CHAPTER 2

Normal Infant Nutrition

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CHAPTER OUTLINE

Reader Objectives

After studying this chapter and reflecting on the contents, you should be able to

1. Describe normal infant nutrition in the first year of life.
2. Compare growth differences between breastfed and formula-fed infants.
3. Describe the impact of early diet on later development of obesity, diabetes, and food allergies.
4. Discuss adequate intake of key nutrients in the first year of life, including energy, protein, fatty acids, iron, zinc, and vitamin D.
5. Describe caregiver behaviors that can affect normal transitioning from an all-milk infant diet to a diet of family foods.
6. Compare and contrast actual complementary feeding patterns with recommended guidelines.

The physiologic changes that occur during pregnancy and lactation affect nutritional requirements. These nutritional requirements include both macronutrients and micronutrients, which in turn affect the health of both mother and baby. After birth, early childhood is an important time for the development of food preferences and eating patterns. Establishment of lifelong eating habits begins in infancy and is based on a complex integration of physiologic and psychological events, including food preferences, food availability, parental modeling, praise or reward for food consumption, and peer behaviors (Stang, 2006).

Normal Infant Nutrition

Nutrition Recommendations for Normal Infant Feeding

Normal infant feeding is breastfeeding. Human milk is designed to support the normal growth and development of human infants. The infant's nutritional and immunologic needs are best supported by the specific components of maternal milk.

In its 2012 Policy Statement the American Academy of Pediatrics (AAP) recommends exclusive breastfeeding for 6 months, followed by continued breastfeeding for 1 year or longer as complementary foods are introduced (American Academy of Pediatrics [AAP] Section on Breastfeeding, 2012) (see **Table 2.1**).

Breast Milk Composition

Human milk is an ever-changing fluid that meets the nutritional needs of the growing infant. It varies by stage of lactation, time of day, maternal nutrition, and during a given feeding. Colostrum is the first milk that is usually available in small quantities during the first 4 days of life. It is yellow colored as a result of high levels of beta-carotene. It is high in protein, fat-soluble vitamins, minerals, and immune factors. It is lower in fat and lactose than later mature milk and therefore easier to digest. Colostrum contains bifidus factor to enhance the establishment of friendly gut bacteria *Lactobacillus bifidus* and aids in the passage of meconium from the newborn gut to reduce the risk of hyperbilirubinemia.

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TABLE 2.1 Infant Feeding Recommendations

- Breast milk or infant formula exclusively for the first 6 months of life
- Introduction of soft or puréed foods at 6 months
- Self-feeding of soft finger foods when developmentally ready
- Cup feeding with water, milk, or juice after 6 months
- Continue breastfeeding for at least 1 year and as long as desired by mother and baby
- If not breastfeeding, formula feeding until 1 year of age
- Introduction of whole cow's milk after 12 months

Data from World Health Organization. (2003). *Global strategy for infant and young child feeding* [pamphlet]. Geneva, Switzerland: Author; and American Academy of Pediatrics Section on Breastfeeding. (2012). Breastfeeding and the use of human milk. *Pediatrics, 129*, e827–e841.

Approximately half of the calories in mature human milk come from fat. This gives the growing infant a readily available source of energy for growth requirements. The fat composition of human milk varies based on the maternal diet. The concentration of fat in milk increases during the feeding with the highest percentage occurring when the breast has been emptied. The protein in human milk is easy to digest and well absorbed. The whey-to-casein ratio changes during the course of lactation. Early milk is predominantly whey protein (80:20), whereas later milk has 50:50 whey-to-casein ratio. The total protein in human milk is the lowest of all mammals because of the slower growth of humans compared to other mammals. The primary carbohydrate in human milk is lactose, which is found in all mammalian milk. It is the least variable of all the macronutrients. It is secreted by the mammary gland and is unrelated to maternal intake. Carbohydrates provide approximately 40% of the energy in human milk. Vitamins in human milk vary with the stage of lactation, maternal stores, and dietary intake. The mineral content of human milk changes over time but is not influenced by maternal stores or intake.

The unique components of human milk offer newborn infants important immunologic protection at a time when they are most vulnerable to infection. Human milk contains immune cells, immunoglobulins, lactoferrin, cytokines, nucleotides, glycans, oligosaccharides, hormones, and bioactive peptides to aid the infant's immature immune system. Many of these components enhance infant immunity by either destroying or neutralizing pathogens or by preventing pathogens from binding to mucousal surfaces (Hanson, 2004).

Formula Feeding

When breastfeeding is not chosen by the mother or is not possible because of maternal or infant factors, and in situations where the infant needs to be supplemented with a breast milk substitute, infant formula is an acceptable alternative for the first year of life. Recent studies have reported that there are significant risks associated with not breastfeeding (see **Table 2.2**). Infants who are exclusively formula fed from birth have increased risk of many acute and chronic illnesses compared to infants who are exclusively breastfed. The risk of otitis media is reduced by 23% for any breastfeeding compared to no breastfeeding and exclusive breastfeeding for either 3 or 6 months reduces the risk by 50% (Ip et al., 2007).

Studies have shown a 72% reduction in the risk for hospitalizations from lower respiratory tract infections for infants exclusively breastfed longer than 4 months compared to formula feeding (Ip et al., 2007). Both exclusivity and duration

TABLE 2.2 Risks Associated with Not Breastfeeding

- Increased incidence and severity of infection: otitis media, lower respiratory tract infection, urinary tract infection, diarrhea, bacterial meningitis, sepsis
- Increased rate of sudden infant death syndrome (SIDS), necrotizing enterocolitis (NEC), postneonatal deaths
- Increased risk of atopic dermatitis, leukemia, lymphoma, Hodgkin's disease, asthma, diabetes
- Decreased cognitive development
- Increased obesity
- Pathogen contamination in formula
- Manufacturing errors and warehouse contamination of formula
- Adulteration of formula

Data from Ip, S., Chung, M., Raman, G., Chew, P., Magula, N., DeVine, D., … Lau, J. (2007, April). *Breastfeeding and maternal and infant health outcomes in developed countries*. Evidence report/technology assessment No. 153 (Prepared by Tufts-New England Medical Center Evidence-Based Practice Center, under Contract No. 290-02-0022). AHRQ Publication No. 07-E007. Rockville, MD: Agency for Healthcare Research and Quality; and American Academy of Pediatrics Section on Breastfeeding. (2012). Breastfeeding and the use of human milk. *Pediatrics, 129*, e827–e841.

of breastfeeding have been noted to affect health outcomes. Not breastfeeding increases the infant's risk of dying. Sudden infant death syndrome (SIDS) risk is reduced by half with exclusive breastfeeding at 1 month (Vennemann et al., 2009), and any breastfeeding reduces the risk of SIDS by 36% (Ip et al., 2007). Compared to never breastfeeding, children who ever breastfed had 0.79 times reduction in postneonatal mortality from all causes, and longer breastfeeding was associated with lower risk (Chen & Rogan, 2004). If 90% of U.S. families breastfed their infants exclusively for 6 months as recommended, 911 deaths per year would be prevented (Bartick & Reinhold, 2010).

There are additional long-term outcomes associated with mode of infant feeding. Breastfeeding is associated with a reduced risk of atopic dermatitis, allergies, asthma, childhood cancer, and diabetes (Ip et al., 2007). Infants who have never been breastfed are at higher risk for later childhood obesity than are infants who have ever been breastfed. Increased breastfeeding duration is associated with lower rates of childhood obesity.

Contraindications to Breastfeeding

There are a small number of health concerns related to the mother or the infant that may require temporary or permanent cessation of breastfeeding. Whenever alternatives to breastfeeding are considered, the benefits of breastfeeding should be compared to the risks posed by the specific condition or concern.

Infants with galactosemia, maple syrup urine disease (MSUD), or phenylketonuria (PKU) require a specialized formula to meet their nutritional needs. Infants with galactosemia cannot tolerate breast milk as a result of their metabolic disorder (AAP Section on Breastfeeding, 2012). Some breast milk may be allowed with careful monitoring for infants with PKU and MSUD (World Health Organization [WHO], 2009). Mothers who are HIV positive are advised to avoid breastfeeding and to use an acceptable substitute (WHO, 2009). If a mother has a herpes simplex virus type I lesion on the breast, direct contact between the lesion and the infant's mouth should be avoided. The baby can safely breastfeed on the unaffected breast (WHO, 2009). A mother with untreated tuberculosis should not have direct contact with her baby but may express her milk for the baby's feedings because tuberculosis is not passed through her milk (WHO, 2009).

Certain maternal medications may be of concern for breastfeeding infants, causing side effects such as drowsiness or respiratory depression and should be avoided or minimized (WHO, 2009). Mothers should be encouraged to avoid substances that have been demonstrated to have harmful effects on the baby, such as illicit drugs, opioids, and benzodiazepines (AAP Section on Breastfeeding, 2012; WHO, 2009). Although not absolutely contraindicated, it is recommended that lactating mothers wait 2 hours after ingesting no more than 2 oz liquor, 8 oz wine, or 2 beers (AAP Section on Breastfeeding, 2012; WHO, 2009) before breastfeeding. Maternal smoking should be strongly discouraged, not only because of infant respiratory effects and increased rates of SIDS but also because it is a risk factor for low milk supply and poor weight gain (AAP Section on Breastfeeding, 2012).

Expression, Handling, and Storage of Human Milk

Mothers need to be instructed on establishing and maintaining lactation if they are separated from their babies. The first 2 weeks are critical in establishing an adequate milk supply, and mothers need support and guidance (Meier, 2001; Spatz, 2004). Mothers who cannot directly breastfeed their infant need to initiate pumping within hours of birth. They should pump and/or hand express both breasts every 2 to 3 hours, eight times daily and save this milk for the baby's feedings. Mothers need encouragement and support to establish adequate milk production during this critical period when their infants are too sick or premature to feed directly at the breast. Guidelines for storage of human milk for home use in healthy term infants are available from the Academy of Breastfeeding Medicine (ABM) and the Centers for Disease Control and Prevention (CDC).

Donor Human Milk

In general, a healthy term newborn does not require any supplementation in the first 24–48 hours of life and should remain with the mother skin-to-skin to facilitate frequent breastfeeding (Academy of Breastfeeding Medicine Protocol Committee, 2009). If mother and baby are separated, or the mother has inadequate milk production, or the baby is not able to transfer available milk from the breast, supplementary feeding may be necessary. It is important to feed the baby appropriately while maximizing maternal milk production.

Whereas a mother's own milk is the standard food for infants and young children, there are situations when a mother cannot provide sufficient milk for her child. In such cases, human milk from screened donors that is pasteurized is the next best option, particularly for high-risk or ill infants (AAP Section on Breastfeeding, 2012; WHO, 2003). The Human Milk Banking Association of North America (HMBANA) has developed guidelines for establishing and operating human milk banks to ensure the safety of the milk. There are currently 11 operational human milk banks in the United States and Canada and 5 that are in the developmental stages.

Holder pasteurization (62°C for 30 minutes) is used to eliminate the threat of pathogen contaminants. All milk is cultured to ensure that there is no bacterial growth after pasteurization. Milk is frozen and shipped to users in a frozen state. Most bioactive components are still active in human milk after pasteurization, and donor milk has been shown to reduce the incidence of necrotizing enterocolitis, sepsis, and infection and to result in shorter hospital stays. Donor milk improves outcomes in a variety of conditions including bowel surgery, failure to thrive, formula intolerance, allergies, leukemia, and HIV.

Early Feeding

Colic

Infantile colic is characterized by paroxysms of uncontrolled crying or fussing in an otherwise healthy and well-nourished infant. The crying and fussing behavior can be described by the rule of threes: It starts at 3 weeks of age, there is more than 3 hours of crying a day for at least 3 days a week, and it lasts for more than 3 weeks. Colic resolves spontaneously without any further sequelae. Some attribute this behavior to psychogenic causes from tension in the maternal–infant bond and to maternal smoking or alcohol consumption, whereas other models focus on possible allergens in breast milk or infant formula as the causative agent (Schach & Haight, 2002).

Colic can be particularly distressing for not only the infant, but for the parents as well. Colic occurs in both breastfed and formula-fed infants. Breastfeeding is not protective against colic, and it is estimated that at 6 weeks the overall prevalence of colic in all infants is 24% (Clifford, Campbell, Speechley, & Gorodzinsky, 2002). Colic appears earlier and resolves earlier in formula-fed infants. Lucas and St. James-Robert (1998) reported that at 2 weeks 43% of formula-fed infants showed signs of intense crying and colic behavior but only 16% of breastfed infants demonstrated these symptoms. By 6 weeks, distressed behavior was seen in 31% of breastfed infants but only in 12% of formula-fed infants.

In searching for a remedy for this stressful condition, attempts to modify the infant's diet may be implemented. Cow's milk protein may contribute to the etiology of colic, and removal of the protein may alleviate the symptoms. Use of a hypoallergenic formula for non-breastfed infants may be recommended (Canadian Paediatric Society, 2003). Switching to a low-lactose formula or a formula with fiber was not found to be helpful in reducing colic symptoms. A hypoallergenic maternal diet for breastfeeding mothers may reduce colicky symptoms in some infants. For some, removal of all cow's milk from the mother's diet can provide relief for the colicky breastfed infant.

Research About Colic

Studies have failed to show a clear link between dietary factors in either breast milk or formula as the cause of infant colic. Evidence suggests that dietary interventions may be helpful for some infants, especially those with a family history of atopic disease and severe colic. Most of the studies on the impact of dietary changes on colic have had a small sample size and were not blinded or controlled. Colic always improves over time, and any intervention is susceptible to a placebo effect affecting the outcome. Speculations as to the origins of colic abound, and treatment options are limited.

Food Safety

Safe Handling of Infant Formula

Infant formula should be prepared with careful attention to manufacturer's instructions for use and storage. Bottle-fed infants are at an increased risk for exposure to food-borne pathogens, particularly if the bottles are left at room temperature for several hours. Freshly expressed, but not previously frozen, breast milk contains live white cells that destroy pathogens and can remain at room temperature for up to 8 hours before feeding. All bottles, nipples, and other feeding equipment should be properly cleaned and disinfected between uses.

Powdered infant formula products are not sterile and can be a source of illness and infection in infants. At greatest risk are neonates in the first 28 days of life, premature infants, low-birth-weight infants, and immunocompromised infants. Intrinsic contamination of powdered infant formula products with

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Cronobacter sakazakii and *Salmonella* has been a cause of significant disease, resulting in severe developmental sequelae and death (Centers for Disease Control and Prevention, 2002). The Infant Formula Act of 1980 (revised 1986) requires formula makers to use "good manufacturing practice" but does not guarantee or require sterility (Baker, 2002). Formula manufacturers are urged to develop a sterile powdered product for high-risk infants. Even low concentrations of *C. sakazakii* in powdered infant formula can cause serious harm because of the potential for exponential multiplication during preparation and holding at ambient temperatures.

Good hygienic practices, such as hand washing, using sanitized containers, and preparing only the amount needed for one feeding and using immediately, have been recommended to minimize risk (European Food Safety Authority, 2004). The WHO (WHO in collaboration with Food and Agriculture Organization of the United Nations, 2007) recommends boiling water no longer than 30 minutes and using water no cooler than 70°C (158°F) to prepare powdered infant formula. The prepared formula should be consumed immediately or refrigerated and consumed within 24 hours to prevent growth of *C. sakazakii*. The U.S. Food and Drug Administration (FDA) issued warnings regarding the use of powdered infant formula in neonatal intensive care units.

Nitrates

Infant methemoglobinemia results in cyanosis in infants with few other clinical symptoms and is caused by nitrates in food or water that are converted to methemoglobin-producing nitrites before or after ingestion. The resulting compound, methemoglobin, cannot bind oxygen and results in hypoxemia. Absorbed nitrate that has not been converted to nitrite can be readily excreted in the urine without adverse effects. The greatest risk to infants comes from well water contaminated with nitrates (Greer, Shannon, the Committee of Nutrition, & the Committee on Environmental Health, 2005). It is estimated that 2 million families drink water from private wells that fail to meet federal drinking water standards for nitrate, and 40,000 infants younger than 6 months old live in homes that have nitrate-contaminated water supplies. Breastfed infants whose mothers consume water with high nitrate nitrogen concentrations are not at increased risk because nitrate concentration does not increase in human milk.

Nitrates also occur naturally in plants and may be concentrated in foods such as green beans, carrots, squash, spinach, and beets. Some commercially prepared infant foods are voluntarily monitored for nitrate content, and because of exceedingly high levels in spinach, this product is often labeled as not to be used for infants younger than 3 months of age. Concerns for home-prepared foods are unfounded because there is no nutritional indication for introduction of complementary foods before 6 months. The risk of methemoglobinemia decreases with age as the infant's gastric pH approaches lower levels typical of later childhood and fetal hemoglobin, which more readily oxidizes to methemoglobin, is replaced by adult hemoglobin after 3 months.

Risks of Infant Formula and Bottle-Feeding

Infant feeding methods other than direct breastfeeding may be associated with increased risk of adverse outcomes for infants. Bottle-feeding of either expressed breast milk or formula may be of concern because of bisphenol A (BPA), a synthetic compound used in the production of hard, clear polycarbonate plastic bottles. BPA mimics the effects of estrogen, and exposure early in life is concerning because of the potential effects of BPA on the brain, behavior, and prostate gland of fetuses, infants, and children. Major manufacturers of infant feeding bottles and cups have voluntarily limited the use of BPA; however, BPA continues to be used in liners of infant formula cans (see www.fda.gov/NewsEvents/PublicHealthFocus/ucm064437.htm). Furthermore, inherent risks are associated with formula feeding because of manufacturing errors and contamination during processing. Formulas have been recalled for bad odors and contamination with beetle parts. Adverse outcomes including neurologic and cardiac effects, hospitalizations, and death have resulted from formula lacking important nutrients, including sodium chloride and thiamine, or from toxic levels of aluminum or mercury.

Safe Handling of Complementary Foods

Infants are at risk of exposure to food-borne pathogens when complementary foods are not prepared using safe food-handling techniques. Contamination of food with microbes is recognized as the leading cause of diarrheal disease and ill health in infants. A wide range of symptoms, including diarrhea, vomiting, abdominal pain, fever, and jaundice, occurs with potentially severe and life-threatening consequences.

Two particular areas of food preparation are of concern because they allow the survival and growth of pathogens to disease-causing levels. The first is preparation of food several hours before consumption along with storage at ambient temperatures, which favors the growth of pathogens and/or toxins. The second concern is insufficient cooling of foods or inadequate reheating to reduce or eliminate pathogens (Motarjemi, 2000). General food safety guidelines for both commercially prepared and homemade infant food should be followed.

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Growth

Adequate Growth in Infancy

In general, if a mother is well nourished and is exclusively breastfeeding, her milk will provide adequate nutrition for her infant to grow at an appropriate rate (see **Table 2.3**). Human milk has unique nutritional characteristics, such as a high ratio of whey to casein, a high proportion of nonprotein nitrogen, and fatty acids essential for brain and retinal development. It is not known at what point human milk is no longer sufficient for sustained growth, but it is unlikely that complementary foods are required before 6 months of age. Although it is commonly believed that insufficient calories and protein in human milk limit growth, it is probably more likely that other factors, such as iron and zinc, affect growth. This applies to infants in both disadvantaged and affluent populations (Dewey, 2001).

Feeding mode has been found to affect weight gain and body composition during the period of exclusive or predominant milk feeding in early infancy. Infant feeding practices are one of the few modifiable risk factors for childhood obesity. Excess weight gain in the first year of life has been found to be positively associated with the development of subsequent obesity (Druet et al., 2012; Griffiths, Smeeth, Sherburne-Hawkins, Cole, & Dezateux, 2009). The effects of breastfeeding initiation and duration on weight gain from birth to 3 years were examined in a prospective cohort study of 10,533 children in the U.K. Millennium Cohort Study (Griffiths et al., 2009). The researchers found that children not breastfed or breastfed shorter than 4 months gained weight more quickly and were both heavier and fatter at 3 years than were children breastfed longer than 4 months. The choice to bottle-feed rather than breastfeed contributes to accelerated infant growth and an increased risk for developing childhood obesity (Johnson, Wright, & Cameron, 2012).

TABLE 2.3 Signs that Breastfeeding is Going Well

- Breastfeeding 8–12 times per day
- More than 6 wet diapers daily
- More than 3 yellow seedy stools daily
- Mother is not having any nipple pain
- Baby is gaining appropriately according to the WHO growth chart

Data from U.S. Department of Health and Human Services, Office on Women's Health. (2011, January). *Your guide to breastfeeding*. Washington, DC: Author. Retrieved from www.womenshealth.gov/publications/our-publications/breastfeeding-guide/BreastfeedingGuide-General-English.pdf

Development of Growth Charts

The nutritional status of children is assessed by plotting height and weight on **growth charts** to determine adequacy of nutrient intake, particularly calories and protein. There is considerable evidence to show that growth rates differ for breastfed and formula-fed infants.

growth charts Graphs used to assess nutritional status of children by plotting height and weight and comparing these to reference data.

The World Health Organization conducted a 6-year multicenter international study to develop new growth charts derived from the growth of exclusively or predominantly breastfed infants based on the assumption that optimal infant growth occurs in infants from healthy populations who are exclusively breastfed for the first 6 months of life with continued breastfeeding until 2 years of age. The WHO Child Growth Standards (de Onis, Garza, Onyango, & Borghi, 2007) show how every child in the world should grow when free of disease and when their mothers follow healthy practices such as breastfeeding and not smoking. The standards depict normal human growth under optimal environmental conditions and can be used to assess children everywhere, regardless of ethnicity, socioeconomic status, and type of feeding (de Onis et al., 2007). These charts, released in 2006, are growth standards, as opposed to the previous charts from the CDC from 2000 that were growth references describing how certain children grew in a particular place and time. The difference is significant because the former describes the growth of healthy children in optimal environmental and health conditions, whereas the latter describes the growth patterns of a sample of children in the United States from 1963 to 1994 that lacked racial diversity and included infants who were mostly formula fed (Grummer-Strawn, Reinold, & Krebs, 2010).

In 2010, the CDC recommended that the WHO international growth charts be used for children younger than 24 months based on the recognition that breastfeeding is the recommended standard for infant feeding and that the healthy breastfed infant is the standard against which all infants

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are compared. Because of the normally slower growth of breastfed infants from 3–18 months, the formula-fed infant gaining weight more rapidly on the WHO chart will be identified as at risk for the development of overweight at an earlier age (Grummer-Strawn, Reinold, & Krebs, 2010). See **Figure 2.1** and **Figure 2.2** for proper growth velocity for boys and girls birth to 1 year old.

Nutrient Requirements

Energy

It is difficult to estimate energy requirements for infants and young children. The 1985 Food and Agriculture Organization/WHO/ United Nations Organization (FAO/WHO/UNO)

	Percentiles (Weight Increments in Grams)										
Interval	**1st**	**3rd**	**5th**	**15th**	**25th**	**50th**	**75th**	**85th**	**95th**	**97th**	**99th**
0–4 weeks	280	388	446	602	697	879	1066	1171	1348	1418	1551
4 weeks–2 months	410	519	578	734	829	1011	1198	1301	1476	1545	1677
2–3 months	233	321	369	494	571	718	869	952	1094	1150	1256
3–4 months	133	214	259	376	448	585	726	804	937	990	1090
4–5 months	51	130	172	286	355	489	627	703	833	885	983
5–6 months	–24	52	93	203	271	401	537	611	739	790	886
6–7 months	–79	–4	37	146	214	344	480	555	684	734	832
7–8 months	–119	–44	–2	109	178	311	450	526	659	711	811
8–9 months	–155	–81	–40	70	139	273	412	489	623	675	776
9–10 months	–184	–110	–70	41	110	245	385	464	598	652	754
10–11 months	–206	–131	–89	24	95	233	378	459	598	653	759
11–12 months	–222	–145	–102	15	88	232	383	467	612	670	781

FIGURE 2.1 WHO weight gain goals: Girls monthly weight velocity

Courtesy of the World Health Organization.

	Percentiles (Weight Increments in Grams)										
Interval	**1st**	**3rd**	**5th**	**15th**	**25th**	**50th**	**75th**	**85th**	**95th**	**97th**	**99th**
0–4 weeks	182	369	460	681	805	1023	1229	1336	1509	1575	1697
4 weeks–2 months	528	648	713	886	992	1196	1408	1524	1724	1803	1955
2–3 months	307	397	446	577	658	815	980	1071	1228	1290	1410
3–4 months	160	241	285	403	476	617	764	845	985	1041	1147
4–5 months	70	150	194	311	383	522	666	746	883	937	1041
5–6 months	–17	61	103	217	287	422	563	640	773	826	927
6–7 months	–76	0	42	154	223	357	496	573	706	758	859
7–8 months	–118	–43	–1	111	181	316	457	535	671	724	827
8–9 months	–153	–77	–36	77	148	285	429	508	646	701	806
9–10 months	–183	–108	–66	48	120	259	405	486	627	683	790
10–11 months	–209	–132	–89	27	100	243	394	478	623	680	791
11–12 months	–229	–150	–106	15	91	239	397	484	635	695	811

FIGURE 2.2 WHO weight gain goals: Boys monthly weight velocity

Courtesy of the World Health Organization.

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recommendations for energy intake were derived from the observed intakes of healthy thriving children. This assumes that the natural *ad libitum* feeding of infants and toddlers reflects desirable intake. However, the observed energy intake of infants and toddlers may not be optimal and may reflect outside influences such as type of feedings and caregiver behaviors. The FAO/WHO/UNO recommendations for energy were based on data compiled from the literature predating 1940 and up to 1980 and included an extra 5% allowance for presumed underestimation of energy intake (Institute of Medicine [IOM], 2002).

Experts questioned the validity of the 1985 FAO/WHO/UNO recommendations for energy intake, and in 1996 experts concluded that the guidelines were too high. Energy requirements for infants and toddlers based on actual energy expenditure and energy deposition or growth, rather than observed intake, would more accurately reflect true energy needs (Butte, 2005). Energy requirements of infants and young children need to support a rate of growth and body composition consistent with good health. Satisfactory growth is an indicator that energy needs are being met. Researchers in Scotland using the doubly labeled water method found that the average energy intake among healthy, exclusively breastfed infants with normal weight gain was 91 kcal/kg at 4 months and 82 kcal/kg at 6 months (Nielsen, 2011).

Butte, Wong, Hopkinson, Heinz, and colleagues (2000) used data obtained from doubly labeled water studies on infants aged 3 to 24 months to define energy requirements in the first 2 years of life based on total energy expenditure and energy deposition. Energy expenditure of infants is calculated from basal metabolic rate, thermic effect of feeding, thermoregulation, and physical activity. They were able to demonstrate that total energy expenditure was greater in older infants than in younger infants, greater for males than for females, and greater for formula-fed infants than for breastfed infants. After adjusting for body weight and fat-free mass, only feeding mode, not gender or age, influenced total energy expenditure. Energy expenditure was 12% higher in formula-fed infants at 3 months and 7% higher at 6 months than in breastfed infants (Butte, 2005). The energy cost of growth is important in early infancy when energy deposition contributes significantly to energy requirements. At 1 month of age, 40% of energy requirements are utilized for growth. This drops dramatically to 6% at 6 months and even further to 2% to 3% of total energy requirements in late infancy.

Protein

It is not difficult to meet the protein needs of infants. Exclusively breastfed infants receive adequate protein for at least the first 6 months of life. The most recent recommended Adequate Intake (AI) of protein for infants from birth to 6 months is 1.5 g/kg/day and reflects the observed mean intake of infants who are fed mostly human milk (IOM, 2002). This value is calculated from various studies in which the volume of human milk consumed is measured by test weighing, and the average protein content of human milk was determined using values from several studies.

DuPont (2003) reported that total protein in breast milk varies greatly during the course of lactation, providing from less than 2.0 g/kg/day in the first weeks of life to approximately 1.15 g/kg/day at 4 months, less than the AI recommendations of the IOM. Dewey, Cohen, Rivera, Canahuati, and Brown (1996) reported that protein intake of breastfed infants decreases from 2.0 g/kg/day at 1 month to 1.0 g/kg/day at 6 months as protein concentration in milk decreases and average breast milk intake increases slightly. According to Dewey and colleagues, estimated daily protein intake of a 6-month-old breastfed infant is 8.0 to 8.4 g/day, lower than the calculated AI of 9.1 g/day.

Protein content of infant formula is greater than protein in human milk, but no study has shown that the amount of protein in human milk has deleterious effects. Multiple studies have shown that infants fed human milk have improved immune function and fewer illnesses than do formula-fed infants. The casein and whey in infant formula are different from those present in human milk; therefore, the digestibility, absorption, and functionality of these proteins differ. The FAO/WHO (1989) states that digestibility and comparative protein quality need to be considered when determining the amount of protein to be included in infant formula based on various protein sources. Protein requirements for formula-fed infants may be greater because of their less efficient utilization and retention of protein compared to that of breastfed infants. Dewey, Cohen, and colleagues (1996) found that adding extra protein to the diet of 4- to 6-month-old exclusively breastfed infants

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did not improve weight or length gains despite an additional 20% protein in their diet, and no differences were found in growth rate based on protein intake.

The amount of protein required for growth is highest in early infancy and decreases over time. At 1 month of age 64% of protein intake is used for growth, decreasing to 24% at 6 to 12 months. Daily increments in body protein gains in male breastfed infants decreased from 1.0 g/kg/day at 1 month to 0.2 g/kg/day at 6 months. Protein needs for growth in early infancy are influenced by birth weight as well. Infants with higher birth weights generally grow at a slower rate and would require less protein than do infants born at a lower birth weight, who experience faster rates of weight gain (Dewey, Beaton, Fjeld, Lonnerdal, & Reeds, 1996). Protein requirements (both total protein and protein per kilogram of body weight) for infants older than 6 months are lower than the requirements for younger infants. High-protein follow-up formulas are not indicated or necessary for infants consuming a variety of foods (Dewey, 2000b).

Calculations for protein requirements for infants ages 7 through 12 months are based on the relationship between protein intake and nitrogen balance. Studies examining protein losses, requirements for maintenance, and protein deposition were used to derive the Dietary Reference Intake (DRI) and Recommended Dietary Allowance (RDA) for older infants of 1.5 g/kg/day, which do not differ greatly from the AI for younger infants. Higher protein intake would be indicated for a child requiring catch-up growth or recovery from an infection. Infants older than 6 months may receive a significant portion of their protein needs from complementary foods.

An adequate growth rate has traditionally been used as the determinant for sufficient protein intake. Dewey, Beaton, and colleagues (1996) reported that other measures of protein intake, such as immune function and behavioral development, may become compromised long before growth falters. Observed differences in growth rates between infants who are breastfed and formula-fed raise the question of whether maximal growth rate is synonymous with optimal growth rate. Higher intakes of protein in formula-fed infants have been a cause for concern because the liver and kidneys need to metabolize and excrete the increased levels of plasma amino acids and urea nitrogen, which could have long-term consequences on immature organs.

Fatty Acids

Both human milk and currently available infant formula contain generous amounts of the essential fatty acids linoleic acid and alpha-linolenic acid. Cow's milk contains very little, and infants and toddlers who drink cow's milk often have low levels of these fatty acids. Corn, soybean, or safflower oil can be added to the diet of a child who has been weaned from breast milk or formula to provide these nutrients (Butte et al., 2004).

In addition to the essential fatty acids linoleic acid and alpha-linolenic acid, there is growing concern that infants also need **long-chain polyunsaturated fatty acids (LCPUFAs)** in their diets. The fetus and newborn infant are not capable of converting adequate amounts of linoleic acid and alpha-linolenic acid to docosahexaenoic acid (DHA) and arachidonic acid (AA) until 16 weeks after term age and therefore rely on an exogenous source from the mother or from milk to meet their needs for LCPUFAs (Hadders-Algra, 2010).

long-chain polyunsaturated fatty acids (LCPUFAs) A category of dietary fats important in brain and retinal growth; normally present in human milk, they are now added to infant formula.

These fats, particularly AA and DHA, are vital for neural development and visual acuity. Infants fed formula containing only linoleic and alpha-linolenic acid, the precursors for AA and DHA, can synthesize only a limited amount of long-chain fatty acids. When compared with breastfed infants, formula-fed infants had less mature neurophysiologic maturation and brain function (Khedr, Farghaly, Amry Sel, & Osman, 2004). These LCPUFAs are concentrated in the phospholipid bilayer of biologically active brain and retinal neural membranes during the periods of rapid brain and retinal growth from the last trimester of pregnancy until 2 years of age. During this critical period of rapid growth and maturation, the quantity and quality of the LCPUFAs may influence the efficiency of nerve cell signaling and have long-lasting effects on brain function.

In 1998, an expert panel for the FDA in the United States and a working group for the Canadian authorities did not recommend the addition of LCPUFAs to infant formula because of the uncertainties related to product safety and efficacy (Koo, 2003). In February 2002, term infant formula with added DHA and AA became readily available, and shortly thereafter DHA and AA were added to preterm infant formula. The rationale for adding these LCPUFAs to infant formula is based on the observation that they are present in large quantities in the brains and retinas of breastfed children and are present in breast milk. Maternal plasma and human milk DHA levels as well as the infant's plasma levels can be increased by adding DHA to the maternal diet at levels of 200 mg/day or greater. However, studies have not shown marked improvement in infant outcome related to visual function and neurodevelopment in breastfed infants whose mothers received 200 mg/day DHA supplementation (Jensen et al., 2005).

A comparison of the multitude of studies on LCPUFA supplementation and visual acuity and neurodevelopmental outcomes in infants is hindered by the fact that many of the neurodevelopment tests were never designed to test normal healthy infants and lack predictive ability for long-term neurodevelopment outcomes. Although DHA and AA supplementation no doubt raises plasma levels in both infants and breastfeeding mothers, it remains highly controversial whether there is any functional benefit in visual acuity or neurodevelopment. A meta-analysis of available evidence on the effects of LCPUFA supplementation in infant formula shows that although there is a beneficial effect on short-term neurodevelopmental outcomes in full-term infants, there are no long-term effects beyond 4 months of age (Hadders-Algra, 2010). The safety of these additives is an additional concern, although there have been few reported adverse events. The oils used for the supplementation are new food products from Martek Biosciences. They have been approved by the FDA as "Generally Recognized as Safe" and are approved for use in infant formula and baby food.

The DHA used to supplement infant formula is an oil derived from microalgae, and the AA is an oil derived from soil fungi. An imbalance of omega-3 to omega-6 fatty acids could have biological effects such as prolonged bleeding time and diminished growth, and close monitoring of infants consuming infant formula with added LCPUFAs through scientific studies is indicated and indeed required by the FDA. Although families will embrace a new product promising to deliver a formula that is closer to human milk and is good for the brain and eyes, the cost of these products is a burden on the family budget and on public funding for nutrition programs. Justification of increased costs of up to 25% may prove difficult without substantial scientific evidence of improved clinical outcomes in vision and intelligence.

Iron

Iron-deficiency anemia is the most common childhood nutritional deficiency worldwide, with consequences of delays in motor and cognitive development caused by irreversible brain injury. Developmental deficits occur when iron deficiency becomes severe and chronic enough to result in anemia. Although iron supplementation increases iron stores, poor developmental outcomes may persist, with lower scores on mental and motor tests and functional impairment in school-aged children.

iron-deficiency anemia The most common childhood deficiency resulting in motor and cognitive developmental deficits.

In the 1930s, in the United States a high prevalence of nutritional iron-deficiency anemia was first noted in infants and the prevalence has decreased dramatically since the 1960s, when it was acknowledged as a public health problem. Interventions, including an increase in breastfeeding, the start of the **Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)** in 1972, and education of physicians and the public, resulted in a dramatic decrease in iron-deficiency anemia across all socioeconomic groups in the United States. The interventions were so successful that in the 1980s it was suggested that routine screening of all infants be replaced by selective screening of high-risk patients.

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) A program that serves to safeguard the health of low-income women, infants, and children up to age 5 years who are at nutritional risk by providing nutritious foods to supplement diets, information on healthy eating, and referrals to health care.

It now appears that the prevalence of iron-deficiency anemia is increasing in 1- to 3-year-olds (Kazal, 2002). Data from the 2001 Pediatric Nutrition Surveillance System indicated that 16.6% of 6- to 11-month-old infants and 15.3% of 12- to 17-month old children were anemic. The subjects in this national sample were largely from low-income populations, where 82% were enrolled in WIC (Altucher, Rasmussen, Barden, & Habicht, 2005). It is not unusual for children ages 1 to 3 years to have low intakes of iron. Most 12-month-olds receive 100% of the daily requirement for iron, but this declines to less than recommended intake by 18 months, likely because of cessation of breastfeeding, switching from iron-fortified infant formula to cow's milk, and reduced intake of iron-fortified cereals (Kazal, 2002). Juice intake can decrease a child's appetite for other more nutritional solid foods, further contributing to iron deficiency.

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Healthy, normal-birth-weight, full-term infants receive adequate iron from human milk for approximately the first 6 to 9 months of life. Reserves at birth are a critical factor for anemia. Delaying clamping of the umbilical cord for 30–120 seconds at birth improves iron status at 2–3 months (Hutton & Hassan, 2007; Van Rheenen & Brabin, 2004). Total body iron is fairly stable in infants from birth through age 4 months as stored iron is gradually used to support growth. Between 4 and 12 months there is a significant increase in iron requirements as body size increases. These needs cannot be met through the iron available in human milk. The concentration of iron in human milk is 0.2 to 0.4 mg/L and remains stable throughout lactation. Although the absolute amount of iron in human milk is low, efficiency of iron absorption from human milk is quite high, at about 50%. Once iron stores are depleted, iron-related physiologic functions may become compromised, with both cognitive and motor deficits even in the absence of anemia. After age 2 years when growth velocity decreases, iron stores start to accumulate and the risk for deficiency decreases (AAP, 2004).

The risk for anemia is much greater in low-birth-weight infants. In a study of low-birth-weight infants born in Honduras, infants with birth weights less than 3,000 g were at risk for anemia at 6 months even when iron-fortified complementary foods were introduced between ages 4 and 6 months (Dewey, Peerson, & Brown, 1998). It is recommended that low-birth-weight breastfed infants receive iron drops beginning at ages 2 to 3 months.

Fomon (2001) stated that infants who are exclusively or predominantly breastfed are at risk of becoming iron deficient by 8 to 9 months of age. Whereas Fomon recommended beginning iron supplementation of breastfed infants at an early age to prevent depletion of body stores, the AAP notes that iron deficiency is rare in breastfed infants as a result of increased absorption and the absence of microscopic blood loss in the intestinal tract that may occur with whole cow's milk. Supplementation of healthy term breastfed infants with iron to prevent deficiency is controversial. Unnecessary supplementation can increase the prevalence of gastrointestinal infection, sepsis, and cancer because iron is essential for the growth of microorganisms and malignant cells. Gastrointestinal effects such as nausea, vomiting, constipation, and abdominal pain have been reported by individuals on iron supplementation. Routine iron supplementation of breastfed infants with normal hemoglobin levels resulted in increased diarrhea and poor linear growth, possibly as the result of the pro-oxidant effect of iron on the intestinal mucosa. Reduction in zinc absorption leading to poor growth can occur from excessive iron intake (Dewey et al., 2002). Ermis, Demirel, Demircan, and Gurel (2002) found that supplementation of breastfed infants from ages 5 to 9 months with iron at a dose of 2 mg/kg every other day prevented iron deficiency and iron-deficiency anemia. Every-other-day dosing improved compliance and reduced unpleasant side effects.

Domellof, Lonnerdal, Abrams, and Hernall (2002) found that regulation of iron absorption in breastfed infants undergoes developmental changes from ages 6 to 9 months that enhance the ability of the infant to adapt to a low-iron diet. Unlike iron absorption in adults, which increases in states of iron depletion, iron absorption in infants was found to be directly related to the dietary intake rather than to iron status. Iron status as measured by serum ferritin was improved in infants given iron supplementation, but there was a significant inverse relationship between dietary iron provided and absorption of iron from human milk. Unsupplemented infants absorbed 37% of the iron in human milk compared with only 17% absorption in breastfed infants supplemented with 1 mg/kg/day. Supplemental iron drops had a greater effect on decreasing iron absorption from human milk than absorption of iron from complementary foods. Domellof and colleagues concluded that breastfeeding with the addition of complementary foods containing adequate iron likely provides sufficient iron for some, but not all, healthy 9-month-old infants, possibly because of up-regulation of iron in response to low dietary intake, thus avoiding iron deficiency.

Iron absorption from foods varies greatly from less than 1% to 50% of available iron. About 4% of the iron in fortified infant formula is absorbed versus 50% of the iron in human milk. The AAP estimates that for infants consuming iron-fortified formula there is an 8% risk for iron deficiency and less than 1% risk for iron-deficiency anemia. Infants drinking cow's milk have a 30% to 40% risk of iron deficiency by ages 9 to 12 months. Exclusively breastfed infants have a 20% risk of iron deficiency by 9 to 12 months of age. Formula-fed infants should not be switched to whole cow's milk until after 1 year of age, and there is no medical indication for low-iron formulas. The AAP has recommended that the manufacture of low-iron formulas be discontinued because there is no scientific evidence to support the claim that iron-fortified formulas increase gastrointestinal distress in infants.

The main sources of iron from complementary foods in the infant diet are iron-fortified cereal and meats. Absorption of iron from infant cereal is only about 4%. The form of iron used in dry infant cereals is an insoluble iron salt or metallic iron powder that is used to reduce oxidative rancidity, and these forms have low bioavailability. Meat is a much better source of iron because the iron is in the heme form, with an absorption efficiency of 10% to 20%. Nonheme iron from plant foods and fortified products is less well absorbed. Plant-based foods have a high phytic acid, polyphenol, and/or dietary fiber content that can inhibit absorption of micronutrients. Ascorbic acid counteracts the effects of phytate on iron absorption by preventing it from binding with available iron.

Estimates for absorption of iron depend on the amount of animal or fish protein in a meal relative to plant-based foods. Consumption of meat, fish, or poultry enhances the absorption of nonheme iron from plant-based foods. Vitamin C in the form of fresh fruits such as cantaloupe, kiwi, or strawberries or vegetables such as broccoli and kale consumed at the same time as nonheme iron enhances absorption. Tea, bran, and milk inhibit nonheme iron absorption. Heme iron is absorbed in the intestines intact and is not affected by inhibitors of nonheme iron.

Engelmann, Sandstrom, and Michaelsen (1996) studied the effect of meat intake on hemoglobin levels in breastfed infants. When healthy 8-month-old partially breastfed infants were fed a high meat intake of 27 g/day for 2 months, they had only minimal decreases in hemoglobin of 0.6 g/L compared with a similar group of breastfed infants with a low meat intake of 10 g/day who had decreases in hemoglobin of 4.9 g/L. The group with the low meat intake had overall greater intakes of iron (3.4 versus 3.1 mg/day) but lower intakes of iron from meat (0.1 versus 0.4 mg/day), suggesting that animal muscle protein has an iron absorption–enhancing effect and can minimize decreases in hemoglobin that are typically observed from ages 8 to 10 months in breastfed infants.

Heath, Tuttle, Simons, Cleghorn, and Parnell (2002) found that 9- to 18-month-old New Zealand breastfed infants experienced low rates of iron-deficiency anemia of 7% even while their intake of breast milk and infant formula declined. Their intake of highly bioavailable iron in the form of meat, poultry, and fish increased from 0 g/day at 9 months to 21 g/day at 12 months and 32 g/day at 18 months. Their intake of vitamin C was also high, at 52 to 96 mg/day, likely further enhancing iron absorption.

Kattelmann, Ho, and Specker (2001) found that the age of introduction of complementary foods to formula-fed infants did not affect iron status parameters. Infants introduced to complementary foods early, at 3 to 4 months of age, had greater iron intakes at age 6 months but no difference in hemoglobin levels at age 12, 24, or 36 months than infants with later introduction to complementary foods at age 6 months. These infants were all formula fed and received at least the RDA for iron for the first 6 months of life.

Zinc

The AI for zinc for infants from birth to age 6 months reflects the usual zinc intake of infants fed exclusively human milk. Zinc is crucial for growth and development (Otten, Hellwig, & Meyers, 2006). Human milk is sufficient to meet the infant's requirements for the first 6 months of life (Brown, Engle-Stone, Krebs, & Peerson, 2009; IOM, 2001). Zinc deficiency is prevalent in undernourished children and is linked to reduced activity and play with subsequent poor developmental outcomes. **Zinc deficiency** is associated with poor growth as well as diarrheal disease. Globally, there is a widespread prevalence of zinc deficiency, often along with iron deficiency, in infants and young children (Krebs et al., 2006). It is estimated that 12- to 24-month-olds only meet 50% to 60% of the DRI/RDA for zinc (Krebs, 2000). Meeks Gardner and colleagues (2005) found that when poor, undernourished Jamaican children ages 9 to 30 months were supplemented with 10 mg zinc daily and also participated in a weekly program to improve mother–child interactions, the developmental quotient and hand and eye coordination improved. Diarrheal morbidity

zinc deficiency Prevalent in undernourished children and associated with poor growth, poor developmental outcomes, and diarrheal disease.

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was reduced, but there were no improvements in the children's growth.

Zinc concentration in human milk is low, but bioavailability is high. Neonatal stores are likely sufficient to maintain zinc homeostasis until 6 months of age. The young infant has a relatively high zinc requirement to support the rapid growth of early infancy. Zinc concentration in human milk decreases throughout lactation but continues to be an important source of zinc beyond 6 months (Otten et al., 2006). There is greater bioavailability of zinc in human milk than in cow's milk. The concentration of zinc in human milk decreases rapidly from 4 mg/L at 2 weeks to 2 mg/L at 2 months and to 1.2 mg/L at 6 months (Krebs, Reidinger, Robertson, & Hambridge, 1994). Despite an increased intake in volume over the first 6 months, this steep decline in zinc concentration in human milk results in a decline in zinc intake. Zinc concentration in human milk of well-nourished mothers is resistant to changes in the maternal diet. Although zinc supplementation is associated with improved growth, exclusively breastfed infants grow well without additional zinc. Dewey and associates (1998) found that when breastfed children received complementary foods fortified with zinc to double their average zinc intake there was no significant increase in weight or length.

Zinc absorption is greater from a diet high in animal protein, and the best source of zinc is red meat (Krebs et al., 2006). Meat provides adequate amounts to meet requirements of breastfed infants 7 to 12 months of age. Plant-based foods containing phytic acid bind with zinc in the intestines and reduce absorption. Vegetarians who rely on a plant-based diet may need to increase their zinc intake by 50% because of decreased bioavailability of zinc from phytic acid. Complementary foods based on unrefined cereals and legumes have a high phytate-to-zinc ratio and can compromise zinc status, whereas rice has a lower phytate-to-zinc ratio (Gibson & Holtz, 2000). Offering infants complementary foods of animal origin such as red meat and fish improves zinc intake and bioavailability. Supplementation with a combination of micronutrients can lead to problems of interaction and limitations of absorption. A zinc supplement given in water interferes with absorption of iron but not when both are added to food (Rossander-Hulten, Brune, Sandstrom, Lonnerdal, & Hallberg, 1991).

Vitamin D

Rickets was almost universally seen in African American infants living in the northern United States at the turn of twentieth century. With the discovery of vitamin D and a public health campaign to fortify infant foods and supplement breastfed infants with cod liver oil, rickets were nearly eradicated (Rajakumar & Thomas, 2005). Once again, nutritional rickets is a public health concern. Breastfed infants are at risk for vitamin D deficiency because of limited amounts of vitamin D in breast milk and the current trend to limit sun exposure (Fomon, 2001). Vitamin D–deficiency rickets can cause significant morbidity, including delays in growth and motor development, failure to thrive, short stature, tetany, seizures, and skeletal deformities. A review of published reports from 1986 to 2001 found 166 cases of rickets in children in North Carolina, Texas, Georgia, and the mid-Atlantic region (Weisberg, Scablon, Li, & Cogswell, 2004). Most cases (83%) were African American, and 96% were breastfed. Only 5% of the breastfed infants received vitamin D supplementation, and most were weaned from the breast to a diet low in vitamin D and calcium.

rickets Vitamin D deficiency resulting in growth deficits, developmental delay, failure to thrive, short stature, tetany, seizures, and skeletal deformities.

Dark-skinned infants who are exclusively breastfed are at particular risk because of differences in skin melanin content and the ability to convert UV light to previtamin D3. From 1990 to 1999, in North Carolina 30 cases of nutritional rickets were seen in African American children who were breastfeeding without supplemental vitamin D, even though infants living in sunny southern states were believed to be at low risk (Kreiter et al., 2000). Infants born to African American women in the southeastern United States were found to have lower levels of vitamin D at birth compared to Caucasian infants and are at greater risk of developing rickets (Basile, Taylor, Wagner, Quinones, & Hollis, 2007). Vitamin D deficiency was found to be common among unsupplemented breastfed infants living in Iowa. It was more common in winter, when 78% of unsupplemented breastfed infants were found to be deficient. Deficiency was also observed in summer months and was more common in dark-skinned infants. Deficiency dropped with age but was reported to be 12% at 15 months of age without supplementation (Ziegler, Hollis, Melson, & Jeter, 2006). Vitamin D–deficiency rickets is common in infants

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in Pakistan, Saudi Arabia, and the United Arab Emirates where breastfeeding women have limited sun exposure and a diet low in vitamin D. Infants are not routinely supplemented with vitamin D while breastfeeding, and many mothers avoid consumption of fortified dairy products. Despite abundant sunshine, only rural women who spent more time working outdoors had adequate serum levels of vitamin D (Dawodu, Adarwal, Hossain, Kochiyil, & Zayed, 2003).

Guidelines from the AAP, based on evidence from new clinical trials, recommend a daily intake of 400 IU/day of vitamin D for all infants, children, and adolescents beginning the first few days of life to prevent vitamin D–deficiency rickets and potentially to maintain innate immunity and prevent diseases such as diabetes and cancer (Wagner, Greer, and the Section on Breastfeeding and Committee on Nutrition, 2008).

Vitamin D synthesis occurs in the skin from exposure to ultraviolet B light from sunlight. Dietary sources include fish liver oils, fatty fish, and foods fortified with vitamin D, particularly cow's milk, infant formula, and breakfast cereals. Sunlight exposure may not be sufficient at higher latitudes, during winter months, or with sunscreen use. Individuals with dark skin pigmentation have limited vitamin D synthesis with sunlight exposure. Human milk typically contains 25 IU/L of vitamin D, not enough to meet the recommended requirement.

Maternal vitamin D status has a direct effect on the vitamin D content in human milk. Traditionally, sunlight exposure provided adequate vitamin D for both mothers and breastfeeding infants. For instance, in light-skinned individuals 10 to 15 minutes of total body peak sunlight exposure endogenously produce and release into circulation 20,000 IU of vitamin D. The daily recommended intake for vitamin D for lactating women is 400 IU, an amount unlikely to provide for optimal vitamin D levels in human milk. Wagner, Hulsey, Fanning, Ebeling, and Hollis (2006) found that by supplementing lactating mothers with 6,400 IU/day of vitamin D, they were able to increase maternal vitamin D levels sufficiently to increase the amount of vitamin D in human milk from 82 to 873 IU/L and to significantly improve circulating vitamin D in both the mother and the breastfed infant.

Supplementing breastfeeding mothers with high-dose vitamin D does not adversely affect the level of calcium in maternal milk and does not result in toxicity for mother or baby (Basile, Taylor, Wagner, Horst, & Hollis, 2006). In the Middle East, where severe vitamin D deficiency is a significant health problem, supplementing mothers with high-dose vitamin D and their vitamin D–deficient infants with 400 IU/day vitamin D for 3 months was associated with a three-fold increase in infants' serum vitamin D levels and a 64% reduction in the prevalence of vitamin D deficiency (Saadi et al., 2009).

Supplemental Nutrients

Human milk continues to provide many nutrients in the second half of the first year of life during the period of **complementary feeding**. Human milk intake of infants ages 9 to 11 months meets the estimated needs for vitamin C, folate, vitamin B_{12}, selenium, and iodine. After 6 months, complementary foods are needed to provide 12% of vitamin A; 25–50% of copper; 50–75% thiamin, niacin, and manganese; and up to 98% of iron and zinc (Gibson & Holtz, 2000).

complementary feeding The period that begins with the introduction of the first nonmilk food and ends with the cessation of breastfeeding or formula feeding.

Despite the fact that most young children receive adequate vitamins and minerals from their diet, many families supplement their child's diet with additional vitamins and minerals. Eichenberger Gilmore, Hong, Broffitt, and Levy (2005) studied trends in children younger than 2 years in Iowa and found that by 24 months 31.7% used some type of supplement. In the first 6 months of life, 3.5% to 6.3% of non-breastfed infants received supplements compared with 18.3% to 29.2% of breastfed infants. After 6 months of age, use of multiple vitamin supplements and multiple vitamin supplements with minerals increased with age. Diet alone provided AI of most vitamins and minerals, and with additional supplementation intake of vitamin A exceeded the recommended upper limit. Hypervitaminosis A is a concern because reports associate excessive vitamin A intake with decreased bone mineral density and increased risk of fracture. The long-term adverse effects of high intakes of vitamin A during early life are not clear.

Milner, Stein, McCarter, and Moon (2004) reported that early use of multivitamins increased the risk of developing food allergies and asthma. There was an association between infant multivitamin supplementation within the first 6 months of life and an increased risk of developing asthma by 3 years of age among black children. In addition, multivitamin supplementation in the first 6 months

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of life was associated with increased risk for food allergies by 3 years of age in both formula-fed and breastfed infants. Early infancy may be a sensitive time for exposure to exogenous stimuli that influence the differentiation of naive T cells into either proinflammatory or anti-inflammatory cells. Vitamins may be a potent stimulus for the differentiation of T cells that promote allergic response when encountering specific antigens. Recommendations for routine vitamin supplementation may need reevaluation in light of these findings.

Fortified foods provide a significant portion of nutrient needs, reflecting a limited intake of nutritious foods such as fruits and vegetables (Fox, Reidy, Novak, & Ziegler, 2006). As infants move into the toddler stage, a decrease in naturally occurring vitamin A from vegetables is replaced by vitamin A from cereals and supplements. At the same time, two of three of the leading sources of vitamin C are fortified juices and fortified sweetened beverages rather than fruits and vegetables. Consumption of a wide variety of foods to meet nutrient needs, rather than reliance on fortified foods and supplements, is optimal. There is potential for excess intake and toxicity when vitamin A, zinc, and folate are consumed through fortified foods and supplements.

Vegetarianism

A vegetarian diet during infancy and childhood can be adequate in all essential nutrients, with normal growth and nutritional status expected unless the diet is severely restricted. A breastfed infant of a well-nourished vegetarian mother receives adequate nutrition, particularly if the mother pays close attention to her own intake of iron, vitamins B_{12} and D, and DHA. Women who consume three or more servings of dairy products receive sufficient vitamins D and B_{12} from their diet. Women following a vegan diet need to supplement with foods fortified with vitamin B_{12} such as nutritional yeast or soy milk. Vegan infants who are not breastfed need to receive soy infant formula until 1 year of age. Soy milk, rice milk, or homemade formulas based on grains, nuts, vegetables, or vegetable juice do not provide adequate nutrition for infants younger than 1 year old and should not be used to replace breast milk or commercial infant formula (American Dietetic Association, 2003; Mangels & Driggers, 2012).

A variety of protein-rich vegetarian foods is available for the older infant and toddler, including tofu, legumes, soy or dairy yogurt, and cheese, eggs, and cottage cheese. These foods can be easily puréed or mashed for increased acceptance when the child is first introduced to complementary foods. Later, soft-cooked beans, bean spreads or nut butters on toast, and chunks of tofu, cheese, and soy burgers can be offered as finger foods. Fat is an important source of energy and should not be restricted in children younger than 2 years of age. Vegan infants need a supplementary source of vitamin B_{12} when they are weaned from breast milk or infant formula.

Complementary Feeding

Transitioning from All Milk to Family Foods

Complementary feeding is defined as the period extending from the first introduction of nonmilk feeds to the cessation of breastfeeding or formula feeding (Weaver, 2000). Any food that provides energy and displaces breast milk is considered a complementary food. A gradual progression from an exclusive milk diet to a variety of complementary foods allows the infant's gastrointestinal function to accommodate new types of foods, including starch, sucrose, and fiber. In many other mammals there are abrupt and well-defined changes to the intestinal mucosa and enzyme activity as weaning occurs. However, in humans these changes are less obvious and more gradual. Human milk contains many bioactive substances, including digestive enzymes such as bile salt–stimulated lipase, amylase, and protease, that may be involved in the digestion of complementary foods.

The timing of complementary feeding varies according to cultural practices and the personal beliefs of the mother as well as guidance she receives from her pediatrician. In some instances, pediatricians may suggest adding cereal to the infant's diet before age 4 months when a mother is concerned about the baby's sleeping patterns or growth. Child nutrition experts agree that there is no reason to introduce complementary foods before 4 months of age. At least 60 countries have policies in place to introduce complementary foods after 6 months of age. Earlier introduction of complementary foods can affect immune function and immunotolerance, development of chronic disease, and risk of atopy.

At birth the gut of a full-term infant may be anatomically and functionally mature, but subtle immaturities in luminal digestion, mucosal absorption,

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and protective function could predispose the infant to gastrointestinal and systemic disease during the first 6 months of life. It is not known exactly when the period of immature immune function ends and when it is safe to feed foreign proteins. Early introduction can cause protein-induced enteropathies, leading to mucosal inflammation, villous atrophy, diarrhea, and failure to thrive (Muraro et al., 2004). The question of when the normal-term infant is developmentally ready to discontinue **exclusive breastfeeding** and begin the intake of solid and semisolid complementary foods is an important one. There probably is not a single optimal age for introduction of complementary foods but rather optimal ages that are determined by factors such as infant birth weight, maternal nutrition while breastfeeding, and environmental conditions.

exclusive breastfeeding
Infant receiving only breast milk and no other foods or drinks for the first 6 months.

Feeding Guidelines

From 1979 until 2001, the WHO recommended that normal full-term infants be exclusively breastfed for 4 to 6 months. Later, it was found that discontinuing exclusive breastfeeding before 6 months increased infant morbidity and mortality, and the WHO recommendations were revised to encourage exclusive breastfeeding for 6 months. Early introduction of complementary foods and exposure to pathogens in food could result in symptomatic infection and illness in the infant and reduced sucking at the breast, followed by a decrease in the amount of milk and immune substances consumed as well as decreased maternal milk production from reduced demand. Exclusive breastfeeding for 6 months results in greater immunologic protection and limits exposure to pathogens at an early age when the immune system is immature. Energy and nutrients that are valuable for normal growth and development can be used for their intended purpose rather than diverted for immunologic function.

Malnutrition is the leading cause of death in children younger than 1 year of age worldwide. Inappropriate feeding practices include early cessation of exclusive breastfeeding, introducing complementary foods too early or too late, and providing nutritionally inadequate or unsafe foods. Malnourished children who survive are frequently sick and may suffer lifelong consequences. Overweight and obesity are increasing at alarming rates throughout the world and are associated with poor feeding practices that often begin in early childhood. Global strategies for infant and young child feeding can affect social and economic development.

The WHO feeding guidelines (WHO, 2003) are for generally healthy breastfed infants. These guidelines target primarily low-income countries where most children are breastfed and safe low-cost alternatives to breast milk are not readily available. No information is included for feeding premature infants or children with infections or other acute or chronic diseases that could affect nutritional status. No information is provided on feeding non-breastfed infants. An important goal of the WHO is to improve complementary feeding practices in terms of timeliness, quality, quantity, and safety to ensure adequate global nutrition. It is difficult to make recommendations regarding the optimal age for introduction of complementary foods. Ideally, the appropriate time to introduce complementary foods and the optimal duration of breastfeeding consider infant outcomes, such as growth, behavioral development, micronutrient status, the risks of infection, allergy, and impaired intestinal function as well as those of the mother, such as general health and nutritional status and return to fertility.

The American Academy of Pediatrics Section on Breastfeeding (2012) recommends that infants be exclusively breastfed for approximately 6 months, followed by continued breastfeeding for 1 year or longer as complementary foods are introduced. Aware that complementary feeding occurs prior to 6 months in some families because of family preference and the infant's developmental status, it is advised that breastfeeding continue when complementary foods are introduced. This may be important when gluten-containing cereals are introduced because breastfeeding is immunoprotective and may reduce the risk of developing celiac disease (Silano, Agostoni, & Guandalini, 2010).

The AAP Section on Breastfeeding (2005) recommends that complementary foods rich in iron be introduced gradually around 6 months of age, but because of the unique needs of individual infants the need to introduce complementary foods could occur as early as 4 months or as late as 8 months of age. Exclusive breastfeeding in the first 6 months is defined by the AAP as consumption of human milk with no supplementation of any type (no water, no juice, no nonhuman milk, and no foods) except for vitamins, minerals, and medications. During the first 6 months, water, juice, or other

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liquids are unnecessary, even in hot climates, and can introduce contaminants or allergens.

Exclusive breastfeeding provides protection from many acute and chronic diseases. Breastfeeding is also more likely to continue for at least the first year of life when infants are exclusively breastfed for the first 6 months. For optimal health benefits, breastfeeding should continue for 12 months or longer. The recommendations of the WHO are to breastfeed for at least 2 years, and the AAP states that there is no upper limit to the duration of breastfeeding and no evidence of psychological or developmental harm from breastfeeding into the third year of life or longer (AAP Section on Breastfeeding, 2005). Indeed, in late infancy breast milk provides significant amounts of energy and micronutrients and is a key source of PUFAs crucial for brain development and neurologic function (Villalpando, 2000).

Complementary Foods and Growth

Introducing complementary foods to the exclusively breastfed infant before 6 months does not increase total calorie intake or improve growth. A breastfed infant who receives complementary foods at 4 months decreases his or her intake of human milk to maintain the same level of calories. Dewey (2000a) expressed concern that the improper introduction of complementary foods has the potential to adversely affect breast milk intake and breastfeeding duration. Providing excess energy in the form of complementary foods can reduce the intake of breast milk. Breastfed infants reduce their intake of human milk as non–breast milk foods and fluids are introduced. Although it appears that the timing of breastfeeding in relation to complementary foods (e.g., offering complementary foods before or after breastfeeding) does not seem to affect overall breast milk intake, there is a paucity of information on the effect of the introduction of complementary foods on breastfeeding.

Complementary foods displace human milk, and the infant receives fewer immune factors and is at greater risk for infection. No significant improvement in weight or length was observed by Dewey (2001) in infants up to 12 months of age when they received complementary foods at 4 months compared with infants who received exclusive human milk until 6 months.

Despite recommendations to exclusively breastfeed for the first 6 months of life, this practice may be uncommon. In the developing world, exclusive breastfeeding rates for 6 months are 37%, ranging from 22% in West and Central Africa to 45% in South Asia (Alipui, 2012). In the United States, where the national goal is for 25% of mothers to exclusively breastfeed for 6 months, overall 16.3% of mothers meet this goal (CDC, 2012).

Carruth, Skinner, Houck, and Moran (2000) found that in a study of 94 mothers, 60 added solid food by 4 months and 8 were feeding cereal in a bottle. The median age for introduction of cereal was 4 months and for juice 4½ months. Thirteen mothers introduced cereal, juice, or fruit as early as 2 months. In looking at the growth of the children who had early solids, there was no association between the age of introduction of complementary foods and change in weight or length from 2 to 8 months or from 12 to 24 months. These results were similar to the WHO data (WHO Working Group on the Growth Reference Protocol & WHO Task Force on Methods for the Natural Regulation of Fertility, 2002) showing only minor differences in growth among infants receiving complementary foods at different ages. The WHO data were based on a unique longitudinal seven-country study of predominantly breastfed infants. The study found little evidence of risk or benefit related to growth based on timing of introduction or types or frequency of complementary foods in healthy infants living in environments without major economic restraints and with low rates of illness.

The amount of energy and nutrients needed from complementary foods depends on the amount of breast milk or formula the infant is consuming. Although it is possible for an infant to receive adequate nutrition for the first year solely from iron-fortified formula, all infants need complementary foods for exposure to novel tastes and textures and to develop appropriate feeding skills. A variety of flavors and foods is important in the first 2 years of life and may increase the likelihood that children will try new foods.

Learning Point Food-related behaviors are established early in life, and how and what an infant or toddler eats in the first years of life can influence later food choices.

Meal Patterns and Nutrient Intakes

During infancy and early childhood, lifelong patterns of eating are formed that can influence later eating habits and overall health. As the

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child makes the transition from an all-milk diet to sharing foods from the family table, meeting nutritional guidelines may become more problematic for families. Families strive to follow nutrition recommendations to provide the best for their children, particularly in the year after birth when the infant is eating mostly jarred baby foods. As the infant matures and begins to incorporate more of the family foods into his or her diet, less than optimal nutrition becomes evident. Transitioning from baby food to table food has been associated with a decreased intake of vitamin A, iron, and folate at meals as baby food fruits, vegetables, and meats are not replaced with equivalent table foods.

Children imitate what others around them are eating, and if no one else eats fruits or vegetables, the young child will quickly abandon these foods. When other family members drink sweetened carbonated beverages and eat high-calorie low-nutrient-dense foods, such as french fries, donuts, and potato chips, the young child will happily join in. As rates of obesity, excess weight, and type 2 diabetes are increasing in children, it is evident that the influence of early diet needs to be addressed. At a surprisingly young age, many infants and toddlers do not receive a variety of fruits and vegetables and instead are consuming high-calorie, high-fat, salty snacks and sweetened drinks. It is the parent's responsibility to offer nutritious foods to infants and toddlers. Although a preference for sweet foods is innate, repeated exposure at an early age and observing other family members eating these foods increase the likelihood that young children will develop preferences for these foods. The disappearance of the family meal and the increase in the number of meals eaten outside the home and from fast-food establishments have concerned experts as the prevalence of snacking and the quantity and quality of foods consumed by children and adolescents in recent years have changed.

Learning Point Breastfeeding exposes the infant to a variety of flavors from the very beginning through mother's milk. Repeated exposures to a new food may be necessary before it is accepted.

Food Trends and Preferences

Designed to describe infant and toddler feeding patterns and food group consumption patterns, the **Feeding Infants and Toddlers Study (FITS)** was a cross-sectional telephone study using a national random sample of 3,022 infants and toddlers between 4 and 24 months of age in 2002 and of 3,273 infants and toddlers 0–47 months in 2008 along with a subsample for 2-day dietary recalls. The sample size was sufficiently large to categorize data by age groups: 4 to 6 months, 7 to 11 months, and 12 to 24 months. Conducted first in 2002 and again in 2008, the study consisted of up to three telephone interviews to collect data on growth, development, and feeding patterns. The studies had large sample sizes and were representative of ethnicity of the general population. They also included a large proportion of breastfed infants. Subsequent to the FITS 2002 study, childhood obesity emerged as a major public health concern. Efforts to curb obesity included focusing on the quality of foods consumed by preschoolers; therefore, the upper age of FITS 2008 was extended to 4 years to better assess the food environment of the preschool population (Briefel, 2010).The FITS survey collected data on food choices and their nutritional impact, feeding practices and patterns, and infant and toddler growth and developmental milestones (Devaney, Kalb, et al., 2004). The study was sponsored by Gerber Products Company and provided in-depth nutritional information about feeding behaviors of infants and toddlers and compared intakes with the newly developed DRIs. The data from 2008 were compared to the data from 2002 to identify shifts in food consumption patterns over time. Positive trends were observed related to breastfeeding practices. The percentage of infants currently breastfeeding increased from 26% in 2002 to 43% in 2008 for 4- to 5.9-month-old infants, from 27% to 37% for infants 6–8.9 months, and from 21% to 37% for infants 9–11.9 months (Siega-Riz et al., 2010).

Feeding Infants and Toddlers Study (FITS) This study was conducted on a large random sample of infants and toddlers to collect data on food choices and feeding practices and their impact on growth and development.

Overall, FITS found that most infants and toddlers in the United States were receiving adequate nutrition without getting excessive amounts of nutrients. Inadequacies were noted in FITS 2008, where 12% of infants 6–11 months had inadequate iron intakes and 6% had inadequate zinc intake (Butte et al., 2010). The mean energy intakes were lower in FITS 2008 than in FITS 2002 because the consumption of many desserts and sweets was reduced. Energy intake reported

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by parents was often greater than those recommended by the new DRI standard for energy, called the Estimated Energy Requirement (EER). The mean energy intake exceeded the EER by 10% for infants ages 4–6 months, by 23% for infants ages 7–12 months, and by 31% for ages 12–24 months (Devaney, Ziegler, Pac, Karwe, & Barr, 2004). For infants younger than 6 months of age, the largest discrepancies were for those receiving complementary foods in addition to breast milk or formula. The FITS infants and toddlers consumed more energy than recommended on average for all age groups. Overreporting of food intake by caregivers is possible because parents may perceive the amount of food consumed reflects their success as providers. Parents may also have difficulty accurately assessing food intake because of spillage and a discrepancy between foods offered and foods consumed. However, with 10% of 2- to 5-year-old children considered overweight, it is plausible that overfeeding is occurring in infants and toddlers. Early exposures to fruits and vegetables or to foods high in energy, sugar, and fat at this critical time period can influence food preferences and dietary habits later in life.

In 2002, complementary foods continued to be introduced at ages earlier than recommended by experts, and 29% of all infants were introduced to infant cereals or puréed foods before 4 months of age (Briefel, Reidy, Karwe, & Devaney, 2004). Improvements were noted in 2008 as fewer children were introduced to complementary food before 6 months (65% vs. 50% for infant cereal; 35% vs. 17% for baby food fruit, and 31% vs. 24% for baby food vegetables, for 2002 and 2008, respectively). Although it is recommended that foods rich in iron be introduced as complementary foods at 6 months, fewer children were consuming baby food meats and iron-fortified cereals in 2008 compared to 2002 (Siega-Riz et al., 2010).

There was no significant difference in the mean age of introduction of complementary foods or cow's milk according to income level or ethnicity or in children ever breastfed compared with those never breastfed. The contribution of commercial baby foods and beverages to energy consumption peaks at ages 7 to 8 months and declines as table food intake increases (Briefel, Reidy, Karwe, Jankowski, & Hendricks, 2004).

The FITS study revealed disturbing trends regarding the food consumption of infants and toddlers. Early food preferences can predict future eating behaviors, and an alarming percentage of young children have already developed suboptimal food consumption patterns. Not surprisingly, food consumption patterns in infants and toddlers reflect the typical eating patterns of older children and adults, such as diets lacking in fruits and vegetables with high intakes of readily available low-nutrient snacks and beverages. Daily consumption of fruits and vegetables is the cornerstone of a healthy diet, and a wide variety is encouraged. In 2008, there continued to be a substantial proportion of infants and toddlers who did not receive any fruits or vegetables in a given day. Among 6- to 8.9-month-olds, 35% did not have any fruit or vegetable, and among 9- to 11.9-month-olds 64% did not have any vegetables and 19% did not have any fruit (Siega-Riz et al., 2010). Fewer than 10% of infants and toddlers consumed dark leafy vegetables at any age. Intake of deep yellow vegetables decreased as infants transitioned from commercial baby food to table food. Commercial baby food was the main source of fruits and vegetables until 9 months of age when children were offered a greater percentage of cooked vegetables and fresh fruits. Bananas were the most commonly consumed fruit, followed by apples, and few children received citrus, melon, or berries.

Establishment of healthy patterns of beverage consumption including milk with meals is important for adequate calcium intake during the years of active bone growth in childhood and adolescence. Water is a better choice for quenching thirst than sweetened juice drinks or carbonated beverages are. Consumption of sweetened beverages changed little from 2002 to 2008. Sweetened beverages were consumed by 5% of 6- to 8.9-month-olds and 10% of 9- to 11.9-month-olds. During the second year, this increased to one-third of all toddlers drinking some form of sweetened beverage. FITS found that colas, fruit-flavored carbonated drinks, and carbonated mineral water were consumed by an increasing percentage of children from ages 4 through 24 months. Substitution of fruit drinks or carbonated beverages for milk at lunch, dinner, and snacks was evident after 15 months (Skinner, Ziegler, & Ponza, 2004). Fruit juice is not a necessary component of the diet of infants and toddlers and, if used at all, should be introduced after 6 months of age and limited to 8 ounces per day (Kleinman, 2000a). Fruit juice consumption has decreased overall but continues to be common among all age groups. Introduction before

6 months decreased from 19% in 2002 to 7% in 2008. However, at 1 year more than half of all toddlers drank fruit juice. Adverse gastrointestinal reactions to pear or apple juice are possible because of poor absorption of fructose and sorbitol (Fomon, 2001). Offering juice in a bottle after teeth have erupted can increase the risk of dental caries and should be avoided.

According to the AAP, limited amounts of 100% juice amounting to 4 to 6 ounces per day can be offered after 6 months of age, yet Skinner, Ziegler, and Ponza (2004) found from FITS that 22% of infants were introduced to juice earlier. Juice consumption increases dramatically with age. Ten percent of toddlers ages 15 to 24 months consume more than 14 ounces of juice per day. Fruit drinks are also popular, and 5% of toddlers consume more than 16 ounces of fruit drinks a day. The AAP does not provide recommendations for limitations on fruit drinks or carbonated beverages but states that they are not equivalent to 100% juice and should not be considered a fruit serving. Most fruit juices and fruit drinks contain added vitamin C and provide 20% to 30% of the daily vitamin C requirements, but apple juice, the most commonly consumed juice, contains little vitamin A and folate, nutrients commonly obtained from fruits and vegetables. Overfeeding juice and juice drinks can displace more nutritious beverage options such as milk and water and can be associated with excessive calorie intake and risk of obesity in older children.

Desserts and sweets are introduced at a surprisingly early age, with 5% of 4- to 6-month-olds already consuming a dessert, sweet, or sweetened beverage daily (Siega-Riz et al., 2010). These numbers increased dramatically after age 9 months, when nearly half were consuming one or more foods in this category. Parents should offer age-appropriate finger foods such as soft fresh fruits, diced canned fruit, well-cooked vegetables, and easily dissolvable fortified grains such as unsweetened ready-to-eat cereals.

No controlled studies address the practical aspects of introducing foods for the first time. Although feeding guidelines for parents abound, there is no evidence for a benefit of introducing one particular food first or at any particular rate. The AAP suggests that when complementary food introduction is initiated after 6 months of age, the order of the specific food introduction is not critical. Mixing cereal with breast milk may enhance acceptance of solid foods by breastfed infants. Foods commonly consumed by infants at 1 year of age include cereals and fruits. FITS data showed that infant cereal was the most common source of grains in young infants, but even by ages 7 to 8 months many infants were consuming ready-to-eat cereals, crackers, pretzels, rice cakes, breads, and rolls (Fox, Pac, Devaney, & Jankowski, 2004). After 9 to 11 months, the number of infants receiving infant cereal declined. This was replaced by other noninfant ready-to-eat and cooked cereals, including presweetened cereals. Many presweetened cereals are comparable in vitamins and minerals with unsweetened ready-to-eat cereals, but their use in this age group may lead to preference for sweetened foods.

Infants rarely consume meat. Krebs (2000) suggested that meat intake for breastfed infants at 6 months would adequately support both iron and zinc requirements in this age group. Introduction of red meat is desirable by age 6 months because of the high bioavailability of iron (Fomon, 2001). Offering plain single meats promotes the goals of complementary feeding, which is to gradually increase the variety of flavors and textures in the diet. The formula-fed infant is less reliant on complementary foods for iron and zinc. The addition of cereal to complement the intake of protein and energy from formula is considered adequate (Wharton, 2000). In FITS, few infants were receiving any type of meat, and often the meat appeared in commercially prepared baby food dinners. Fewer than 5% of infants in any age group received plain baby food meats. After 9 to 11 months of age, non–baby food meats were offered, with chicken or turkey the most common, followed by hot dogs, sausages, and cold cuts. Fewer children received beef, fish, and pork and there was a decline in consumption of these foods by infants and toddlers from 2002 to 2008. By 12 months of age, less nutritious high-fat deli meats were the second most commonly consumed source of meat. Popular nonmeat protein sources include cheese, eggs, and yogurt (Skinner, Ziegler, Pac, & Devaney, 2004). Few children were fed dried beans, peas, vegetarian meat substitutes, and foods such as chili, rice and beans, and other bean mixtures. Peanut butter, seeds, and nuts were rarely offered before 2 years of age, likely because of concern regarding the development of allergies.

Cow's milk and cow's milk products make a significant contribution to nutritional intake during the period of complementary feeding.

If breastfeeding continues into the second year of life and the diet contains a reasonable amount of animal protein in the form of meat, fish, poultry, or eggs, most infants thrive without the addition of dairy products to their diet (Michaelsen, 2000). In FITS, nearly all children younger than 24 months of age consumed some form of milk daily. Infant formula was consumed by 82% of 7- to 8-month-olds in 2002 and 75% in 2008 and decreased as cow's milk was introduced. More than 90% of infant formula consumed was iron fortified, and about 10% consumed soy-based formula.

Of concern in the 2008 survey was the use of cow's milk by 5% of infants age 6 to 8.9 months and 17% of infants 9 to 11.9 months (Siega-Riz et al., 2010). AAP recommendations are to wait until after the child's first birthday before introducing whole cow's milk. Furthermore, it was found that 14–33% of toddlers ages 12 to 23.9 months were drinking reduced-fat milk. Although, the AAP suggests waiting until 2 years to transition to reduced-fat milk, the American Heart Association recommends 2% milk in the second year of life. Cow's milk has an undesirably high renal solute load compared with infant formula and is a significant concern for children at risk of dehydration. Iron in cow's milk is low and poorly absorbed, and feeding non-heat-treated cow's milk can cause microscopic gastrointestinal bleeding in infants, resulting in loss of iron and anemia. Cow's milk is low in essential fatty acids, zinc, vitamin C, and niacin and is high in saturated fats. Recommendations to delay cow's milk introduction until 12 months of age are mainly focused on prevention of iron-deficiency anemia (Michaelsen, 2000).

Feeding Skills and Neuromuscular Development

Reflexes

A normal progression of sucking and feeding reflexes is necessary for the child to advance from a milk-only diet to consumption of foods from the family diet. Swallowing is present in early fetal life at the end of the first trimester. The fetus has ample opportunities to practice by swallowing amniotic fluid even before the development of the **sucking reflex**, which appears by the middle of the second trimester. The sucking reflex is quite strong in the newborn and can be easily elicited by stroking the infant's lips, cheeks, or inside the mouth. By about 3 months of age, sucking becomes less automatic and more voluntary. The **gag reflex** is present in the third trimester and is stimulated by contact of the posterior two-thirds of the tongue. This reflex gradually diminishes to one-fourth of the posterior tongue by 6 months of age. The **rooting reflex**, which assists the infant to locate the breast and nipple by turning the head side to side and opening the mouth wide when the skin surrounding the mouth is stroked, disappears by 3 months of age.

sucking reflex Strong reflex present in the newborn elicited by stroking the infant's lips, cheeks, or inside the mouth.

gag reflex Reflex stimulated by contact with the tongue that gradually diminishes over the first 6 months.

rooting reflex Reflex present from birth to age 3 months that assists the infant to locate the breast and nipple by turning the head side to side and opening the mouth wide when the mouth is stroked.

Advanced Motor Skills

Infants need new oral motor skills to transition from a full liquid milk-based diet to a more solid diet of complementary foods. Disappearance of the rooting and sucking reflexes and the accompanying changes in anatomy help prepare the infant for this transition. Phasic biting, resulting in the rhythmic opening and closing of the jaw when the gums are stimulated, disappears between 3 and 4 months of age. Between 6 and 9 months it becomes possible for the infant to receive a bolus of food without reflexively pushing it out of the mouth. By 12 months of age, rotary chewing is well established, along with sustained controlled biting that permits the infant to consume a variety of foods (Kleinman, 2000c).

During the first 2 years of life, there is increasing head and torso control that permits a child to achieve developmental milestones required for proper self-feeding abilities. Finger coordination to permit self-finger feeding usually is adequate by 6 to 7 months of age. The infant must be able to sufficiently stabilize the head and balance the trunk before he or she can sit without support and use arm and hand movements for self-feeding. Carruth, Ziegler, Gordon, and Hendricks (2004) found that one-third of 4- to 6-month-old infants and 99% of 9- to 11-month-olds can sit alone without support. Stability of the trunk is crucial in the process of progressing to complementary foods, and by 6 months most infants have achieved greater strength in the trunk, shoulder, and neck muscles. There is a wide range of ages when feeding skills emerge, and it is crucial that caregivers allow ample opportunities

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for appropriate exploratory activities. Offering the child a variety of nutritious foods and allowing him or her to self-feed when appropriate skill has sufficiently developed will not jeopardize adequate nutrient intake.

Beginning at 6 months, most infants are ready for puréed, mashed, and semisolid foods. By 7 months, soft foods that can be pressed down by the infant's tongue can be introduced, and at 9 months the infant can handle foods that can be compressed by the gums. Teeth are not necessary for chewing soft lumpy foods. The ability to handle advanced textures increases day by day, and children require multiple opportunities to practice new feeding skills. By 8 months, they can progress to finger foods they can pick up and feed themselves. By 12 months of age, most children can transition to the same diet as the rest of the family, keeping in mind the need for calorically and nutrient-dense foods because of the smaller portion size. Infants possessing self-feeding skills are reported to have higher energy and nutrient intakes (Carruth et al., 2004). Foods that are a choking risk that can lodge in the trachea, such as grapes, nuts, hard raw vegetables and fruits, and popcorn, should be avoided. Introduction to a cup usually occurs after 6 months, and by 12 months most infants are drinking from a "sippy cup."

Chewing Ability

Advances in gross motor skills parallel advances in dentition as the first primary teeth erupt at 7 to 8 months and continue throughout the first 2 years, with approximately 15 teeth by 19 to 24 months of age. Carruth and coworkers (2004) found the ability to consume foods that required chewing increases with age. Nutrient intakes of energy, fat, protein, vitamin B_6, vitamin B_{12}, folate, zinc, thiamin, niacin, and magnesium were greater for infants younger than 1 year of age who were able to eat foods that required chewing. Individual differences in the age of eruption of teeth can influence the ability to chew certain foods, especially meat and fibrous vegetables.

Feeding difficulties, particularly difficulty with chewing tough or fibrous foods, in Japanese children are thought to be caused by inappropriate transition from a milk-based diet to a diet of family foods. Sakashita, Inoue, and Kamegai (2004) found that at 2 years of age many preschool children swallowed without chewing or were unable to chew and swallow certain foods and that many kindergarten children did not chew properly, retained food in the side of their mouth, or frequently spit food out. A transitional diet containing very soft and puréed foods for an extended period has been suspected of preventing children from developing proper masticatory system and chewing and swallowing ability. Leafy vegetables were usually offered early as a weaning food but were not well accepted because the fiber makes them difficult to chew. Meats were often introduced later than recommended, possibly because of parental concerns related to food allergies (Sakashita, Inoue, & Tatsuki, 2003). In Japan, foods were specially cooked and fed to children from a spoon, inhibiting the proper development of the masticatory system and mature chewing and swallowing behavior.

Determinants of Food Acceptance

Sakashita and colleagues (2004) found that acceptance of new foods was greatest in children who were offered food prepared from the family table and was lowest in children fed jarred baby food. Offering infants foods prepared from the family table promotes feeding progress by giving the infant an opportunity to experience a variety of food textures from an early age. Infants first offered lumpy solid foods between ages 6 and 9 months had fewer feeding difficulties and improved acceptance than infants not introduced to these foods until after age 10 months. Observing other family members eating at the family table and having the opportunity to try new foods are also important components of transitioning an infant to family foods. Sakashita and colleagues (2004) found that first-born children experience more feeding difficulties than did second- or third-born children. This may be a result of limited opportunities to observe other family members eating and to learn feeding behavior from older siblings.

The number of accepted foods increases rapidly from 6 months to 1 year and continues to increase throughout the first 2 years. Foods requiring significant chewing before swallowing, such as leafy vegetables and sliced meat, may be poorly accepted. Processed sliced deli meats are often more readily accepted when offered. Because chewing ability affects ability to swallow and therefore food acceptance, breastfed infants who have more opportunity to develop the masticatory system have a higher rate of food acceptance than bottle-fed infants do. Exposure to food flavors through mother's milk also prepares the infant for a variety of flavors.

Breastfeeding seems to facilitate increased acceptance of different foods as a result of the greater variation in breast milk flavors compared with infant formula.

Other causes of food refusal include dislike of the taste or smell and an unfamiliar appearance. Often, a child's food preference reflects those of other family members. Early food experiences can be imprinted on the memory, and when children refuse to eat vegetables at an early age, these food preferences may remain throughout the childhood and adolescent years with significant health consequences. Child-feeding practices contribute to the development of food intake controls and energy balance and can affect childhood obesity. Obese individuals tend to prefer fatty foods to fruits and vegetables and dislike tough or fibrous texture. Exposure to fruits and vegetables in infancy and early childhood should be encouraged to reduce risk factors for obesity and obesity-related diseases.

Caregiver Behaviors

Although early childhood malnutrition can be attributable to poverty and lack of resources, family and caregiver characteristics, such as education and household management or coping skills of the mother, can determine normal growth and development. Lack of knowledge regarding appropriate foods and feeding practices can contribute to malnutrition to a greater degree than lack of food. Not only is providing the appropriate combination of complementary foods to meet the child's nutritional needs important, feeding practices such as frequency of feeds and feeding style need to be considered. Caregiving behaviors that have been identified as promoting normal growth and development are (1) active or interactive feeding, (2) selecting foods appropriate to the child's motor skills and taste preferences, (3) feeding in response to the child's hunger cues, (4) feeding in a nondistracting safe environment, and (5) talking and playing with the child in the context of the meal. This type of responsive parenting has been described as sensitive and supportive caregiving associated with good growth and development. Feeding interactions should include the caregiver observing the infant's intake and nonverbal cues and responding accordingly (Pelto, 2000). If children refuse many foods, parents should be encouraged to be creative and experiment with different food combinations, tastes, and textures. Parents should be taught to encourage children to eat, but never to force because this can lead to aversion to food and behavioral problems.

Effect of Feeding Mode in Infancy

In early infancy, parents choose whether the child will be breastfed or bottle-fed and whether human milk or formula will be consumed. They may also control the timing of the feedings and the volume consumed, although this is less likely when the infant is breastfed. When a mother breastfeeds and her infant's sucking slows or stops, the mother assumes the child is satisfied and is finished eating. The amount of milk consumed is primarily under the infant's control. Breastfed infants are able to adjust the amount of milk consumed to maintain a constant energy intake. Formula-feeding mothers may rely on visual cues of formula remaining in the bottle and encourage the infant to continue feeding after he or she has exhibited signs of satiety.

Taveras and associates (2004) found that the longer a mother breastfed, the less likely she was to restrict her child's intake at 1 year. Compared with mothers who formula fed, mothers who exclusively breastfed for 6 months were less likely to restrict their child's intake. Breastfeeding for at least 12 months was associated with lower levels of controlling feedings and resulted in improved intake by toddlers (Orlet Fisher, Birch, Smiciklas-Wright, & Picciano, 2000). Breastfeeding may protect against obesity by allowing the infant to naturally regulate energy intake based on hunger cues and by preventing parents from overriding these cues by controlling the feeding. Mothers who breastfeed may be more responsive to their infants' signals regarding the timing and volume of feedings. Not only does the mode of feeding influence weight gain patterns in the first year of life but also the type of milk. Infants who are fed human milk by bottle gain more weight per month compared to infants fed at the breast, indicating that mode of milk delivery may influence later development of obesity. Compared to infants receiving human milk by bottle, infants receiving nonhuman milk by bottle had higher rates of weight gain (Li, Magadia, Fein, & Grummer-Strawn, 2012).

Feeding Relationship

As the child transitions to a variety of family foods, the need to be independent and autonomous becomes evident in the feeding relationship

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as the child assumes more control of his or her eating. The feeding relationship reflects the overall parent–child relationship, and feeding struggles may be indicative of other difficulties involving parent–child interactions. Feeding is a major area of frequent daily exchanges between the parent and the child, reflecting the characteristics of both the parent and the child that can either support or hinder the child's development. Feeding involves more than providing the correct mix of calories and vitamins to ensure adequate nutrition. The feeding relationship itself is crucial for the child's growth and development (Slaughter & Bryant, 2004). Feeding is a blend of nutrition, parenting, and human development and provides an opportunity for parents to be present and to provide love, support, and attention that can affect the child's physical, social, and emotional health.

As infants progress from a milk-based diet to sharing family foods, they develop unique likes and dislikes regarding the foods they are offered and communicate these preferences to their parents. How the parents respond to this assertiveness can affect the child's developing sense of self and autonomy. The ability to refuse food and have this be accepted by the parents is paramount to future interactions between the child and the parents and provides a base for all future social interactions. It is important for the child's development to be able to say "no" and still be unconditionally loved and supported. If the parent withholds love from the child or forces or pressures the child to eat, the child feels helpless and abandoned. Furthermore, the child learns that he or she does not have the ability to say "no" and be respected, which can have far-reaching effects. By allowing a child to refuse to eat a certain food or to not eat at all because he or she is not hungry, parents are giving the child permission to express his or her needs without fear of repercussions.

High levels of maternal control over when and what children eat are associated with increased adiposity and an increased desire to consume restricted foods. Maternal restrictive feeding practices have been found to increase the child's preference for the restricted food and to promote overeating when the restricted foods are available and are counterproductive in preventing obesity (Birch, Orlet Fisher, & Krahnstoever Davison, 2003). In place of restricting desirable foods, parents should be taught skills that help children learn how to consume appropriate portion sizes, to like healthy foods, and to recognize hunger and satiety cues to determine when and how much to eat.

Portion Size

Children demonstrate an innate ability for self-regulation of energy intake. They can compensate for changes in energy density by adjusting the quantity of food they consume. Parents and caregivers potentially interfere with this natural hunger-driven mechanism by coercing children to eat when they are not hungry or by directing them to "finish their plate" or to "take one more bite" when they have demonstrated signs of satiety. Overrestriction of intake to prevent overeating in infants and toddlers can have negative consequences by preventing the natural development of feeding self-regulation. **Table 2.4** indicates food types and corresponding development infants usually demonstrate; some variances should be expected.

The presence of self-regulation of dietary intake in infants and toddlers was confirmed by analysis of the relationship among portion size, number of eating occasions, number of unique foods, and energy density (Fox, Devaney, Reidy, Razafindrakoto, & Ziegler, 2006). Children who ate less often during the day consumed larger portions, and children who ate more often ate smaller portions. For infants, energy density was negatively associated with portion size. As the energy density increased, portion size decreased, and as energy density decreased, portion size increased. The number of different foods consumed by 6- to 11-month-olds was also positively associated with portion size, indicating that infants with a more varied diet consume larger portions.

Children younger than 2 years of age typically eat seven times a day, although the number of meals and snacks reported ranges from 3 to 15. It is appropriate for infants and toddlers to consume many small meals and snacks because of their small stomachs and high energy demands. Snacks often provide about 25% of a toddler's energy intake (Skinner, Ziegler, Pac & Devaney, 2004). The breakfast, lunch, dinner, and snacks pattern emerges at ages 7 to 8 months and is well established by 9 to 11 months.

TABLE 2.4 Infant Feeding by Age and Development

Age	Development	What to Feed
Birth to 6 months	• Baby can suck and swallow. • Baby should be held for feeding.	• Breast milk is best. • Use formula if not breastfeeding. • No water or juice.
6–8 months	• Baby can sit with support and control head movement. • Spoon-feeding begins. • No honey entire first year.	• Breastfed infants: begin pureed meats first and then eggs, pureed fruits and vegetables, and infant cereal. • Formula-fed infants: begin infant cereals and then pureed fruits, vegetables, and meats and eggs. • Wait 3–5 days between new foods. • Watch for signs of food allergies such as rash, vomiting, or diarrhea.
7–9 months	• Baby can chew, grasp, and hold items. • Finger feeding begins. • Introduce a cup with water, juice, breast milk, or formula.	• Try well-cooked carrots, sliced bananas, unsweetened dry cereals, graham crackers, soft cheeses, pancake bits, and well-cooked pasta.
9–12 months	• Baby can eat with a spoon and will feed self more often. • Expect baby to eat with hands and make a mess.	• Offer new tastes and textures such as plain yogurt, cottage cheese, tofu, and refried beans. • Offer soft foods from the family meal. • Limit juice to 4 oz/day. • Offer fewer pureed foods and more foods from the family meal. • Always try to eat together as a family. • Parents should set a good example by eating fruits and vegetables. • Avoid dangerous foods that are a choking hazard: raw vegetables, nuts, seeds, whole grapes or cherry tomatoes, hot dogs, popcorn, and spoonfuls of peanut butter.
1 year and beyond	• Encourage self-feeding. • Continue breastfeeding. • Wean from bottle. • Begin offering whole cow's milk in cup. No low-fat or skim milk until 2 years of age.	• Infant should eat three meals and two to three snacks each day. • Feeding should be a happy time for the entire family. • Let infant decide when enough is enough. • Never force infant to eat or drink. • No sweetened drinks or soda. • Avoid sweets. Offer fruit for dessert.

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Special Supplemental Nutrition Program for Women, Infants, and Children

Pregnancy, infancy, and early childhood are critical periods of rapid growth and development. Nutritional insult during this time can have far-reaching consequences on cognitive and emotional health and can adversely affect health outcomes. The U.S. Department of Agriculture's Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is the largest governmental nutrition program and is designed to assist low-income, nutritionally at-risk, pregnant, breastfeeding and non-breastfeeding postpartum women and infants and children up to 5 years of age. Millions of families have benefited from the WIC program, and it has successfully improved the nutrient intakes of its participants, particularly by reducing the prevalence of iron-deficiency anemia and improving physical, emotional, and cognitive development. Federal regulations specify that state agencies must encourage and support breastfeeding through specific activities such as nutritional education and peer-counseling programs. Peer counseling has been shown to increase WIC participation, increase breastfeeding initiation and duration, and reduce supplementation (Bronner, Barber, & Miele, 2001; Bronner, Barber, Vogelhut, & Kovar Resnick, 2001).

Nearly half of all mothers of infants born in the United States each year are enrolled in WIC (Jensen & Labbok, 2011). Participants are eligible to receive vouchers for supplemental food packages to meet their nutritional needs. All mothers have the option to receive infant formula, and as a result approximately 54% of all infant formula sold in the United States is for WIC participants. Enhanced food packages for breastfeeding mothers were created in 2009 based on recommendations from the Institute of Medicine to encourage more women to breastfeed. Yet, the retail and perceived market value of the formula packages exceed the value of the breastfeeding package and may limit the impact of the food packages.

Although women participating in the WIC program have lower rates of breastfeeding initiation, duration, and exclusivity than do women of similar socioeconomic backgrounds who are eligible for but do not participate in WIC (68% vs. 78% initiation, 34% vs. 48% at 6 months, and 18% vs. 31% at 1 year), breastfeeding rates have increased for WIC participants (see the 2013 Breastfeeding Report Card at www.cdc.gov/breastfeeding/pdf/2013BreastfeedingReportCard.pdf) From 2000 to 2007, rates for any breastfeeding for WIC participants increased from 62% to 68%, although 6-month, 1-year, and exclusive breastfeeding rates did not increase. WIC programs throughout the United States are an important resource for providing much needed lactation education and support for breastfeeding families.

EFFECT OF EARLY DIET ON HEALTH OUTCOMES

It is well known that a relationship exists between many chronic diseases and nutrition. It has been postulated that the diet during infancy and early childhood can impact the progression of chronic diseases that develop later in life, such as cancer, obesity, diabetes, hypertension, allergy, and osteoporosis. Premature weaning, or not breastfeeding, is associated with health risks. Both short-term and long-term health outcomes have been described. The degree to which these health outcomes are realized depends on the duration, frequency and exclusivity of breastfeeding. The Agency for Healthcare Research and Quality (AHRQ) screened over 9,000 abstracts from studies conducted in developed countries across the world. They reviewed 43 primary studies on infant health outcomes and 29 systematic reviews or meta-analyses that covered 400 individual studies. They concluded that there was substantial evidence that there is significant risk to health outcomes when human milk is not provided.

Obesity

Increasing trends in childhood obesity, with its associated comorbidities and the likelihood of persistence of obesity into adulthood, compelled researchers to investigate preventive strategies. Approximately 10–20% of infants and toddlers in the United States are overweight, and nearly 10% of infants and toddlers from birth to 2 years are obese (Dattilo et al., 2012). Treatment of childhood obesity is costly and rarely effective. Interventions to adjust caloric intake or increase energy expenditure after infancy have little impact on children's weight or adiposity. Childhood obesity is associated not only with adult obesity but also with adverse health outcomes in adulthood independent of weight status. The AAP Section on Breastfeeding (2012) suggests that any campaign to reduce obesity should begin with breastfeeding support. One of the critical periods of attainment of excess weight is in infancy. Indeed, the more rapid and earlier an infant gains excess weight, the more likely he or she is to have undesirable weight later in life. Preventing early excess weight gain through parental feeding practices begins at birth.

A study by Stettler and associates (2005) found that in formula-fed infants, weight gain in the first week of life may be a critical determinant for the development of obesity in later life. Formula feeding is associated with a more rapid increase in weight gain in early infancy and an increased risk for obesity in childhood and adolescence.

An earlier multicenter cohort study by Stettler, Zemel, Kumanyika, and Stallings (2002) demonstrated that a pattern of rapid weight gain during the first 4 months of life was associated with an increased risk of overweight status at 7 years, independent of birth weight and weight at 1 year. For each 100 g of weight gain increase per month, the risk of overweight status at 7 years was increased by 30%. There was a clear association between the rate of early weight gain and childhood overweight status. The greatest proportional weight gain in postnatal life occurs during the time when birth weight is doubled by 4 to 6 months, and this may correspond with a critical period for energy balance regulation mechanisms.

Harder, Bergmann, Kallischnigg, and Plagemann (2005) performed a comprehensive meta-analysis of 17 studies on duration of breastfeeding and risk of overweight in later life. They found that the duration of breastfeeding is inversely and linearly associated with the risk of overweight. The risk of obesity is reduced by 4% for each month of breastfeeding. The dose–response effect continued to decrease the risk of obesity with longer breastfeeding duration. Compared to less than 1 month of breastfeeding, breastfeeding for 9 months showed a 30% risk reduction.

Martorell, Stein, and Schroeder (2001) reviewed and critiqued the literature to determine whether nutrition in early life predisposes individuals to be overweight later in life. They looked at three plausible hypotheses: (1) overnutrition increases the risk of later excess weight; (2) undernutrition, at the other extreme, also is a risk for excess weight; and (3) optimal nutrition during infancy represented by breastfeeding is protective of future obesity. They found the link between undernutrition in infancy and later obesity contradictory and inconsistent. Intrauterine overnutrition, high birth weight, and gestational diabetes were found to be associated with later obesity. Breastfeeding was found to have an enduring influence on the development of subsequent obesity.

Owen, Martin, Whincup, Davey Smith, and Cook (2005) published a quantitative review of the effects of infant feeding on the risk of obesity later in life. Initial breastfeeding protected against obesity later in life, and the association was stronger with prolonged breastfeeding. The consistency of the association they found with increasing age suggested a protective effect of early breastfeeding that was independent of dietary and physical activity patterns later in life. Confounding by maternal factors such as social class and obesity, both of which are associated with childhood obesity and a tendency to formula feed, was a limitation of the observational studies.

Hediger, Overpeck, Kuczmarski, and Ruan (2001) found a reduced risk of obesity for ever breastfed 3- to 5-year-olds compared with those never breastfed, but they found a much stronger association with maternal obesity. Scott, Ng, and Cobiac (2012) found in a study of 2,066 Australian children aged 9 to 16 years that compared to those never breastfed, children who were breastfed more than 6 months were less likely to be overweight (adjusted odds ratio 0.64) or obese (adjusted odds ratio 0.51) after adjusting for maternal characteristics and children's age, gender, mean energy intake, level of activity, screen time, and sleep duration. Von Kries and colleagues (1999) studied 9,357 German children at the time they entered school at ages 5 and 6 years. They found a remarkably consistent, protective, and dose-dependent effect of breastfeeding on excess weight and obesity. This cross-sectional study found that obesity was reduced by 35% when children were breastfed for 3 to 5 months. This protective effect was not attributable to social class or lifestyle factors and remained significant after adjusting for potential confounding factors. Gillman and colleagues (2001) found that adolescents who were mostly or only fed breast milk in the first 6 months of life were at a 22% lower risk of being overweight than were adolescents who were only formula fed. They found an estimated 8% reduction in the risk of adolescent obesity for every 3 months of breastfeeding. Compared to formula-fed infants, breastfed infants are less likely to receive complementary foods before 4 months and are less frequently offered high-fat or high-sugar-containing foods at 1 year. Early introduction of complementary foods is positively associated with rate of weight gain in infants, toddlers, and children (Dattilo et al., 2012). Among infants who were never breastfed or who stopped breastfeeding before 4 months, the introduction of complementary foods before 4 months was associated with a sixfold increase in the odds of obesity at 3 years (Huh, Rifas-Shiman, Taveras, Oken, & Gillman, 2011).

Bergmann and coworkers (2003) found that maternal obesity, bottle-feeding, maternal smoking during pregnancy, and low socioeconomic status were risk factors for becoming overweight and having high adiposity at age 6 years in a longitudinal study of German children from birth. At age 3 months, body mass index and triceps skin-fold thickness were already significantly higher in the children who were formula fed. Children who were formula fed continued to have a higher prevalence of excess weight and obesity, and the findings remained stable after adjusting for maternal weight, maternal smoking, and socioeconomic status. Gale and associates (2012) conducted a systematic review and meta-analysis to compare infant body composition in breastfed and formula-fed infants and found altered body composition in formula-fed infants. Fat-free mass was higher at 3 to 4 months, at 8 to 9 months, and at 12 months, and fat mass was lower at 3 to 4 months and at 6 months compared to breastfed infants. At 12 months, the trend was reversed and fat mass was higher in formula-fed infants. This switch from higher adiposity in breastfed infants at 3–4 months to higher adiposity in formula-fed infants at 12 months may reflect the effects of early metabolic programming, appetite regulation, and abnormal adipose tissue development in formula-fed infants.

Questions regarding the optimal duration of exclusive breastfeeding or whether combining breastfeeding with formula supplementation may weaken the preventive influence of breastfeeding need to be addressed. Gillman and colleagues (2001) found that infants who received more breast milk than formula in the first 6 months of life had a lower risk of obesity in older childhood and adolescence than did children who received mostly or only formula. In a retrospective cohort study, Bogen, Hanusa, and Whitaker (2004) found that in a population of low-income families breastfeeding was associated with a reduced risk of obesity at age 4 years only among white children whose mothers did not smoke in pregnancy and only when breastfeeding continued for at least 16 weeks without formula or at least 26 weeks with formula.

Several explanations are offered for the protective effect of breastfeeding against obesity. Breast milk production is stimulated by the infant's sucking, and it is unlikely that rapid weight gain in an exclusively breastfed infant is a result of overfeeding. A breastfed infant establishes a point of satiety based on internal physiologic cues rather than on external social cues. Children can naturally regulate their energy intake, but parents' behavior can override the child's appetite signals. It is possible that during bottle feeding parents exhibit more control of the feeding and prevent self-regulation by the child. Parents who do not recognize the child's hunger and satiety cues may contribute to the risk of later obesity. Overfeeding in infancy may increase adipose number and fat content at a critical time period and prevent development of lifelong patterns of healthy appetite regulation that would protect against the risk of obesity.

Metabolic consequences of ingesting human milk may help regulate appetite and food consumption. Leptin, a hormone that regulates food intake and energy metabolism, is present in human milk. In a study by Savino, Costamagna, Prino, Oggero, and Silvestro (2002), serum leptin levels were higher in breastfed infants than in formula-fed infants. High levels of appetite-regulating hormones and growth factors (leptin, insulin, and glucose) and inflammatory factors (interleukin 6 and tumor necrosis factor alpha) found in human milk may be bioactive and influence the accrual of fat and lean body mass in breastfed infants (Fields & Demerath, 2012). The effects of human milk components on appetite regulation may be diminished when the milk is expressed and fed in a bottle. Compared to feeding directly at the breast, expressed human milk in a bottle is associated with increased intake, poorer self-regulation, and greater weight gain. The more bottles the infant receives, the greater the weight gain (Li et al., 2012).

Breastfeeding may help to program the infant against later energy imbalance (Gillman et al., 2001). Owen and associates (2005) suggested that breastfeeding affects intake of calories and protein, insulin secretion, and modulation of fat deposition and adipocyte development. A higher protein to nitrogen content of infant formula might induce a metabolic response of increased insulin production in formula-fed infants, leading to excessive weight gain. Protective mechanisms of breastfeeding are difficult to identify because many of the same factors associated with obesity, such as race, ethnicity, maternal education, social status, and maternal obesity, are also associated with the initiation and duration of breastfeeding or the decision to formula feed. The effects of breastfeeding on the later development of obesity can be sustained and persist into adulthood either through learned behavior or perhaps through a more complex programming mechanism.

Allergies

Most food allergies are acquired in the first year or two of life. Sensitization often occurs with the first exposure to an antigen. Data suggest that there has been a rise in the prevalence of food allergies during the past 10–20 years (Burks et al., 2011).

The prevalence of food allergy in children 0–2 years of age is 6.3%. Milk allergies are the most commonly reported, followed by peanut and egg. Less common allergies are reported for shellfish, fish, tree nuts, strawberries, wheat, and soy (Gupta et al., 2011). Symptoms manifest as urticaria, angioedema, anaphylaxis, atopic dermatitis, respiratory symptoms, or gastrointestinal disorders. Children with food allergies are more likely to have related conditions such as asthma, atopic dermatitis, and respiratory allergies compared to children without food allergies. Severe reactions occur in 39% of allergic children and are more common in children with tree nut, peanut, shellfish, fish, and soy allergies. The odds of a severe reaction increases with age, and there is a twofold increase in risk of severe reaction in adolescents compared to children ages 0–2 years.

Food allergies can be classified as (1) IgE mediated, with symptoms such as angioedema, urticaria, wheezing, rhinitis, vomiting, eczema, and anaphylaxis reactions; (2) mixed gastrointestinal syndromes involving both IgE- and T-cell-mediated components, such as eosinophilic esophagitis; or (3) non-IgE-mediated allergies, such as protein-induced enterocolitis. Public health strategies for primary prevention of food allergies are necessary, but results of studies to determine the etiology of food allergies are conflicting. Breastfeeding is presumed to be protective, but study results vary and the size of the effect is controversial. Ingesting small quantities of allergens via breast milk in the presence of anti-inflammatory cytokines may actually offer protection against subsequent development of food allergy later in life.

Recent recommendations to avoid common allergens in infancy to prevent the development of food allergies has come under scrutiny by researchers and public health policy makers. Early, rather than late, exposure to food allergens may promote tolerance during this "critical early window" of development. A Cochrane review concluded that exclusive breastfeeding for 6 months compared to 3 to 4 months with partial breastfeeding to 6 months reduced morbidity from gastrointestinal disease but did not further reduce the risk of allergic disease (Kramer & Kakuma, 2012). Although the WHO recommends 6 months of exclusive breastfeeding for optimal health outcomes, there is an emerging body of evidence that introduction of complementary foods from 4–6 months may reduce the risk of development of food allergies. Delaying introduction of common food allergens may hinder the development of normal discrimination, reduce oral tolerance, and result in inappropriate allergic responses (Bammann, 2012; Kneepkens & Brand, 2010; Prescott et al., 2008). The KOALA (Kind, Ouders en gezondheid: Aandacht voor Leefstijl en Aanleg) Birth Cohort Study of 2,558 infants in the Netherlands found that a delay in the introduction of cow's milk products was associated with a higher risk for eczema and that delayed introduction of other foods was associated with a greater risk of atopy at 2 years (Snijders, Thijs, van Ree, & van den Brandt, 2008).

Postponement of strongly allergenic foods, such as peanuts and eggs, into the second and third of year of life not only does not prevent allergies but is suspected to actually increase the prevalence of food allergies. DuToit and coworkers (2008) found that Israeli schoolchildren typically consume 7 g peanut protein per day from 8–14 months and have a prevalence of 0.17% peanut allergy compared to children in the United Kingdom, who consume no peanut protein at this age and have a prevalence of 1.85% peanut allergy. Koplin and colleagues (2010) found that among 12-month-old infants with confirmed egg allergies, those introduced to egg at 10–12 months had an increased risk of OR 1.6 and those introduced after 12 months had an even greater risk of OR 3.5 compared to those introduced to egg between 4 and 6 months. Breastfeeding until 6 months of age with the introduction of complementary foods between 4 and 6 months has been suggested as a strategy for allergy prevention (Burks et al., 2011; Greer, Sicherer, Burks, American Academy of Pediatrics Committee on Nutrition, & American Academy of Pediatrics Section on Allergy and Immunology, 2008). Restricting maternal diet during pregnancy or lactation is not recommended to prevent allergies (Burks et al., 2011; Greer et al., 2008).

Early introduction of foreign proteins, including cow's milk, wheat, soy, rice, eggs, fish, and chicken, could induce a T-cell-mediated immune reaction of the intestinal mucosa associated with inflammation, villous atrophy, diarrhea, and failure to thrive (Schmitz, 2000). The earlier these foods are introduced to the infant, the greater the risk of developing enteropathy. These enteropathies are linked to the immaturity of the gut's immune system, leading to sensitization rather than to tolerance when exposed to foreign proteins. It is unknown precisely when the gut has matured sufficiently to accept foreign protein, although it is unlikely to occur in the first few months of life. Infants with dietary-induced proctocolitis, a non-IgE-mediated allergy, appear healthy but have visible specks or streaks of blood in their stool. Blood loss is minimal, and anemia is rare. This type of allergy is not usually associated with vomiting, diarrhea, or growth failure and often is caused by sensitivity to cow's milk or soy protein, often through the maternal diet while breastfeeding (Sicherer, 2003). Breastfed infants who develop allergic proctocolitis should not be limited in their exposure to other major food allergens. Infants and their breastfeeding mothers should only avoid the foods that have been identified through a maternal elimination diet as triggering symptoms (Academy of Breastfeeding Medicine, 2011).

Atopic dermatitis is a chronic skin condition often seen in young children and is often the first sign of allergic sensitization in infants. The pathophysiology remains unclear, but it is increased in families with a history of atopic disorders, suggesting a genetic component. In infancy, atopic dermatitis is closely related to both IgE- and non-IgE-mediated food hypersensitivities that occur in formula-fed and breastfed infants. Intact food allergens, particularly from cow's milk, eggs, and peanuts, may be secreted in small quantities by the mammary gland epithelium, causing a reaction with the mucosal immune system in the infant's intestinal lumen (Heine, Hill, & Hosking, 2004).

Use of soy or hypoallergenic infant formula as primary prevention of milk allergy is controversial. The actual prevalence of milk protein allergy in infancy is only 2–3%. Because of the increased costs of using a hypoallergenic formula, their use should be limited to infants with well-defined clinical symptoms. Infants with cow's milk allergies should not be fed milk from goats, sheep, or other animals because of the likelihood of allergic reaction to other mammalian milk. Soy milk is often used as a substitute for cow's milk infant formula and may be well tolerated. Soy formula feeding is not recommended for primary prevention of allergies in high-risk infants (Greer et al., 2008). Infants with IgE-mediated cow's milk allergies may have better tolerance to soy than do infants with non-IgE-mediated symptoms. Eight percent to 14% of infants with IgE-mediated cow's milk allergies have adverse reactions to soy, although anaphylaxis is rare. A higher prevalence of concomitant reactions (25–60%) is seen when soy is fed to infants with non-IgE-mediated cow's milk allergies; therefore, soy is not recommended as a substitute for infants with proctocolitis and enterocolitis reactions. For these children, an extensively hydrolyzed protein formula or a free amino-acid-based infant formula should be used. Benefits should be seen within 2 to 4 weeks, and the formula should be continued until the infant is at least 1 year of age. There is no evidence that there are increased benefits to partially or extensively hydrolyzed infant formula compared to exclusive breastfeeding in the prevention of atopic disease (Greer et al., 2008).

A family history of allergy, defined as both parents or one parent and one sibling with **allergic disease**, is the strongest predictor of allergic disease in children. In high-risk infants, up to 6% of exclusively breastfed infants developed food-specific IgE allergies with symptoms occurring with the first reported direct food exposure. However, in the general population food allergy in exclusively breastfed infants ranges from 0.04% to 0.5% (Zeiger, 2003).

allergic disease
Sensitization to allergens manifested as urticaria, angioedema, anaphylaxis, atopic dermatitis, respiratory symptoms, or gastrointestinal disorder.

Formula feeding and early exposure to potential food allergens are risk factors for atopic disease. Studies suggest that combined maternal avoidance of food allergens while breastfeeding and infant avoidance of allergens for at least the first 6 months may reduce eczema and food allergy in early childhood (Zeiger, 2003). Data supporting a protective effect on respiratory allergy and asthma in later childhood are less compelling. Exclusive, rather than partial, breastfeeding for at least 4 months appears to have a significant impact on the occurrence of atopic dermatitis, allergic rhinitis, and respiratory symptoms (Kill, Wickman, Lilja, Nordvall, & Pershagen, 2002). High-risk infants should be breastfed throughout the first year of life or longer or, alternately, fed with a hypoallergenic formula. Breast milk contains immunomodulating properties to regulate the immune system and also contains milk-specific IgA to bind cow's milk allergens and prevent allergies.

Food antigens have been detected in the milk of mothers after consumption of allergenic foods such as cow's milk, eggs, wheat, and peanuts, and the concentrations are sufficient to trigger reactions in allergic children (Zeiger, 2003). Concentrations of antigens in human milk depend on the amount consumed by the mother and appear in human milk 1 to 6 hours after ingestion. Peanut protein may be quickly cleared from the milk within 3 hours after ingestion. Secretion of antigens into human milk is variable. In a study by Vadas, Wai, Burks, and Perelman (2001), only 48% of lactating women secreted peanut protein in their milk after ingestion of peanuts. Similarly, approximately two-thirds of women secrete cow's milk and egg protein into their milk after ingestion.

Characteristics of women who secrete food antigens into their milk have not been accounted for, making it difficult to determine preventive strategies. One study from Finland found that a maternal diet high in saturated fat and low in vitamin C while breastfeeding was associated with an increased risk of atopic sensitization in the infant (Joppu, Kalliomaki, & Isolauri, 2000). Allergic disease has also been linked to a maternal diet with a high ratio of omega-6 to omega-3 fatty acids, typical of Western diets containing processed and fried foods (Koletzko, 2000). Fish oil supplementation to provide omega-3 fatty acids during pregnancy and to infants older than 6 months has been shown to reduce the severity of atopic disease (Upham & Holt, 2005).

Gut microflora may play a role in immunomodulation in infants, reducing the risk of early atopic disease. Probiotics have successfully been used to reduce atopic eczema in high-risk children by having mothers take *Lactobacillus* GG (GG refers to a healthy strain) 2 to 4 weeks before delivery and 6 months postnatally while breastfeeding (Kalliomaki et al., 2001). However, a Cochrane review found insufficient evidence to recommend probiotics for prevention of allergic disease or food hypersensitivity because study results were inconsistent (Osborn & Sinn, 2007). The hygiene hypothesis continues to be a plausible explanation for the increased prevalence of allergic disease in children. Reduced exposure to microbial stimuli in early life may result in insufficient stimulation of regulatory T cells and an inappropriate allergic response when exposed to food allergens.

There is no way to predict when a child will outgrow a food allergy, but 75% to 90% of milk-allergic children can tolerate cow's milk by 4 years of age. Some infants lose their milk allergy in as little as a few months, whereas others may remain symptomatic for as long as 8 to 10 years (Wood, 2003). Many also become tolerant to egg, soy, and wheat, although fish, tree nut, and peanut allergies may persist throughout the lifetime (Nowak-Wegrzyn, 2003). Other foods that may cause allergic reactions in infants and young children include berries, tomatoes, citrus, and apples. Children with non-IgE-mediated cow's milk allergy often outgrow their allergies by 5 years of age without the development of additional allergic complications. Children with IgE-mediated allergies often have persistent allergic symptoms at 8 years of age. They also more frequently have asthma, rhinoconjunctivitis, atopic eczema, and sensitization to other allergens and are at increased risk for sensitization to inhalant allergens (Saarinen, Pelkonen, Makela, & Savilahti, 2005).

Diabetes and Celiac Disease

The type of feedings in infancy may influence the development of type 1 diabetes. A systematic review of the literature showed that a short duration and/or lack of breastfeeding along with early introduction of cow's milk and formula increases the risk of developing type 1 diabetes (Patelarou et al., 2012). A case-control study of siblings with and without type 1 diabetes showed that the siblings with type 1 diabetes had a shorter duration of breastfeeding (3.3 vs. 4.6 months) and were introduced earlier to cow's milk (Alves, Figueiroa, Meneses, & Alves, 2012).

Two studies by Norris and coworkers (Norris, Barriga, Hoffenber et al., 2005; Norris, Barriga, Klingensmith et al., 2005) looked at the association between the development of type 1 diabetes and celiac disease and early introduction of gluten-containing foods. The Diabetes Autoimmunity Study in the Young is a prospective study of triggers for diabetes and celiac disease in genetically predisposed children with a parent or sibling with type 1 diabetes or celiac disease. The timing of introduction of gluten-containing cereals was found to be associated with the risk of developing diabetes or celiac disease in children at increased risk for the disease. Children initially exposed to wheat, barley, or rye between birth and 3 months or later than 7 months were at increased risk of developing diabetes and celiac disease than were children first exposed to cereal between 4 and 6 months.

In Sweden, where the prevalence of celiac disease is 1–2% of Swedish children, introducing gluten-containing foods at 4 to 6 months is recommended during the time of exclusive breastfeeding. Enacted in 1996, this policy was a change from previous recommendations to introduce gluten after 6 months. New evidence showed that the risk of childhood celiac disease could be reduced with concurrent breastfeeding during the time that gluten is introduced into the infant's diet.

Recommendations to avoid introduction of gluten before 4 months and after 7 months and that gluten be introduced into the diet while the infant is being breastfed are based on multiple studies on the development of celiac disease (Henriksson, Boström, & Wiklund, 2012; Shamir, 2012; Szajewska et al., 2012). A study in Belgrade of infants with celiac disease found that longer breastfeeding and breastfeeding at the time of gluten introduction significantly delayed the onset of celiac disease (Radlovic, Mladenovic, Lekovic, Stojsic, & Radlovic, 2010). The study did not find that early introduction before 4 months resulted in earlier onset of the disease compared to those introduced at 4 to 6 months, but that introduction after 6 months significantly delayed onset of the disease from 12–15 months to 22 months. Because the group of infants receiving gluten after 6 months also had longer duration of breastfeeding, it is unclear whether the timing of gluten introduction was solely responsible for the delayed onset of the disease.

The mechanisms for breastfeeding inducing tolerance to gluten include the presence of gliaden in human milk; the reduction in acute gastroenteritis in breastfed infants; differences in gut flora; and reduced intestinal permeability in breastfed infants. Despite public health programs to inform families of the recommendations, a survey in 2004 showed that only 45% were compliant with the recommendation to introduce gluten earlier than 6 months while breastfeeding. As many as 45% continued to avoid gluten until after 6 months and another 10% introduced gluten without breastfeeding (van Odijk, Hulthen, Ahlstedt, & Borres, 2004).

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Case Study 1

Vitamin D Deficiency in Early Infancy

Emily Burritt, MS, RD, CNSC

David, an 8-week-old Hispanic male, was admitted to the pediatric intensive care unit with seizures and respiratory distress. His birth weight was 2.98 kg (6 lbs 9 oz), and his admission weight was 4.6 kg. It appeared his weight was tracking the 5th–10th percentile for age using the World Health Organization growth chart. Mom did not remember what David's length was at birth, and there was not a length measured on admission. David was breastfed for 20–30 minutes (10–15 minutes each breast) every 2–3 hours prior to admission. He was not taking any other vitamin supplements or medications. Mom reported she had a good appetite and food intake during pregnancy. She took the standard prenatal vitamin (400 IU vitamin D_3) as prescribed during pregnancy but had stopped after the baby was born.

Initial laboratory results revealed a normal sodium level, a calcium level of 7.5 mg/dL (low), and a phosphorus level of 5.5 mg/dL (normal). Vitamin D deficiency was suspected and 25-hydroxyvitamin D level was obtained, which was consistent with deficiency at 13 ng/mL. The registered dietitian (RD) recommended starting vitamin D_3 1,000–2,000 IU/day orally. However, liquid vitamin D_2 was started, 8,000 IU/day orally.

A repeat 25-hydroxyvitamin D level 2 weeks later was 158 ng/mL (toxicity), and the vitamin D_2 supplement was held. Another 2 weeks passed, and the repeat 25-hydroxyvitamin D level had normalized. A maintenance dose of vitamin D_3 400 IU/day orally was prescribed.

The RD assessed the following factors:

1. Infant's growth pattern
2. Infant's diet history
3. Maternal diet history
4. Vitamin D levels and dosing of supplement

Questions

1. What is a major cause of vitamin D deficiency? What foods are good sources of vitamin D?
2. Was David's intake of vitamin D adequate prior to supplementation?
3. What other factors placed David at risk for vitamin D deficiency?
4. What is the difference between vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol)?
5. What caused David's vitamin D level to become toxic?

Case Study 2

Normal Infant Nutrition

Rachelle Lessen, MS, RD, IBCLC

Caleb was born by standard vaginal delivery to a healthy 30-year-old mother. Caleb's mother decided while she was pregnant to exclusively breastfeed him for the first 6 months of his life because she was familiar with the advantages associated with exclusive breastfeeding, such as reduction of illness and allergies, enhanced intelligence, convenience of feedings, and cost savings. Caleb weighed 7 pounds at birth (25% percentile) and gained weight appropriately for the first 6 months of life. At his 6-month checkup he weighed 18 pounds and was at the 50% to 75% percentile for weight.

Caleb's mother chose to introduce puréed foods she prepared herself when Caleb was 6 months old. At this time, he exhibited an interest in what his parents were eating and had developed good head and neck control. She prepared sweet potatoes, carrots, squash, and peas and puréed them in a food processor until they were a smooth consistency. She froze them in single serving portions in an ice cube tray. She introduced one food at a time and waited 3 to 5 days between foods while observing Caleb for signs of food allergy. Gradually, she added more foods to his diet, including chicken, turkey, beef, cereal, pears, peaches, and bananas. When Caleb was 7 months old he was offered a sippy cup with water at meals.

Caleb was developing fine motor control and was able to grasp foods and attempt self-feeding. His mother offered him small pieces of toast, Cheerios, cut-up fresh melon, soft-cooked carrots, French toast, and pieces of cheese and turkey. He also began to eat cottage cheese and yogurt and a greater variety of foods from the family meal. Caleb continued to breastfeed, but the number of feedings per day began to decrease as he increased his intake of complementary foods. Caleb was breastfed without any supplemental formula until he was 13 months old, when he was offered whole cow's milk by cup. By 1 year of age he had gradually transitioned from an all-milk diet in the first 6 months to a mixed diet of breast milk and puréed foods and finally to a diet of family foods including a variety of fruits and vegetables, grains, meats, and dairy.

Question

1. What did Caleb's mother do correctly?

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Case Study 3

Infant Nutrition

Rachelle Lessen, MS, RD, IBCLC

Emory is a 6-week-old former full-term infant. Her mother is 30 years old, healthy, does not smoke, and this is her first baby. Emory has been exclusively breastfeeding since birth. She latched well from the beginning, and mom denies any difficulties or problems with sore nipples. Her output includes 10–11 wet diapers and 2 stools per day. Her mother reports that she breastfeeds more than 12 times per day and that her feedings are very long, typically more than 1 hour. Mom's goal is to breastfeed her for more than 1 year.

Emory's birth weight was 3.487 kg (75th percentile on the WHO growth chart). Her discharge weight from the hospital was 2.98 kg (10% below birth weight). At 1 week, she weighed 3.345 kg, and at 2 weeks she weighed 3.289 kg. Now at 6 weeks she weighs 3.52 kg (<2nd percentile on the WHO growth chart). She has gained 33 g since birth. Her head circumference and length are within normal.

Questions

1. What is the primary nutrition concern?
2. What is the most likely cause of the problem?
3. How would you improve her nutritional status while taking into consideration the mother's breastfeeding goals?

Case Study 4

Failure to Thrive

Ancy Thomas, MS, RD, CSP, LDN

RS is 8 months and 3 weeks old. She is a full-term female with a history of gastroesophageal reflux, now presenting with suboptimal weight gain and poor feeding for 2–3 months. RS has been falling off her growth curve for weight, but length and head circumference growth velocities have been maintained. She had age-appropriate intake of a standard formula (Good Start Gentle) until 2–3 months ago. The patient's mother switched formula to a soy-based formula (Good Start Soy) because RS had emesis after each feeding; however, the emesis was ultimately attributed to a viral gastroenteritis rather than formula intolerance. At a visit for weight check, her primary pediatrician sent RS to the emergency department for concern about failure to thrive (FTT).

Anthropometrics/Growth Plotted on the WHO Growth Chart:

- Admission weight: 6.14 kg (< 2nd percentile)
- Length: 68 cm (25thpercentile). Standard length/age: 70 cm
- Ideal body weight (IBW): 7.8 kg
- Head circumference: 41.7 cm (5–10th percentile)
- Weight-for-length: Less than 2nd percentile
- Weight history: At 7 months was 6.2 kg (2–5th percentile)
- Diet history: Mom reports mixing 4 scoops of Gerber Good Start Soy powder in 4 oz of water with 2 tablespoons of rice cereal. RS drinks 1–2 oz six times daily.
- Pertinent medications: Cefuroxime, multivitamin 1 mL daily
- Significant labs: Unremarkable. Albumin normal
- Estimated nutritional needs: ≥100 kcal/kg/day; protein: 1.2 g/kg/day; fluids: 100 mL/kg/day

This patient's growth parameters reveal that she is at 79% of her IBW, indicative of moderate wasting per Waterlow Criteria and suggestive of acute malnutrition. She is 97% of the standard height-for-age, which is normal. RS has lost 60 g total from 7 months of age to present, as compared to the goal of gaining 10–13 g per day.

Based on the history, RS is admitted with nonorganic FTT because no other disease or disorder is identified as the cause of her FTT. Diet history reveals that her mother was incorrectly mixing the formula and adding excessive amounts of rice cereal, making it a 40 kcal/oz formula (standard concentration of infant formula is 20 kcal/oz). The patient's mother reported that rice cereal was added for reflux, as suggested by the patient's primary provider. However, no clear guidance was given on how much rice cereal was to be added. This resulted in a thick mixture of inappropriate caloric concentration. RS was taking in only 12 ounces of this mixed formula daily, which provided 480 calories (78 kcal/kg/day), 12 g of protein per day (2 g/kg/day), and 59 mL/kg/day of fluid (59% of her maintenance daily fluid requirement).

After performing an initial nutrition assessment, the dietitian suggested Gerber Good Start Soy at 24 kcal/oz with 1 tsp rice cereal per 1 oz of formula with a goal of minimum intake of 770 mL/day, which provided the following: 125 mL/kg/day, 693 calories per day (113 kcal/kg/day), and 17 g of protein per day (2.8 g/kg/day). The RDA for a 7- to 12-month-old child is 98 kcal/kg/day and 1.2 g of protein/kg/day. The nutritional plan was to make adjustments, as needed, to the nutrition prescription based on change in growth parameters.

Questions

1. Other than the information provided in this case study, what other questions would you ask Mom?
2. What other services do you believe should be consulted while the patient is admitted in the hospital?
3. What instructions would you give to the mom or the caregiver?

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Case Study 5

Failure to Thrive and Breastfeeding

Phuong Huynh, MS, RD, CSP

A 14-day-old term male infant presented to the pediatrician's office and was found to have significant weight loss. His weight was down by 7% and 15% during his first visit at day of life (DOL) 5 and during the second visit at DOL 14, respectively. He appeared lethargic, leading to further work-up that showed elevated serum sodium and dehydration. He was sent to the emergency department to receive intravenous fluid for rehydration and to be admitted for failure to thrive.

Birth history was uneventful; birth weight was 3,500 g. He was discharged home at 48 hours of life. He is the first child to his parents. He is exclusively breastfed. He feeds on demand about every 3–4 hours during the day and every 5–6 hours at night. He stays on the breast 5–10 minutes on each side. His mother felt milk came in on DOL 3, but breasts do not always feel full. Mom feels breastfeeding is going well, but she feels baby seems very sleepy. He stools 2–4 times daily and has 3–5 wet diapers, but they are not always heavy. Stool is seedy, yellowish green.

Questions

1. Is maternal milk supply adequate?
2. Is milk transfer effective?
3. Should breastfeeding be supplemented?

Issues to Debate

1. Discuss obstacles to breastfeeding that women encounter and possible public health strategies to overcome these challenges.
2. What are the effects of early feeding on the development of obesity and what can be done to reduce the increasing rates of childhood obesity?
3. Infant formula manufacturers add DHA and AA to their products. This has greatly raised the cost to consumers (including the U.S. government, which is the largest purchaser of formula because of the WIC program), yet studies fail to show long-term benefit of these additions. Discuss the ethical implications of this practice.
4. What are some of the cultural aspects that affect the transitioning from an all-milk infant diet to a diet of family foods?

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