infant cereal, play an important role in meeting nutrient needs during this life stage. Infant cereals fortified with iron include oat, barley, multigrain, and rice cereals. Rice cereal fortified with iron is a good source of nutrients for infants, but rice cereal shouldn't be the only type of cereal given to infants."	Page 60

[1]Lists of nutrient-dense iron-rich foods are provided at https://www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials/food-sources-select-nutrients/food-1 (9). DGA, Dietary Guidelines for Americans.

intake "particularly for human milk fed infants" (not defined further as exclusively breastfed or ever breastfed), noting in one instance that "Infants receiving most of their milk feeds as iron fortified infant formula are likely to need less iron from complementary foods beginning at 6 months of age" [**Table 1**; (11)]. While true, the statement does not offer practical guidance.

Far from being dichotomous, milk feeding in the United States represents a continuum between exclusive breastfeeding and exclusive formula feeding, with most US infants consuming a mixed pattern that is continually shifting throughout the initial 12 mo of life (12, 13). Clear guidance regarding the importance of iron-rich foods during complementary feeding is necessary for all older infants and young children. In fact, the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition European (ESPGHAN) notes, "Although there are theoretical reasons why different complementary foods may have particular benefits for breast-fed or formula-fed infants, attempts to devise and implement separate recommendations for breast-fed and formula-fed infants are likely to be confusing and is therefore not recommended" (14). Instead, the ESPGHAN Committee on Nutrition recommended that "From the age of 6 months, all infants and toddlers should receive iron-rich (complementary) foods, including meat products and/or iron-fortified foods. Unmodified cow milk should not be fed as the main milk drink to infants before the age of 12 months and intake should be limited to <500 mL/day in toddlers. It is important to ensure that this dietary advice reaches high-risk groups such as socioeconomically disadvantaged families and immigrant families" (14). While the DGAC scientific report provides example combinations of complementary foods emphasizing iron-rich first foods for all infants between 6 and 12 mo of age (**Table 2**), these combinations were not incorporated into the 2020–2025 DGA due to dietary pattern modeling constraints.

Exclusive breastfeeding rates in the United States are estimated at 47% at 3 mo and 25% at 6 mo, with the majority of breastfed infants in the United States supplemented with iron-containing infant formula (12). The NESR SR conclusion of strong evidence supporting iron-rich complementary foods for "infants with insufficient iron stores or breastfed infants who are not receiving adequate iron from another source" considered findings of studies enrolling "exclusively" breastfed infants (15–19). Importantly, however, in most of these studies (16, 18, 19) up to 50% of participants began formula supplementation during the course

TABLE 2 Example intake amounts of iron-rich complementary foods for older infants provided in the 2020 Dietary Guidelines Advisory Committee Scientific Report[1]

Food group identifier	Age group	Intake recommendation (ounce equivalents)—2020 DGAC scientific report[2]
Meats[3]	6–9 mo	4.66 –16 (per week)[4]
Poultry	6–9 mo	0.5–1.25 (per week)
Fortified infant cereals	6–9 mo	0.5 (per day)
Meats	9–12 mo	8.5–15.5 (per week)
Poultry	9–12 mo	1 (per week)
Fortified infant cereals	9–12 mo	0.5 (per day)

[1]Data from reference (10). DGAC, Dietary Guidelines Advisory Committee.
[2]The DGAC report makes the following note: "Total protein foods includes a majority from meats rather than poultry because meat has higher iron content than poultry."
[3]"Meats" in the DGAC report is considered as red meat.
[4]"When a range is shown, the lower amounts generally correspond to the lower energy levels and/or a higher proportion of energy from human milk, and the higher amounts correspond to the higher energy levels and/or a lower proportion of energy from human milk." (10)

of the trial, initiated anywhere from enrollment at 4 mo of age to periods within complementary feeding. Two of these studies (16, 18) reported no significant between-group differences for measures of iron status. The NESR SR further concluded that the benefit of iron-rich complementary foods to infants fed iron-fortified formulas is "less evident," but only 1 study in the NESR SR evidence base randomly assigned exclusively formula fed infants to high or low iron from complementary foods and considered iron status (20).

Additional evidence considered by the DGAC was provided by NHANES data from 2007–2014 ($n = 988$ infants), which finds that "human milk fed infants" ($n = 141$; milk feeding group not specified, but assumed exclusive) are at highest risk for iron inadequacy, with 77% of these US infants under 1 y failing to meet the Estimated Average Requirement (EAR) (21). NHANES data further suggest that "less than 7% of infants in the formula and mixed-fed group have total dietary intakes of iron less than the EAR (all dietary sources, not including dietary supplements)" (10) and "infants who do not have compromised iron stores or who receive fortified infant formula with iron likely have adequate intakes or may have intakes that approach or exceed the Tolerable Upper Intake Level (UL)" (10). Importantly, however, these same data estimate that 19% of all US infants under 1 y of age, nearly 750,000 infants annually (22), fail to meet the EAR for iron. These data are supported by the ongoing FITS with FITS 2016 data indicating that iron intakes among older infants (6–11.9 mo of age; $n = 902$) have been on a declining trajectory since 2002 (23). FITS results indicate that this decline is due to a 30% decrease in consumption of iron-fortified cereal from 2002 to 2016 (23) and a shift away from intake of iron-rich red meat such as beef and pork (23), noting that "the types of meats consumed were not iron-rich sources, like turkey, chicken or processed meats" (24). In fact, findings from the 2016 FITS indicate that chicken or turkey was the most popular meat (consumed by 17% of infants) between 6 and 11.9 mo followed by processed meat (hotdogs, cold cuts, sausages) consumed by 7.0% of infants, as compared to 2.5% of infants consuming beef or 1.6% consuming pork (23). Declining intake of iron-fortified cereal may be exacerbated by guidance to decrease exposure to arsenic in rice and rice products (25). FITS researchers note, however, that "if the decline of infant cereal, a key source of iron for infants, is not replaced with other bioavailable sources of iron in the diet, lower consumption of infant cereal could contribute to inadequate iron intakes" (25).

The decline in iron-rich foods during complementary feeding has also been attributed to an "increased focus on preventing excessive energy intake and increasing fruit and vegetable intake in the wake of the childhood obesity epidemic" (24). Consequently, 12% of older infants participating in FITS consumed less than the EAR for iron in 2008. By 2016, the percentage was estimated to be 18% of older infants failing to meet the EAR (23). Evidence is lacking from biomarkers or clinical health indicators as "serum ferritin is not measured as part of national nutrition monitoring for children younger than age 12 months" (10), making estimates of iron adequacy (inadequate or sufficient) for the entire US infant population unreliable.

Despite the assumption that infants receiving iron-fortified infant formula are likely to have adequate iron intake, based on an 11-mg estimated requirement and fortification of infant formula at 10–12 mg/L, iron sufficiency is not guaranteed. Iron absorption varies due to many factors, including milk source of iron (e.g., human vs. cow), iron compound consumed (e.g., ferrous sulfate vs. pyrophosphate), foods eaten at the same time, and iron status of the infant (26, 27). While greater than 50% of iron from human milk is absorbed, generally less than 12% of iron is absorbed from infant formula (26). Iron from meat sources is better absorbed than iron from nonmeat sources (26). Infants with poorer iron status or in negative iron balance absorb a higher percentage of dietary iron (26). Larger dietary doses are also necessary when conditions that promote iron losses (e.g., inflammation, chronic disease, occult gastrointestinal bleeding associated with exposure to cow-milk protein, food allergies, or infectious agents) are considered (26, 27). A recent study by Abrams et al. (28), using data from FITS, reported that daily iron absorption was below the recommended amount in 54.3% of 6–24-mo-old infants and ranged from 19.5% in exclusively formula-fed infants, to 95.8% in exclusively breastfed infants, with 72.2% in mixed-fed infants. The calculated mean iron absorption of 6- to 9-mo-old breastfed infants was lower than the estimated physiologic requirement (i.e., 0.27 mg/d vs. 0.69 mg/d, respectively). The authors concluded that "rates of low absorbed iron indicate that all infants may need monitoring for clinical evidence of low iron status" (28).

Concerns regarding excess intake from the combination of iron-fortified infant formula and iron-rich complementary foods are likely misplaced. The daily need for iron in the 6–12-mo age range is 11 mg, while the UL for iron is 40 mg (29), representing considerable latitude. The risks of iron supplementation in infants who are already iron-sufficient have been reviewed and include limitations of growth, higher risk of infections (malaria), interference with zinc absorption, and possibly delayed cognitive development (3, 26). However, these issues have been attributed almost exclusively to medicinal iron supplementation where a spike in free iron following medical iron occurs, which is not seen with dietary iron (30). Adverse effects from consumption of iron-fortified foods consumed along with iron-containing infant formulas appear to be unlikely (26). In fact, the DGAC scientific report includes a summary of estimated iron from combinations of complementary foods and beverages with and without 0.5 ounces of fortified infant cereal for infants fed varying combinations of human milk and formula. This analysis found the highest estimated intake of iron to be 19.9 mg at 6 to 9 mo, which is half the 40 mg UL for iron (31).

Why Recommend Red Meat as a Primary Source of Iron during Complementary Feeding?

The DGAC scientific report provides approximate amounts of food groups and subgroups in example combinations of complementary foods and beverages for ages 6 to 12 mo (10). These example combinations provide a range of intakes anchored on estimated human-milk and/or energy intake and emphasize more servings of red meat (Text Box 1) than any other food group, with allowance for up to 16 ounces of red meat per week during complementary feeding (Table 2).

Text Box 1

What is Red Meat?

"Red meat" is referred to as mammalian meat, most commonly noted as beef, pork, and lamb. In contrast, "white meat" is inclusive of poultry (muscles from birds) and fish (muscles from aquatic animals). While some consider pork "white meat" due to appearance, pork is red meat.

However, because these example food combinations could not be adequately modeled within the dietary pattern methodologies utilized to create recommended food patterns for the general population, these example food combinations were not included in the 2020–2025 DGA. Thus, while the DGA recommend introducing iron-rich foods to infants starting at about 6 mo old (Table 1), no guidance regarding specific intake amounts or distribution of iron-rich first foods for 6–12-mo-old infants could be provided. Lack of specific guidance may have implications for iron sufficiency. Animal and plant proteins are not interchangeable with regard to iron bioavailability, and meat currently makes up little of the complementary diet of American infants. Heme iron from red meat (i.e., beef, pork) is estimated to be 25% bioavailable, while that found in iron-fortified cereal-based foods is estimated to be 10% bioavailable (32). High-quality protein, iron, zinc, and other nutrients from red meat strengthen a balanced diet and complement the nutrients found in plant foods, while enhancing the absorption of nutrients, including nonheme iron from plant foods (32).

To compensate for the limited bioavailability of iron and other micronutrients in plant foods, the National Academy of Medicine Committee on Micronutrients recommends that vegetarians consume 1.8 times the daily iron compared with those consuming meat (29). Despite the endorsement of vegetarian diets as healthful for infants and young children (33), a recent systematic review of vegetarian diets in children found insufficient evidence "to draw firm conclusions on the health benefits or risks of present-day vegetarian type diets on the nutritional or health status of children and adolescents in industrialized countries" (34). With regard to iron, the systematic review found that iron deficiency was reported in more than half of studies of vegetarian children and other studies reported lower or similar biomarkers of iron status (34). As such, regarding meatless complementary diets, medical experts note that while "a similar intake of most nutrients and protein can be achieved…," "there is a higher risk of deficiency of individual nutrients, such as iron, zinc and DHA" (35). Similarly, with regard to micronutrient status and fruits and vegetables in complementary feeding, NESR found insufficient evidence to determine the relation between these plant-based foods and iron status (11).

With regard to the need to raise awareness among clinicians for the importance of meat in the diet of US children, FITS researchers note that it "is imperative that they emphasize the importance of iron, recognizing the very low intake of iron-rich meats and the declining use of iron-fortified infant cereal among young children in the US as strong reasons to recommend iron-rich and iron-fortified complementary foods" (24). Educating caregivers about the importance of iron-rich foods in complementary feeding is important and can be accomplished by increasing clinician awareness about declining iron intake (24), promoting the American Academy of Pediatrics' endorsement of meat and other iron-rich foods as an early complementary food (4), and providing clear guidance via the DGA (23).

Conclusions

Given the consequence(s) of insufficient iron during early complementary feeding, food-based dietary guidance that aims to provide specific intake amounts and distribution of iron-rich first foods for 6–12-mo-old infants is justified and necessary. Emphasizing iron-rich foods for infant population subgroups based on milk feeding may lead to confusion and exacerbation of an already concerning public health situation. The preponderance of available literature, and the high benefit versus low risk of iron-rich complementary feeding, supports creating clear, specific, and strong future DGA recommendations for the consumption of iron-rich foods with high bioavailability starting at the first introduction of solid foods, and continuing regularly throughout the complementary feeding time frame.

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