Medical Position Paper

Complementary Feeding: A Commentary by the ESPGHAN Committee on Nutrition

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ABSTRACT

This position paper on complementary feeding summarizes evidence for health effects of complementary foods. It focuses on healthy infants in Europe. After reviewing current knowledge and practices, we have formulated these conclusions: Exclusive or full breast-feeding for about 6 months is a desirable goal. Complementary feeding (ie, solid foods and liquids other than breast milk or infant formula and follow-on formula) should not be introduced before 17 weeks and not later than 26 weeks. There is no convincing scientific evidence that avoidance or delayed introduction of potentially allergenic foods, such as fish and eggs, reduces allergies, either in infants considered at increased risk for the development of allergy or in those not considered to be at increased risk. During the complementary feeding period, >90% of the iron requirements of a breast-fed infant must be met by complementary foods, which should provide sufficient bioavailable iron. Cow's milk is a poor source of iron and should not be used as the main drink before 12 months, although small volumes may be added to complementary foods. It is prudent to avoid both early (<4 months) and late (≥7 months) introduction of gluten, and to introduce gluten gradually while the infant is still breast-fed, inasmuch as this may reduce the risk of celiac disease, type 1 diabetes mellitus, and wheat allergy. Infants and young children receiving a vegetarian diet should receive a sufficient amount (∼500 mL) of breast milk or formula and dairy products. Infants and young children should not be fed a vegan diet. *JPGN 46:99–110, 2008.* **Key Words:** Complementary feeding—Solid foods—Beikost—Breast-feeding—Dietary intakes—Early nutrition programming of adult health. © 2008 by European Society for Pediatric Gastroenterology, Hepatology, and Nutrition and North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition

The timely introduction of complementary foods during infancy is necessary for both nutritional and developmental reasons, and to enable the transition from milk feeding to family foods. The ability of breast milk to meet requirements for macronutrients and micronutrients becomes limited with increasing age of the infant. Furthermore, infants gradually develop the ability to chew, and they start to show an interest in foods other than milk. Complementary feeding is associated with major changes in both macronutrient and micronutrient intake. Yet, in contrast to the large literature on breast and formula feeding, relatively little attention has been paid to the complementary feeding period, the nature of the foods given, or whether this period of significant dietary change influences later health and development. The limited scientific evidence-base is reflected in considerable variation in complementary feeding recommendations between countries. The aim of this position paper is to review current knowledge and practice, summarize the evidence for the short- and long-term health effects of the timing and composition of complementary feeding, provide advice to health care providers and regulatory bodies, and identify areas for future research. This position paper focuses on healthy term-born infants living in

Europe, generally in affluent populations, but recognizes that within this population there are groups and families at higher risk for infections and poor nutrition. The emphasis will be on complementary feeding during the period until 12 months of age.

DEFINITIONS

The definition of exclusive breast-feeding by the World Health Organisation (WHO) implies that the infant receives only breast milk and no other liquids or solids except for drops or syrups consisting of vitamins, mineral supplements, or medicines. Full breast-feeding includes breast-feeding in combination with the supply of water or water-based drinks, including, for example, oral rehydration solutions.

In this review we use the term "complementary feeding" to embrace all solid and liquid foods other than breast milk or infant formula and follow-on formula. Other terms commonly used in this context are "weaning," "weaning foods," and "Beikost."

The WHO has described the complementary feeding period as "the period during which other foods or liquids are provided along with breast milk" and states that "any nutrient-containing foods or liquids other than breast milk given to young children during the period of complementary feeding are defined as complementary foods" (http://www.who.int/nutrition/databases/infant-feeding/en/index.html). The WHO decision to include human milk substitutes (HMS), infant formula, and follow-on formula as "complementary food" is intended to emphasize and encourage breast-feeding. However, the Committee regards including HMS as complementary food to be unhelpful and even confusing because infants are frequently fed HMS even from the first weeks of life.

CURRENT RECOMMENDATIONS

Timing of First Introduction of Complementary Foods

Current WHO recommendations on the age at which complementary foods should be introduced are based on a consideration of the optimal duration of exclusive breast-feeding. Given that infant formula is defined by WHO as a complementary food, the issue of the optimal age for introduction of complementary foods in formula-fed infants has received little attention. In early 2000 a WHO-commissioned systematic review of the optimal duration of exclusive breast-feeding (1) compared mother and infant outcomes with exclusive breast-feeding for 6 months versus 3 to 4 months. Of 20 eligible studies identified, only 2 were randomized intervention trials of different exclusive breast-feeding recommendations, both conducted in a developing world setting (Honduras). All of the studies from the developed world were observational. The review concluded that there were no differences in growth between infants exclusively breast-fed for 3 to 4 months versus 6 months. An analysis of observational data from a trial of breast-feeding promotion in Belarus found that during the period from 3 to 6 months, infants who were exclusively breast-fed for 6 months experienced less morbidity from gastrointestinal infection than did those exclusively breast-fed for 3 months followed by partial breast-feeding, even though no significant differences in risk of respiratory infectious outcomes or atopic eczema were apparent (2). However, the extent to which conditions and practices in Belarus resemble those in other European countries may be questioned.

A second systematic review, commissioned in the late 1990s and published in 2001 (3), specifically addressed the optimal age for introducing solid foods and included studies in both breast-fed and formula-fed infants. The authors concluded that there was no compelling evidence to support a change in the 1994 UK Department of Health recommendation or the (then current) WHO recommendation (both 4–6 months).

Following the WHO systematic review and expert consultation, in 2001 the World Health Assembly revised its recommendation to exclusive breast-feeding for 6 months and partial breast-feeding thereafter. In the recommendations from the expert consultation, it was stated that the recommendation applies to populations, and it was recognized that some mothers would be unable to, or would choose not to, follow this recommendation and that these mothers should also be supported to optimise their infant's nutrition (4). Many countries have since adopted this recommendation for the duration of exclusive breast-feeding, sometimes with qualifications, whereas other countries continue to recommend the introduction of complementary feeding between 4 and 6 months. However, there has been disagreement between advisory bodies even within the same country, reflecting the limited scientific evidence from industrialised countries upon which the WHO recommendation was based, and the fact that the recommendation is far removed from current feeding practices in many countries. Given that the WHO recommendation is not directly applicable to formula-fed infants, some countries have adopted different recommendations regarding the introduction of complementary foods in these infants.

On the basis of available data, the Committee considers that exclusive or full breast-feeding for around 6 months is a desirable goal (ESPGHAN Committee on Nutrition, in preparation). In all infants, in consideration of their nutritional needs, developmental abilities, and reported associations between the timing of introduction of complementary feeding and later health, which are discussed later, the introduction of complementary foods should not be before 17 weeks but should not be delayed beyond 26 weeks.

Other Recommendations on Complementary Feeding

The debate on the optimal duration of exclusive breast-feeding has largely overshadowed consideration of the optimal types of complementary foods. Evidence for the optimal timing for the introduction of individual complementary foods is lacking, and recommendations vary widely between countries. For example, most countries recommend that whole cow's milk not be introduced as a drink before the age of 12 months, whereas Denmark, Sweden, and Canada state that whole cow's milk can be introduced from the age of 9 to 10 months. The suggested age for the introduction of fish or egg whites also differs considerably, with several countries recommending that they can be introduced from 4 to 6 months, whereas others recommend waiting until 9 or 12 months.

CURRENT PRACTICE

Figures from different European countries indicate a wide variation in the age at introduction of complementary foods, with several showing marked departures from the current WHO recommendation to introduce complementary feeding only from the seventh month onward. For example, 34% of mothers in Italy reported introducing complementary foods before 4 months (5); in Germany, 16% had done so by 3 months (6), whereas in the UK 2005 Infant Feeding Survey, 51% of infants were reported to have received complementary foods before 4 months (7). Mothers in some countries may be delaying the introduction of complementary feedings for too long. One study showed that about 20% of German mothers thought exclusive breast-feeding should continue for >6 months (E. Sievers, personal communication, 2007). It is likely that cultural and economic factors and also maternal and infant cues are responsible for variations in practice between and within countries. For example, the earlier introduction of complementary foods in British infants was associated with formula feeding (on average 2 weeks earlier than in breast-fed infants), lower maternal age, and maternal smoking (8).

BIOLOGICAL AND DEVELOPMENTAL ASPECTS OF COMPLEMENTARY FEEDING

Physiological and Neurological Maturation

The physiological maturation of renal and gastrointestinal function that is required for an infant to metabolise nonmilk foods, and the neurodevelopmental changes necessary for safe and effective progression to a mixed diet, have been reviewed in several reports (9–11). The available data suggest that both renal function and gastrointestinal function are sufficiently mature to metabolise nutrients from complementary foods by the age of 4 months (12). With respect to gastrointestinal function, it is known that exposure to solids and the transition from a high-fat to a high-carbohydrate diet is associated with hormonal responses (eg, insulin, adrenal hormones) that result in adaptation of digestive functions to the nature of the ingested foods, by increasing the maturation rate of some enzymatic functions and/or activities (13,14). Thus, to a large degree gastrointestinal maturation is driven by the foods ingested.

With respect to neurodevelopment, it is likely that, as with any motor skill, there will be a range of ages in infant populations for the attainment of most milestones. For example, by around 6 months, most infants can sit with support and can "sweep a spoon" with their upper lip, rather than merely suck semisolid food off the spoon. By around 8 months they have developed sufficient tongue flexibility to enable them to chew and swallow more solid lumpier foods in larger portions. From 9 to 12 months, most infants have the manual skills to feed themselves, drink from a standard cup using both hands, and eat food prepared for the rest of the family, with only minor adaptations (cut into bite-sized portions and eaten from a spoon, or as finger foods). An important consideration is that there may be a critical window for introducing lumpy solid foods, and if these are not introduced by around 10 months of age, it may increase the risk of feeding difficulties later on (15). It is therefore important for both developmental and nutritional reasons to give age-appropriate foods of the correct consistency and by the correct method.

The Committee considers that gastrointestinal and renal functions are sufficiently mature by around 4 months of age to enable term infants to process some complementary foods, and that there is a range of ages at which infants attain the necessary motor skills to cope safely with complementary feedings.

Nutritional Aspects

Nutritional recommendations for the first 6 months are mainly based on the estimated nutrient intakes of the breast-fed infant, and the assumption that the volume of human milk ingested by exclusively breast-fed infants at about 6 months becomes insufficient to meet the requirements of energy, protein, iron, zinc, and some fat-soluble vitamins (A and D). These areas were the subject of a WHO-commissioned review by Butte et al (16) and a recent systematic review by Reilly et al (17). Some specific aspects of macronutrient and micronutrient intakes are discussed in the following sections covering the potential effects of complementary feeding on different outcomes.

European infants are unlikely to experience deficiencies of macronutrients during the complementary feeding period. Rather, they may be at risk for excessive intakes—a matter of potential concern, given the increasing rates of childhood obesity. Different growth patterns are observed in breast-fed and formula-fed infants (18). Thus, from around 3 months, on most current growth charts, breast-fed infants typically show a deceleration of growth, compared with the growth acceleration of formula-fed infants. WHO recently published a new growth standard for children from birth to age 5 years (19,20) based on the growth of breast-fed healthy infants. Relative to these new WHO growth standards, the apparent deceleration in breast-fed infants should be less apparent, whereas the acceleration of growth seen in formula-fed infants may be more pronounced. Nevertheless, these early growth differences mean that breast-fed and formula-fed infants are likely to start the complementary feeding period with differences in anthropometric measures and potential differences in neurodevelopment, renal, and gastrointestinal maturation.

The concentrations of some nutrients are generally higher in infant formula compared to mean values in breast milk (eg, for iron, zinc, protein). Furthermore, formula-fed infants tend to ingest higher volumes of milk. On a theoretical basis, it may therefore seem sensible to offer breast-fed infants complementary foods with higher micronutrient content, or to introduce complementary feeding earlier. For example, Foote and Marriott (21) have suggested that meat should be introduced earlier to breast-fed infants than formula-fed infants. However, despite these theoretical considerations, the Committee considers that devising and implementing separate recommendations for the introduction of solid foods for breast-fed infants and formula-fed infants may present practical problems and cause confusion among caregivers. A further issue that requires consideration and investigation is the possibility that European infants consuming fortified infant foods may consume excess amounts of micronutrients, vitamins, or trace elements, as reported recently for zinc in infants in the United States (22).

Infants receiving a vegan or macrobiotic diet, with limited or no animal foods, have a high risk for the development of nutritional deficiencies. The problems have been described in detail in studies of infants and children fed a macrobiotic diet in the Netherlands (23). In these infants, deficiencies of energy, protein, vitamin B_{12}, vitamin D, calcium, and riboflavin developed, and the infants had retarded growth, fat and muscle wasting, and slower psychomotor development. If the mother is following a vegan diet, is breast-feeding, and is not taking nutritional supplements, then there is a significant risk that the infant will experience severe cognitive impairment, and the risk is increased further if the infant continues on a diet containing no animal foods. Minimal weekly supplements with animal foods such as milk and fish have therefore been recommended (23).

Milk Feeding During the Complementary Feeding Period

Continued breast-feeding is recommended along with the introduction of complementary feeding. Infant formula or follow-on formula may be used in addition to or instead of breast milk. There are differences between industrialized countries in the recommended age for the introduction of cow's milk. Most countries recommend waiting until 12 months, but according to recommendations from some countries (eg, Canada, Sweden, Denmark), cow's milk can be introduced from 9 or 10 months. The main reason for delaying introduction is to prevent iron deficiency because cow's milk is a poor iron source. One study showed that a milk intake above 500 mL/day was associated with iron deficiency (24,25). Some data have also suggested that the early introduction of cow's milk can provoke microscopic intestinal bleeding, but this has not been shown after the age of 9 months. There are major differences between the composition of cow's milk and that of breast milk and infant formulae. Cow's milk has a higher content of protein, minerals, and saturated fat, and a different composition of long-chain polyunsaturated fatty acid (LCPUFA), with a low content of linoleic acid but a lower ratio of linoleic acid to α-linolenic acid ratio than most infant formulae. This is likely to explain the fact that red blood cell docosahexaenoic acid (DHA) levels seem to be more favorable in infants fed cow's milk, compared with infants drinking infant formula that is not supplemented with DHA (26). It has been suggested that cow's milk intake can affect linear growth and later blood pressure and risk of obesity, but the evidence is not convincing. There are also considerable differences between countries in recommendations on the age at which cow's milk with reduced fat intake can be introduced. The main consideration has been that low-fat milk may limit energy intake and thereby growth. However, with the current obesity epidemic, which affects both preschool children and older children, the potential beneficial effects of low-fat milk on energy intake and later preferences should also be taken into account.

The Committee suggests that recommendations on the age for introduction of cow's milk should take into consideration traditions and feeding patterns in the population, especially the intake of complementary foods rich in iron and the volume of milk consumed. It is acceptable to add small volumes of cow's milk to complementary foods, but it should not be used as the main drink before 12 months.

EFFECTS OF COMPLEMENTARY FEEDING

Growth

Most studies have focused on the effect of the timing of introduction of complementary foods on growth, rather than the effects of specific complementary foods. There is little evidence that the introduction of complementary foods between 4 and 6 months influences growth, at least in the short term (1,2,4). The situation is complicated by the fact that infant feeding practices may themselves be influenced by infant growth because infant weight was found to predict the age at introduction of complementary foods better than birth weight or early weight gain, with heavy infants introduced to solid foods earlier than light-weight infants (27–29).

A low fat content of the complementary feeding diet will typically result in a diet with a low energy density. If the energy density of the diet is too low, then the total amount of food needed to achieve energy requirements can be so large that the infant is unable to eat enough, and the diet becomes too bulky (30,31). In an analysis of fat intake and growth from 19 countries in Central and South America, it was concluded that poor growth was observed only when the fat content of the diet was below 22% (32). A comment on dietary fat intake from the ESPGHAN Committee concluded in 1994 that fat intake should not be actively reduced before the age of 3 years, but no lower limit for fat content was suggested (33). The preferential use of cow's milk with a reduced fat content (1.5%–2%) was recommended from 2 to 3 years of life onward (33).

With the increasing incidence of childhood obesity, it is relevant to consider whether complementary feeding practices influence the risk of overweight and obesity. In the cohort studies cited above, although heavier infants received complementary feeding earlier, they did not remain heavier at 1 to 2 years of age. However, in the Scottish cohort, infants who received complementary foods before 12 weeks were found to have increased fatness at age 7 years (34), emphasizing the potential for the late emergence of effects on body composition, as previously reported in baboons (35). Several studies of infants and preschool children have investigated associations between fat intake and weight gain or body mass index and have been unable to demonstrate any relationship (36–38). No studies have, to our knowledge, examined this issue in the complementary feeding period.

Overconsumption of energy-dense complementary foods may induce excessive weight gain in infancy, which has been associated with a 2- to 3-fold higher risk of obesity in school age and childhood (39–41). Semiliquid complementary feeds with high energy density designed for bottle-feeding have recently been marketed. Inasmuch as bottle-feeding of complementary feedings with a high energy density, close to 1 kcal/mL, may markedly increase the risk of overfeeding, this practice should be discouraged.

Several studies have examined the relationship between early protein intake and obesity risk. Although not entirely consistent, some data suggest that dietary intakes of 4 g protein per kilogram per day (~16% of total energy intake) or even higher between 8 and 24 months of age are associated with later overweight, whereas such associations are not seen with dietary protein intakes below 15% energy (42). There are few data on the effects of specific complementary foods on growth, although Morgan et al (43) reported from an observational study in term infants that the consumption of greater amounts of meat was associated with faster weight gain during the first year. Further analysis suggested that this observation may be mediated by protein intake rather than energy intake.

In summary, the fat content of the diet is an important determinant of the energy density, and the Committee recommends that this should be above, not below, 25% of energy intake. A higher level may be necessary if the appetite is poor or if the infant has recurrent infections. Despite theoretical concerns about the potential effects of different aspects of complementary feeding on later obesity risk, the available evidence is not persuasive.

Neurodevelopment

The critical period during which the dietary supply of specific nutrients may influence the maturation of cortical function is unknown. Although feeding human milk has often been associated with better later cognitive outcome, few studies have addressed the effects of specific nutrients on cognitive performance.

Two studies have investigated the effect of supplying additional LCPUFA in complementary foods. Makrides et al (44) showed that breast-fed infants who received DHA-enriched egg yolks 4 times per week from 6 to 12 months had higher red cell DHA levels at 12 months than did those fed standard egg yolks or no egg yolks. Hoffman et al (45) randomized breast-fed infants to receive either 1 jar per day of weaning foods containing DHA-enriched egg yolk, or control baby food, between 6 and 12 months. By 12 months, those receiving the enriched food showed an increase in red cell DHA and greater increase in visual acuity resolution. Two additional trials investigated the role of LCPUFA supplementation of infant formulae during the complementary feeding period, with infants randomized to LCPUFA-supplemented formulae when they stopped breast-feeding at either 6 weeks (46) of age or 4 to 6 months (47) of age. Those who received the supplemented formula had significantly better visual acuity up to 1 year of age than did those weaned to unsupplemented formula. These studies suggest that the intake of DHA during the complementary feeding period may influence short-term

visual function. However, further research is required to establish whether these effects persist and whether there are broader effects on cognitive function.

Two recent studies examined the impact of eating meat on neurocognitive outcome. In a prospective observational study in the United Kingdom, Morgan et al (43) recorded the intake of red and white meat using 7-day weighed food intake diaries at 4, 8, 12, and 16 months, and found positive associations between meat intake averaged over the 4- to 12-month and 4- to 16-month periods and psychomotor development at 22 months. It was calculated that an average increase in meat intake of 2.3 g/day was associated with an increase of 1 point in the Bayley Psychomotor Development Index. In a randomized trial of pureed beef versus iron-fortified cereal given to breast-fed infants as the first complementary food between 5 and 7 months, significantly higher behavioral indices were reported at 12 months in the meat group (48). Meat is a rich source of some micronutrients (iron and zinc) and arachidonic acid (the major LCPUFA of the n-6 series, well represented in brain), and these findings are consistent with a food-related beneficial effect on cognitive outcome related to specific micronutrients.

Iron deficiency continues to be observed in pregnant women and infants in Europe and the United States, especially in lower socioeconomic groups. The iron content of breast milk is low, and prolonged breast-feeding has been associated with iron-deficiency anemia. For example, in a Chilean study, anemia (hemoglobin <110 g/L) was seen in 27% of 9-month-old breast-fed infants and in only 2.2% and 4.3%, respectively, of those fed 1 of 2 iron-fortified formulas (49). Infants in Honduras who were exclusively breast-fed to 6 months rather than 4 to 6 months had significantly lower hemoglobin (mean 104 vs 109 g/L) and ferritin values (mean 48 vs 67 μg/L) (50). There are few available data on the relationship between specific foods and iron status. Engelmann et al (51) investigated the effect of meat intake in partially breast-fed infants between 8 and 10 months in a randomized trial and found that an increase in meat intake prevented a decrease in hemoglobin in late infancy but had no effect on iron stores or on cellular iron deficiency. Lind et al (52) investigated the effect of weaning cereals with different phytate contents and found little effect on iron or zinc status. Davidsson et al (53) reported that iron bioavailability from iron-fortified infant cereals can be improved by using an iron compound with high relative bioavailability and by ensuring adequate ascorbic acid content of the product.

A previous statement of this Committee considered the topic of iron requirements during early childhood (54). The Committee concluded that it is unclear whether iron deficiency in the absence of anemia has adverse effects on neurological outcome and that the available literature did not show a causal relationship with moderate iron-deficiency anemia. Until further knowledge is available,

it was suggested that measures should be taken to avoid iron deficiency, for example, promoting exclusive breast-feeding, using iron-fortified formula when formula is required, postponing the introduction of cow's milk as the main drink until the end of the first year of life, and promoting iron-rich complementary foods. Although the evidence that moderate iron deficiency and a low intake of LCPUFA have an adverse effect on neurodevelopment is not strong, the Committee considers it advisable to include good sources of both iron (eg, meat) and LCPUFA (eg, oily fish) in the complementary feeding diet.

Allergy

Attempts to reduce the risk for the development of allergy using dietary modification have generally focused on the delayed introduction or elimination of foods identified as potentially most allergenic, although there is also increasing interest in the active prevention of atopy using specific dietary components.

There is good evidence that certain foods are more allergenic than others. They include eggs, fish, nuts, and seafood. There is also observational evidence that the early (<4 months) introduction of more than 4 foods is associated with an increased risk of atopic dermatitis, both in the short term and, more important, at 10-year follow-up (55). However, the evidence that delaying or avoiding the introduction of allergenic foods prevents or delays the development of allergy is not persuasive and is limited by the fact that the available data are almost exclusively from observational studies, in infants considered to be at increased risk for the development of allergy. This is reflected in the fact that many expert panels and consensus documents have concluded that, whereas complementary foods (including infant formulae based on whole cow's milk proteins) should not be introduced before 4 to 6 months, recommendations cannot be made regarding the introduction of specific complementary foods because of the limitation and contrasting conclusions of available studies (56,57). Indeed, a critical review of existing evidence concluded that the most effective dietary measure for the prevention of allergic diseases even in high-risk patients is exclusive breast-feeding for 4 to 6 months (58). In clear contrast, a recent consensus document from the American College of Allergy, Asthma, and Immunology (59), emphasizing the need for specific practical guidelines for parents and health professionals, suggested that in at-risk infants the introduction of dairy products should be delayed until 12 months; eggs until 24 months; and peanuts, tree nuts, fish, and seafood until 3 years. This extreme position was immediately questioned by other specialists (60). It is important to consider the potential nutritional consequences of delaying or avoiding specific foods. Although the avoidance of certain foods, such as nuts

and shellfish, is unlikely to cause harm, the likely reduction in n-3 LCPUFA intake associated with avoiding fish could potentially have consequences for cognitive outcome or immune function. Recent evidence suggests a protective role of early dietary n-3 LCPUFA, raising questions about the net balance of pros and cons of avoiding fish, the richest natural source of n-3 LCPUFA (59–63). An additional consideration is that some studies suggest that delayed introduction of certain foods did not reduce, and may actually increase the risk of allergic sensitization (64–67). An increased risk of allergy was also found in 1 of the few cohorts including infants without a family history of allergy, in whom delayed exposure to cereal grains after the age of 6 months increased the risk of wheat allergy (68).

On the basis of the available data, the Committee recommends that complementary foods should not be introduced before 17 weeks and that foods should be added 1 at a time to allow detection of reactions to individual components. Taking into account the available data on delaying or eliminating specific foods and also the potential wider nutritional consequences, there is no convincing scientific evidence that avoidance or delayed introduction of potentially allergenic foods, such as fish and eggs, reduces allergies, either in infants considered at risk for the development of allergy or in those not considered to be at risk.

Cardiovascular Disease

Although there is increasing evidence for an adverse effect of rapid infant growth on later cardiovascular outcomes, less is known about the specific role of diet as a potential mediator of these effects and, in particular, whether diet during the complementary feeding period may affect later cardiovascular outcome. Evidence relating breast-feeding to later cardiovascular risk is beyond the scope of this article (69,70). The role of salt intake during the complementary feeding period has not been extensively explored. Investigations demonstrating that an excess of dietary sodium may raise blood pressure in newborns and young infants have suggested that infancy may be a period of greater salt sensitivity than later in life (71,72), as experimentally shown in animals (73). Zinner et al (74) demonstrated that newborns can distinguish between dilute salt solutions and water and that those with a preference for salty tastes had higher blood pressure during the first week and at 1 month of age. In a Dutch study started in the early 1980s, infants were randomized to a low or a normal sodium diet for the first 6 months of life. At 15-year follow-up, those from the control group had significantly higher blood pressure (systolic 3.6 mmHg and diastolic 2.2 mmHg) than did those from the low-sodium group (75). Interestingly, there was no difference in the mean sodium intake between groups at follow-up, suggesting that the effect

was not mediated by alterations in salt preference. The innate preference for the salty taste seems likely to reflect the requirement to meet dietary needs in an environment poor in salt. This preference becomes inappropriate in an environment with high salt bioavailability, and the consequent habituation may lead in turn to a progressive "salt addiction" (76,77).

The specific role of LCPUFA intake during the complementary feeding period on later blood pressure was evaluated by a study in which 9-month-old infants were randomized to a fish oil supplement for 3 months or no supplement (78). Those receiving fish oil had a lower systolic blood pressure (6 mmHg) but also slightly, but significantly, higher concentrations of serum low-density lipoprotein and total cholesterol. Forsyth et al (79) also reported that 6-year-old children randomized to LCPUFA-supplemented infant formula from birth to 4 months of age had significantly lower blood pressure (systolic 3 mmHg, diastolic 3.6 mmHg) than did those fed unsupplemented formula.

Protein intake may also have an effect on later blood pressure. In the Barry Caerphilly Growth study cohort, infants born from 1972 to 1974 and not breast-fed were given formulae based on dried whole cow's milk, which consequently had a high protein and sodium content. There was a significant positive association between the amount of whole cow's milk given at the age of 3 months and systolic blood pressure during early adult life (80). By contrast, in a study of 2.5-year-old children, protein intake measured as protein energy percentage was significantly negatively associated with both systolic and diastolic blood pressure (81). However, as with many other issues in this field, the "critical window" for an effect of protein intake on blood pressure is not known; in particular, it is not known whether the complementary feeding period from 6 to 18 months is a sensitive one in this respect.

Given the current level of evidence, the Committee considers that it is not possible to make specific recommendations for choices or composition of complementary feedings based on cardiovascular outcomes. However, as a general guideline, additional salt should not be added to foods during infancy.

Celiac Disease

The risk for the development of celiac disease (CD) depends on genetic, immunological, and environmental factors. Recent observational studies suggest that the introduction of small amounts of gluten while the infant is still breast-fed may reduce the risk of CD. A meta-analysis showed that the risk of CD was significantly reduced in infants who were breast-feeding at the time of gluten introduction (pooled odds ratio 0.48, 95% CI 0.40–0.59) compared with infants who were not breast-feeding during this period. Both breast-feeding during the

introduction of dietary gluten, and increasing duration of breast-feeding, were associated with reduced risk for the development of CD. It is not clear from the primary studies whether breast-feeding delays the onset of symptoms or provides a permanent protection against the disease (82) More recently, Norris et al (83) reported that both early ($\leq$3 months) and late ($\geq$7 months) introduction of gluten-containing cereals were associated with an increased risk of CD. This study was based on a cohort at risk for the development of CD or type 1 diabetes mellitus, based on HLA typing, or having a first-degree relative with type 1 diabetes mellitus. Experience from Sweden showed a sharp increase in cases of CD after the advice was given to delay the introduction of gluten to after 6 months (84), with a subsequent fall when earlier introduction (from 4 months) was reintroduced (85). Ivarsson et al (86) studied the epidemiology of this epidemic and found that the risk for the development of CD was reduced in children younger than 2 years if they were still being breast-fed when dietary gluten was first introduced (OR: 0.59; 95% CI: 0.42–0.83). A further decrease in the risk for the development of CD was observed when children continued to be breast-fed after dietary gluten was introduced (OR 0.36, 95% CI 0.26–0.51). The risk was greater when gluten was introduced in large amounts, but the contribution of age at introduction was inconclusive

On the basis of current data, the Committee considers it prudent to avoid both early (<4 months) and late ($\geq$7 months) introduction of gluten and to introduce small amounts of gluten gradually while the infant is still breast-fed.

Type 1 Diabetes Mellitus

Recent studies seem to suggest that the introduction of food antigens (including gluten) while infants are still breast-fed, even if the infant is younger than 6 months, may have lasting protective effects against the development of CD and type 1 diabetes mellitus, and that this may be more important than the absolute time of exposure. An early introduction of gluten (<3 months) seems to be linked to an increased risk for the development of islet cell autoantibodies in infants at risk for type 1 diabetes mellitus (87,88), and 1 study also found an increased risk in infants first exposed to gluten at 7 months or later (88).

Development of Taste and Food Preferences

An enormous amount of learning about food and eating occurs during the transition from the exclusive milk diet of infancy to the diet consumed in early childhood. Prenatal and early postnatal exposure to a flavor enhances the infant's enjoyment of that flavor in solid foods during weaning. These early flavor experiences may provide the foundation for cultural and ethnic differences in cuisine (89). Longitudinal follow-up studies suggest that early flavor experiences and food preferences during infancy even track into childhood and adolescence (90). The early learning is constrained by children's genetic predispositions, which include innate preferences for sweet and salty tastes and the rejection of sour and bitter tastes. Children are also predisposed to prefer high-energy foods, to reject new foods, and to learn associations between food flavors and the postingestive consequences of eating. These genetic predispositions appear to have evolved over thousands of years when foods, especially those high in energy density, were relatively scarce. Genetic selection allowed humans to be weaned by means of safe energy-dense foods, marked by pleasant tastes, and enabling survival in an unfavorable environment (91). Concern has been raised that these food preferences could predispose growing children toward unbalanced early dietary intakes, inasmuch as the present food environment has changed tremendously in recent years and is now characterized by the ready availability of inexpensive energy-dense foods that are high in sugar, fat, and salt (92,93). However, from birth genetic predispositions may be modified by experience, and in this context parents may play a particularly important role. Beauchamp and Moran (94) examined the preference for sweet solutions versus water in approximately 200 infants. At birth, all of the infants preferred sweet solutions to water, but by 6 months of age, the preference for sweetened water was linked to the infants' dietary experience. Infants who were routinely fed sweetened water by their mothers ($\sim$25%) showed a greater preference for it than did infants who were not. Parents can thus play a critical role in the development of food preferences. It has been shown that forcing a child to eat a particular food will decrease the liking for that food and that restricting access to particular foods increases rather than decreases preferences. By contrast, repeated exposure to initially disliked foods may break down resistance (95). Therefore, offering complementary foods without added sugars and salt may be advisable not only for short-term health but also to set the infant's threshold for sweet and salty tastes at lower levels later in life.

Dental Caries

Sugar intake is the major dietary risk factor for the formation of dental caries. Sucrose is the most cariogenic sugar because it can form glucans that enable bacterial adhesion to teeth and limit diffusion of acid and buffers in the plaque (96). Nutrition education and counseling aimed at reducing caries in children is directed at teaching parents the importance of reducing high-frequency exposure to apparent and hidden sugars (97,98). Guidelines include, among others, avoiding frequent consumption of juice or other sugar-containing drinks in bottles or

beakers, discouraging the habit of a child sleeping with a bottle, limiting cariogenic foods to mealtimes, and establishing good dental hygiene (99).

Miscellaneous

Whereas different foods may contain spores of *Clostridium botulinum*, the consumption of honey has been repeatedly associated with infant botulism. Therefore, honey should not be introduced before 12 months of age unless the heat-resistant spores have been inactivated by adequate high-pressure and high-temperature treatment, as used in industry (100).

CONCLUSIONS AND RECOMMENDATIONS

Infant nutrition research has historically focused on the prevention of malnutrition and deficiency states. With increasing economic prosperity, these concerns have receded. The emphasis has shifted toward achieving a balanced protein and energy intake and preventing the risk of long-term disease. Most current guidelines on complementary feeding are not evidence based. Dietary schedules for the progressive introduction of solids during the complementary feeding period in most countries originate from cultural factors and available foods. More data are required to clarify the effects of specific foods and/or nutrients (particularly micronutrients) on growth, development, and metabolic status during this period when growth and development are still rapid. Nevertheless, there are some data suggesting that the composition of the diet during the complementary feeding period, and the type of milk feeding, may have health effects not just in the short term but also in the medium to long term.

- Exclusive or full breast-feeding for about 6 months is a desirable goal. Complementary feeding should not be introduced in any infant before 17 weeks, and all infants should start complementary feeding by 26 weeks.
- The term "complementary feeding" should embrace all solid foods and liquids other than breast milk or infant formula and follow-on formula. The Committee suggests that including HMS as complementary foods is unhelpful and even confusing.
- Although there are theoretical reasons why different complementary foods may have particular benefits for breast-fed or formula-fed infants, the Committee considers that attempts to devise and implement separate recommendations for breast-fed and formula-fed infants may present considerable practical difficulties and are therefore undesirable.
- Avoidance or delayed introduction of potentially allergenic foods, such as fish and eggs, has not been convincingly shown to reduce allergies, either in infants considered at risk for the development of allergy or in those not considered to be at risk.
- During the complementary feeding period, >90% of the iron requirements of a breast-fed infant must be met by complementary foods. These should provide sufficient bioavailable iron.
- Cow's milk is a poor iron source. It should not be used as the main drink before 12 months, although small volumes may be added to complementary foods.
- It is prudent to avoid both early (<4 months) and late ($\geq$7 months) introduction of gluten and to introduce gluten gradually while the infant is still breast-fed because this may reduce the risk of CD, type 1 diabetes mellitus, and wheat allergy.
- Infants and young children receiving a vegetarian diet should receive a sufficient amount ($\sim$500 mL) of milk (breast milk or formula) and dairy products.
- Infants and young children should not receive a vegan diet.

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