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Nutrition and Lactation

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INTRODUCTION

Breastfeeding in the United States has continued to experience a pronounced resurgence since the early 1970s. Slightly more than 74% of all women who are hospitalized for birth breastfeed their infants. The duration of lactation also has increased,[1] although only about 15% of women in the United States continue exclusive breastfeeding through the infant's first 6 months, as recommended by the American Academy of Pediatrics.[2]

Mothers who breastfeed their infants have been characterized as being middle class, married, and white, and as having some college education and one or two children. Women in other situations also are breastfeeding their infants, so to assume that an unmarried nonwhite teenager is unlikely to breastfeed her child is unwise. Some of the greatest increases in breastfeeding initiation rates occur among nonwhites.[1] In one study, there was no difference in breastfeeding duration rates when low-income, often nonwhite, single women were provided information and support for breastfeeding during the prenatal and early postpartum periods.[3]

Factors that influence the decision to breastfeed and its duration are prenatal support and information,[4] support in the early postpartum period,[5] attitudes and management suggestions by health professionals,[6, 7] timing of any obstetric advice,[8] any previous infant feeding experience,[9] mode of delivery,[10] mother–infant separation in the early neonatal period,[11] and patterns of maternal employment soon after the infant's birth.[12]

Most well-nourished mothers successfully breastfeed their infants without need for significant dietary changes. Nutritional requirements during lactation and specific nutritional concerns are addressed in this chapter. How the special maternal and infant needs can be met while encouraging lactation also is discussed.

NUTRITIONAL REQUIREMENTS

Fluid

When a breastfed infant has poor weight gain or is acting fussy and dissatisfied, the mother is often told to drink more fluids. Dusdieker and co-workers[13] found that women consuming an average of 2000 ml of fluid each day produced an average of 814 ml of milk in 24 hours. Increasing fluid intake by 25% had no effect on milk production.

Several studies in underdeveloped countries showed a decrease in milk volume in severely malnourished mothers.[14] In these studies, the mothers' milk volume was increased from an average of 742 ml to 872 ml per day by supplemental food programs providing increased calories and protein.[14]

Energy

Estimates of the energy required for milk production vary from 60% to 90% efficiency in converting maternal kilocalories ingested into the kilocalorie content of breast milk.[15] An average of 5.2 kg of weight gained during pregnancy is not accounted for by the fetus or other components, and it is assumed that some of this weight gain is used to meet the energy requirements for subsequent breastfeeding.[16] The United States recommended daily allowance for additional maternal calorie take for breastfeeding is about 500 kcal/day. This is in addition to estimated basal energy requirements which range from 1700 to 3100 kcal depending on height, activity level and weight for BMI correction factor (Table 1).[17]

Historically recommended daily allowances (RDA) have been used for assessment and dietary planning as the RDA is sufficient to meet the nutrient requirements of about 97% of the healthy persons in each group listed. Between 1997 and 2011 the Institute of Medicine released the dietary reference intakes (DRIs) and future changes will be issued on individual nutrients as the science updates sufficiently. DRIs include the estimated average requirement (EAR) which is estimated to meet requirements of half the healthy persons in each group listed, the RDAs, the adequate intake (AI) for nutrients without a RDA, the upper intake level (UL) without causing harm, the estimated energy requirement (EER) and the acceptable macronutrient distribution range (AMDR). For the clinician wanting a quick and simplified assessment and planning tool, Table 1 summarizes some of the RDAs for women aged 19–50.

Table 1. Recommended dietary allowances for selected nutrients for nonpregnant, pregnant, and lactating women*

Nutrients	Nonpregnant women	Pregnant women	Lactating women
Carbohydrate (g/kg/day)	100	135	160

Nutrients	Nonpregnant women	Pregnant women	Lactating women
Protein (g/kg/day)	0.66	0.88	1.05
Fat-soluble vitamins			
A (µg retinal equivalents)	700 (5000 IU)	750 (5360 IU)	1200 (8571 IU)
D (µg)	15 (400 IU)	15 (400 IU)	15 (400 IU)
E (α-tocopherol equivalents)	15 (30 IU)	15 (30 IU)	19 (38 IU)
Water-soluble vitamins			
C (mg)	75	85	120
B_1 (mg)	1.1	1.4	1.4
B_2 (mg)	1.1	1.4	1.6
Niacin (mg)	14	18	17
Folic acid (µg)	400	600	500
B_6 (mg)	1.3	1.9	2.0
B_{12} (µg)	2	2.2	2.4
Minerals			
Calcium (mg)	1000	1000	1000
Magnesium (mg)	320	350–400	310–320
Iron (mg)	18	27	10
Zinc (mg)	8	11	12

*A supplement containing 30–60 mg elemental iron is recommended for all pregnant women and for the first 2–3 months of lactation.
(Modified from Food and Nutrition Board: Dietary Reference Intakes: Recommended Dietary Allowances and Adequate Intakes. Institute of Medicine. Reports from 1997-2011 may be accessed via www.nap.edu)

An evaluation of successful and unsuccessful lactation, as defined by the need to offer supplemental bottle feedings during the infant's first 2 months of life, found that all of the mothers who were successfully breastfeeding their infants were eating more than their previous pre-pregnancy normal volume of food.[18] Mothers who were unsuccessful in breastfeeding were consuming fewer than 2000 kcal/day, and many of them reported that they felt a need to diet. Whichelow[19] concluded that mothers must be informed of their extra caloric requirements during lactation and that they should be advised to eat more if they are concerned about the adequacy of their milk supply.

Butte and associates[20] also found that successful lactation was compatible with gradual weight reduction in the mother whose energy intake was less than the current recommendations. They concluded that maternal ingestion of approximately 2200 kcal/day was adequate for both appropriate milk production and gradual maternal weight loss.[20]

Protein

The average protein content of human milk from healthy mothers in one study was 1.09 g/dl compared with 0.93 g/dl from chronically malnourished mothers.[21] Women who are chronically "moderately" malnourished generally weigh less than 90% of standard parameters of weight for height, are from underdeveloped countries, or follow strict vegetarian diets, consuming less than 50 g of protein/day.

In some studies in underdeveloped countries, protein supplementation resulted in increased protein content of human milk and increased daily weight gain of the infant.[21] A healthy lactating mother consuming 1.05 g/kg/day of protein needs no additional dietary protein.

Carbohydrates

Approximately 90% of the carbohydrate in human milk is lactose. The amount of lactose in human milk is relatively constant at 7.3–7.4 g/dl, and appears to be independent of the maternal carbohydrate ingestion.[22] Because of its constant concentration, lactose is thought to be the regulating factor in the volume of human milk produced.

Fat

Fat is the major source of calories in human milk. The average fat content is about 52% of total calories.[23] Both human milk and standard infant formulas contain about 3.6 g of fat per 100 ml. Short-chain fatty acids (up to 16 carbons) may be synthesized in the mammary glands. Maternal plasma triglycerides are the source of long-chain fatty acids and cholesterol in human milk.[24]

The recent change in the American diet toward increased intake of vegetable fats rather than animal fats is reflected in a human milk fatty acid content, with increased long-chain fatty acids and an increase in linoleic acid.[24] Human milk produced by vegetarian mothers also shows high levels of linoleic acid.[25] Manipulation of the maternal diet does not appear to alter the total cholesterol content of human milk significantly.[26] The amount of omega-6 fatty acids and omega-3 fatty acids in human milk is reflective of the maternal diet, with a higher marine fish intake resulting in a higher omega-3 fatty acid content.[27] Initial benefits of omega-3 fatty acids focused on cardiovascular effects of improving the lipid profile as well as their anti-inflammatory properties. Supplementation of the maternal diet with omega-3 fatty acids may be useful in reducing the prevalence of hypertensive disorders of pregnancy, postpartum depression and preterm birth. There is good evidence that one of the omega-3 fatty acids, docosahexaenoic acid (DHA) is necessary for brain and retinal development in pregnancy and the newborn time period. Nonbreastfed newborn infants should be fed a formula with supplemental DHA. The current formulas used in the United States Woman Infant Children (WIC) programs include Similac Advance® made by Abbott laboratories (0.15% of total fat as DHA); Enfamil Premium® made by Mead Johnson (0.32% of total fat as DHA) and Gerber Good Start® (0.32% of total fat as DHA). Most formula carried by large discount stores contains about 0.32% of total fat as DHA. The current literature recommends pregnant and breastfeeding mothers should take either 4 g of regular fish oil capsules, or 2 g of concentrated fish oil capsules daily. Capsules may be kept refrigerated or in the freezer to reduce nausea. Alternatively, a supplement containing 200–300 mg daily of DHA may be taken. (Examples are Expecta Lipil 200 mg or Kirkland DHA 240 mg or Nature Made DHA 288 mg). An excellent review of the supplements found free of mercury and pesticides is found online from ConsumerLab.com/results/omega3.asp.

When a mother is taking inadequate calories so that she is using her own fat stores for milk production, her milk still contains 3–3.5% fat, but the fatty acid composition resembles the composition of her fat stores.[28, 29] Similarly, total milk fat content is the same when maternal caloric sources are chiefly protein and carbohydrate. However, milk composition changes and levels of saturated fatty acids increase as lipids are synthesized from fat stores and are not merely carried as plasma triglycerides from the portal system to the mammary gland.[26, 28] A restricted maternal diet containing less than 20 g total fat may produce essential fatty acid deficiency in the infant if supplemental essential fatty acids are not provided.

Vitamins

WATER-SOLUBLE VITAMINS

The vitamin and mineral content of human milk is the standard to which cow's milk and infant formulas are compared (Table 2). The human milk content of these vitamins may vary and be related to the maternal diet. The vitamin C content of human milk depends on maternal diet, and may be five times as high as that of cow's milk.[30, 31]

Table 2. Approximate nutrient content of mature human milk, cow's milk, and typical standard infant formula

Nutrient	**Human milk/100ml**[†]	**Whole cow's milk/100 g***	**Standard formula/100 ml**[†]
Kilocalories	65–73	61	67
Protein (g)	0.9–1.2	3.15	1.4
Carbohydrate (g)	6.7–7.9	4.8	7.4–7.6
Fat (g)	3.4–3.9	3.25	3.4–3.7
Fat-soluble vitamins			
A (IU)	225	142	202

Nutrient	Human milk/100ml[†]	Whole cow's milk/100 g*	Standard formula/100 ml[†]
D (IU)	2.0	42	52
E (IU)	0.4	0.08	1.0–1.3
K (μg)	2.3	3	5.4
Water-soluble vitamins			
B_1 (μg)	20	46	100
B_2 (μg)	40–60	169	150
Niacin (μg)	180	890	676-1050
Folic acid (μg)	8–14	0	10–15
B_6 (μg)	9–30	36	40–60
B_{12} (μg)	0.5–1	0.45	0.17–0.2
C (mg)	10	0	9
Minerals			
Calcium (mg)	20–25	113	53
Iron (mg)	0.9	0.03	1.2
Zinc (mg)	1–3	4	0.5–0.7

*Data from US Department of Agriculture, Agricultural Research Service 2005, USDA Nutrient Database for Standard Reference, Release 18 Nutrient Data Laboratory Home Page (http.//www.nal.usda.gov/fnic/foodcomp)[†]Product and human milk analysis: NeoFax® 2010. Formulas cited are: Enfamil Premium Newborn® and Similac Advance Early Shield®

Infantile beriberi has been reported when a breastfeeding mother consumes a diet chiefly composed of unfortified, milled grains. Vitamin B_1 supplementation provides prompt resolution.[32] Deficiencies of vitamin B_2, vitamin B_6, niacin, and folic acid usually are not seen in nursing infants, although supplemental amounts of these vitamins given to malnourished mothers will increase the levels found in human milk.[33] The vitamin C content of human milk can be raised by dietary supplement, and seasonal variations in vitamin C content are seen.[33] Most healthy mothers consume a diet that meets the recommended daily allowances for water-soluble vitamins. Malnourished and vegan vegetarian mothers require vitamin B_{12} supplementation to prevent megaloblastic anemia in their infants (Table 1 and Table 3).[34, 35]

Table 3. Recommended supplements for maternal vegetarian diet

Vegetarian diet	**Supplement**
Semi-vegetarian (no red meat)	Iron sulfate, 300–600 mg/day
Ovo-lacto-vegetarian (no-flesh)	Iron sulfate 300–600 mg/day, zinc sulfate 225 mg/day
Lacto-vegetarian (no flesh or eggs)	Iron sulfate 300–600 mg/day and zinc sulfate 225 mg/day, vitamin B_1 1.5 mg and vitamin B_{12} 10 μg/day, or use prenatal vitamins 1 tablet daily (check protein intake for adequacy)
Vegan	Prenatal vitamin or multivitamin supplement with vitamin B_{12} and calcium 1000 mg/day (check protein pattern for essential amino acid content)

FAT-SOLUBLE VITAMINS

No deficiency syndromes of vitamins A and E have been reported in healthy, term, breastfed infants.[36] Vitamin E-deficient hemolytic anemia has been reported in premature infants and in infants with malabsorption syndromes.[37] Vitamin E supplementation usually is not recommended for the term infant. Increases in serum vitamin E levels have been reported in newborns whose lactating mothers were using vitamin E oil to treat early nipple tenderness.[38] Studies of maternal supplementation have not been performed for significant periods to allow assessment of the potential for toxicity of excessive supplementation.

Rickets has been reported in breastfed infants, particularly those living in northern climates in winter, in urban areas, and among nonwhites and vegetarians. Daily maternal dietary supplementation of about 15 μg (400 IU) of vitamin D can prevent rickets in these infants.[39, 40] All breastfed infants should receive 400 IU of oral vitamin D drops daily beginning during the first 2 months of life. [23]

Vitamin K deficiency (hemorrhagic disease of the newborn) is seen primarily in breastfed infants (or infants receiving formula without supplemental vitamin K) who did not receive vitamin K after delivery.[41] Fortified infant formula usually contains 5.4 μg/dl of vitamin K, whereas breast milk only contains 2.3 μg/dl of vitamin K (Table 2). Severe deficiency, resulting in massive intracranial hemorrhage, has been reported in several case reports from Taiwan in older breastfed infants. These infants usually had a preceding gastroenteritis that affected the bacterial flora and its ability to synthesize vitamin K.[42]

Minerals

Sodium, potassium, calcium, phosphorus, magnesium, and iron levels in breast milk are unaffected by maternal dietary intake.[36, 43] There are reports from 1920 to 1940 of malnourished mothers who nursed and had maternal osteomalacia and tetany.[44] There also was one report of increased sodium content in the milk of a mother with cystic fibrosis who was not nursing but who gave an expressed milk sample. This finding may not be valid.[45] One mother with cystic fibrosis who was actively breastfeeding her infant did not have increased breast milk sodium content.[46]

Iron absorption of breastfed infants appears to be aided by the higher lactose levels in human milk. Woodruff and associates[47] found that breastfed infants had higher serum iron concentrations after birth, and lower total iron-binding capacity at 3, 6, and 9 months of age. Breastfed infants appear to use dietary iron more efficiently than bottle-fed infants.[48] Several authors have reported that iron is absorbed in breastfed term infants in sufficient quantities to ensure adequate iron intake for the first 6–9 months of life.[49, 50] After 6 months of age, as infants show greater interest in chewing, iron-rich solid foods are recommended in the infant's diet.[36]

Zinc in human milk is more completely absorbed than that in formula, and breastfed infants have higher serum and hair zinc levels.[51] The improved bioavailability of zinc in breast milk may prevent clinical zinc deficiency in acrodermatitis enteropathica.[51] Clinical zinc deficiency may be seen in breastfed premature infants with necrotizing enterocolitis or other disorders with extensive small bowel resection or unusually high gastrointestinal losses.[52] Maternal dietary supplements usually do not increase breast milk zinc content sufficiently; thus, additional oral or intravenous zinc must be given to the high-risk infant.[36, 52]

No relationship between maternal dietary copper and breast milk copper concentration is seen.[36] Like zinc, copper deficiency in breastfed infants usually is confined to those receiving parenteral nutrition and affected with short gut syndrome or prematurity.

The use of iodized salt in the maternal diet may double the level of iodine in human milk, which may prevent iodine deficiency.[36]

Fluoridation of drinking water is not associated with a major increase in maternal milk fluoride levels.[36] Fluoride supplementation, 0.25 mg/day, is recommended for the nursing infant from 6 months to 3 years of age, living in an area with drinking water containing less than 0.3 ppm fluoride concentration.[53] The mean selenium concentration of human milk is 2 µg/100 ml, which is about twice that of formula and correlates with the protein content of milk.[54] There are reports of selenium toxicity in adults living in areas of seleniferous soil. The symptoms included chronic dermatitis, fatigue, and dizziness.[54] No reports of this syndrome in breastfed infants have been identified.

ASSESSING ADEQUACY OF BREAST MILK

Individualization is required to determine when supplementation with formula or solid foods is appropriate. One approach is to compare human milk production with recommended dietary allowances. Recommended daily allowances estimate nutrition requirements based on metabolic balance studies to which a generous safety margin has been added. They may overestimate actual needs. These recommendations do not take into account individual variability and the infant's ability to adjust physiologic efficiency to food availability.

If human milk contains an average of 69 kcal/dl, a child weighing 5 kg at 2 months would need an average of 900 ml/day of breast milk to meet the recommended daily allowance.[55] The average amount of breast milk produced in the second month of lactation in American mothers is reported to be 500–675 ml/day.[13] Because most 2-month-old infants grow well on breast milk alone, either the recommended daily allowance is overly generous or the methods for estimating human milk production grossly underestimate the amount produced.

As long as a breastfed infant is growing appropriately, maternal milk is providing adequate volume, calories, and protein, and the mother's diet is adequate. The World Health Organization released new international growth charts in April 2006 for children from 0 to 59 months based on the healthy breastfed infant as the recommended standard. Fewer US children will be considered underweight using the WHO charts instead of the 2000 CDC growth charts and slower growth of breastfed vs. formula fed infants during ages 3–18 months is normal.[56] The CDC recommends that health care providers use the WHO growth standards to monitor growth for infants and children aged 0–2 years of age in the United States. Assessing the adequacy of other nutrients in the breastfed infant does not vary according to the mode of feeding. A combination of anthropometric measures and clinical symptoms can be used to assess adequacy. Clinical symptoms of specific nutritional deficiencies in the infant are listed in Table 4.

Table 4. Clinical signs of nutritional deficiencies in the infant

Nutrient	**Sign of deficiency**
Inadequate fluid or free water intake	Clinical dehydration, increased serum electrolyte level (particularly sodium), hyperbilirubinemia in the newborn period
Inadequate calories and protein	Weight and height under 25th centile; sparse, bleached-out hair (flag sign); decreased mid-upper-arm muscle circumference and triceps skinfold; decreased serum albumin and protein levels
Essential fatty acid	Follicular hyperkeratosis
Vitamin D and calcium	Rickets, delayed closing of fontanelle or bossing of skull
Iron	Anemia, pale mucous membranes and skin
Zinc	Irritability, perioral or anal dermatitis

Nutrient	Sign of deficiency
Copper	Triad of anemia, neutropenia, rickets (often found in infants given goat's milk or with short gut syndrome)
Vitamin B_{12} and folic acid	Megaloblastic anemia, ataxia, neurologic deficits
Vitamin C	Tender, bleeding mucous membranes, rickets (due to interaction with copper), petechiae
Other B vitamins	Deficiencies not seen unless the infant has generalized severe malnutrition

VITAMIN AND MINERAL SUPPLEMENTATION

Except for vitamin D, routine vitamin and mineral supplementation is not necessary for the healthy, well-nourished breastfeeding mother. Many mothers continue to take their prenatal vitamins after delivery, which is reasonable until the infant is consuming a variety of solid foods in addition to human milk. Clinical signs that suggest maternal deficiencies of selected nutrients are listed in Table 5.

Table 5. Clinical signs of nutritional deficiencies in the mother

Nutrient	Sign of deficiency
Kilocalories	Weight and height under 90% of standard or triceps skinfold thickness under 90% of standard
Protein	Mid-upper-arm circumference 90% of standard; decreased serum protein and albumin levels; hair brittle, with bleached-out color; skin with areas of patchy, dark pigmentation; dependent edema (with serum albumin levels less than 2.5 g/dl)
Essential fatty acids and vitamin A	Follicular hyperkeratosis and xerosis, thickened opaque conjunctiva, and Bitot's spots (with vitamin A)
Niacin, vitamin B_2, and vitamin B_{12}	Nasolabial seborrhea; cheilosis; angular fissures at corners of month; glossitis; beefy, red painful tongue (especially with B_{12})

Nutrient	Sign of deficiency
Niacin	Shirt-sleeve dermatitis (dark pigmentation in sun-exposed areas)
Vitamin B_{12} and folic acid	Macrocytic anemia, symmetrical peripheral neuropathy, absent deep tendon reflexes, ataxia

Vitamin B_{12} and calcium supplementation may be necessary if the mother consumes a vegetarian diet.[33, 34] Women who are undernourished and eating a diet during pregnancy containing less than 70% of the recommended daily allowances may need a multivitamin and mineral supplement.[33, 36]

The effects of megavitamin supplementation are unknown. Because increased maternal intake of vitamin A and vitamin D can substantially increase their content in human milk, prolonged excessive maternal vitamin A and vitamin D supplementation has the potential for infant toxicity.[23, 36]

Excessive vitamin C ingestion in pregnant women has resulted in withdrawal scurvy in their infants.[57] The vitamin C content of human milk increases within 30 minutes of maternal ingestion.[31] Mothers who ingest large doses of vitamin C should taper rather than abruptly stop its ingestion.

MATERNAL CONSIDERATIONS

Employment

Maternal employment soon after the infant's birth is increasingly common and need not preclude continued breastfeeding. Frequency of breast emptying while away from the infant varies with infant age, maternal discomfort and desire to provide human milk for missed feedings, and availability of facilities for comfortable pumping and appropriate storage of pumped milk.[12, 58] Women are likely to breastfeed longer when provision is made for use of an electric breast pump in privacy, with adequate facilities for storage of the milk at work.[59] Many women substitute one or more formula feedings for breastfeeding instead of pumping and saving milk while at work.

The nutritional needs of the lactating mother will vary with the frequency of her daily nursing periods. One or two missed infant feedings a day probably does not substantially alter the mother's nutritional needs, especially if she is active and has other energy needs. More than two missed feedings will either proportionally reduce the mother's dietary needs or lengthen the time it takes for her to use her pregnancy-acquired fat stores.

Vegetarian diet

Many lactating women exclude meats or animal products from their diets. The semi-vegetarian (who only avoids red meats) and the ovo-lacto-vegetarian (who eats no flesh foods) are at risk for maternal iron and zinc deficiency.[60] The lacto-vegetarian (who also avoids eggs) may be at additional risk for protein deficiency without careful selection of complementary proteins.[60] The vegan (who consumes only vegetables, grains, and fruits) is at high risk for maternal and infant mineral, protein, vitamin D, vitamin B_{12}, and other B vitamin deficiencies.[34, 35, 60] Recommended supplements for lactating mothers who follow vegetarian diets are listed in Table 3.

Megaloblastic anemia with profound neurologic manifestations has been reported in some infants of vegan mothers. The maternal serum vitamin B_{12} levels in these cases are marginal to slightly low.[34, 35]

The zen macrobiotic diet is nutritionally inadequate in almost all required nutrients. It is contraindicated for the pregnant or lactating woman.[60] Any diet containing high amounts of fiber and whole grain with excessive dietary phytates may impair absorption of iron, zinc, and calcium. The maternal intake may appear to be adequate, but clinical symptoms of iron, zinc, and calcium deficiency in the mother are present.[60]

The fatty acid content in human milk is altered in vegetarian women whose diet meets the recommended daily allowance for all other nutrients.[61] Long-chain saturated fatty acid levels are reduced, and levels of polyunsaturated fatty acids are increased.[61] The clinical significance of this effect is unknown.

Diabetes

Mothers with diabetes may breastfeed their infants successfully. Close control of blood glucose levels during pregnancy produces infants with few hypoglycemic and hypocalcemic episodes in the neonatal period.[62] These infants often are alert and are not likely to have difficulties in breastfeeding or a need for prolonged intravenous administration of glucose and calcium.

Just as with nondiabetic mothers, attention must be paid to increasing the maternal diet by about 500 calories/day to provide for the energy needs for breast milk production.[17] Some of the energy required may be derived from fat stores developed during pregnancy.

Close monitoring of maternal serum glucose levels is recommended to avoid ketonuria and ketonemia that may occur during fat store mobilization. Although most mothers with diabetes experience about a 10% decrease in insulin requirements during lactation, some may require an increase in insulin dosage.[63]

Breastfeeding in the immediate postpartum period may be slow to be fully established because infants of some diabetic mothers are delivered before 40 weeks' gestation. These infants may have hypoglycemia and hypocalcemia, and they may not have a vigorous suck.[64] A breast pump may be useful to stimulate milk production until the infant can nurse. Because the volume of milk obtained with a mechanical pump often is less than that after established breastfeeding, maternal insulin needs may vary during this period.

Gastrointestinal disease

The lactating mother who has gastrointestinal disease resulting in malabsorption may be at risk for nutritional deficiencies. Moderate nutritional depletion is defined as a score of less than 90% on standard parameters of nutritional assessment (including weight for height). Severe depletion is defined as a score of less than 60% of standard parameters.[65]

Lactating mothers with Crohn's disease, ulcerative colitis, or short gut syndromes (such as following intestinal bypass surgery) must be evaluated for nutritional deficiencies. Loss of weight or an increase in diarrhea may precede other clinical symptoms. These mothers are at risk for decreased absorption of protein, fat and fat-soluble vitamins, and minerals, such as calcium, magnesium, and zinc.[66]

The degree of loss may be quantified by analysis of a 24-hour stool collection. The maternal diet may need to be increased, and some of these women may require chemically defined diets or even total parenteral nutrition. No large studies exist on breastfeeding while the mother is receiving total parenteral nutrition. Breastfeeding would be possible with careful attention to maternal intravenous solution content and nutritional monitoring of the mother and infant.

Phenylketonuria

Many women with classic phenylketonuria (PKU) have reached childbearing age. Many of these women enter pregnancy with elevated serum phenylalanine levels. Several studies have shown a direct correlation between maternal serum phenylalanine level and mental retardation in the otherwise normal fetus, who may or may not have the gene for PKU.[67, 68] The current recommendation is that the mother resume her low-phenylalanine diet, using a special low-phenylalanine formula (Lofenalac®, Phenyl-Free 2® Mead Johnson Nutrition, Evansville, IN; Phenex-2® from Abbott Nutrition; or similar formula) to keep her level of phenylalanine, before and during her pregnancy, less than 5 mg/dl.[68]

Little information exists as to dietary recommendations during lactation for these woman. The mother's milk could be tested periodically for phenylalanine content. If it is significantly higher than the normal range for human milk (29–69 mg/dl), then the maternal phenylalanine intake can be adjusted to keep the milk phenylalanine content within the normal range. A comprehensive website on management of phenylketonuria is maintained by the University of Washington PKU clinic in Seattle, Washington. (depts.washington.edu.pku.resources/essentials.html)

Another group of women with hyperphenylalanemia, not classic PKU, has been identified.[69] These women have borderline to normal intelligence and usually are identified by having a newborn with a transiently positive phenylalanine screen result, a child with unexplained mental retardation, or a relative with mental retardation or PKU.[69] There is a strong positive correlation between maternal serum phenylalanine level during pregnancy and mental retardation in the offspring.[70] Dietary recommendations for diet during pregnancy and lactation are the same as for mothers with PKU.

Type I hyperlipoproteinemia

Of the hyperlipidemias, usually only type I results in a marked change in the fat composition of the milk of the affected lactating mother.[71] Few case reports are available on lactation in mothers with type I hyperlipidemia.[71] The fat composition in the milk differs greatly from that in other women's milk. Plasma lipids cannot be taken up by the mammary gland. This inability results in replacement of much of the plasma long-chain fatty acids usually present in breast milk by short- and medium-chain fatty acids synthesized *de novo* in the mammary gland.[70] An unaffected nursing infant can synthesize some long-chain fatty acids, but linoleic acid and linolenic acid must be supplied in the infant's diet to prevent essential fatty acid deficiency.[71]

Maternal dietary recommendations include maintaining serum lipid levels within normal limits by following a restricted fat diet, and increasing dietary carbohydrate and protein to provide the additional calories required for lactation. The infant should be monitored for any signs of essential fatty acid deficiency, because it is unknown whether the mother's milk will provide adequate linoleic and linolenic acid.[71]

Cystic fibrosis

Case reports are available on lactation in the mother with cystic fibrosis. One brief report described a 20-year-old woman whose breastfed infant was growing and thriving at 15 weeks after delivery. The mother was unable to maintain her prepartum weight, and her pulmonary status worsened. The sodium content of the breast milk did not differ significantly from the mean values for human milk. The total fat, immunoglobulin (Ig) G, and IgM levels were low, however, and the total protein and IgA levels were elevated. No pathogens were cultured from the milk.[46] The number of mothers with cystic fibrosis that are breastfeeding is increasing and a current website (cysticfibrosis.about.com/od/pregnancyandcf/a/breastfeed.htm) is a good resource for these mothers.

INFANT CONSIDERATIONS

Prematurity

The nutritional needs of the preterm infant differ from those of the term infant and the immaturity of these infants may cause problems such as malabsorption, poor suck and swallow reflexes, and necrotizing enterocolitis.[72]

The estimated *in utero* accretion requirements for sodium, potassium, chloride, protein, vitamin D, calcium, phosphorus, and potassium may not always be met by human milk alone. In the infant less than 32 weeks gestation or weighing less than 1500 g, current recommendations are to supplement human milk with a fortifier designed for premature infants.[73] Commercially available breast milk fortifiers (Enfamil® Human Milk Fortifier (Mead Johnson Nutrition) and Similac® Human Milk Fortifier (Abbott Laboratories) are available to add to breast milk to increase the caloric content from 20 kcal per ounce to 22 or 24 kcal per ounce as well as supply additional vitamins and minerals.

Other advantages of using human milk for the premature infant are a decrease in necrotizing enterocolitis, decreased diarrhea, increased gastric emptying and reduced antibiotic usage.[74] The amount of breast milk produced may not be adequate because of the infant's poor suck reflex, infrequent breast stimulation by the infant, and maternal anxiety about the infant.[72] Frequent, consistent pumping or hand expression may be useful in maintaining the maternal milk supply. It is recommended the mother pump at least every 3 hours during the daytime and at least every 5 hours at night. Pumped milk should be obtained in a sanitary manner and immediately refrigerated or frozen. Refrigerated human milk should be used within 48 hours (24 if mixed with fortifier). Frozen milk can be stored in a home freezer for 3 months and should be used within 24 hours of being thawed. Frozen milk should be thawed in the refrigerator, or under running warm water, but never microwaved. Nonfortified human milk may be used exclusively when the infant reaches term size or after 36 weeks' gestation. Metoclopramide 10 mg orally every 8 hours may increase milk production.[75] It also increases prolactin levels through a dopamine antagonist mechanism.

Milk produced by mothers of premature infants in the first few weeks after birth differs from the milk they produce later and from the milk produced by mothers of term infants.[76] The initial milk of mothers of premature infants born before 31 weeks' gestation is usually higher in protein, sodium, fatty acids, and energy.[77]

The well-nourished mother of a premature infant should follow a dietary plan based on recommended dietary allowances for lactation. Maternal anxiety may be high, and additional emotional support often is needed. With time, practice, and emotional support, mothers of premature infants often provide for most, if not all, of their infant's nutritional needs.

Multiple births

Successful breastfeeding of twins or triplets is possible. The maternal diet should be increased by at least 800 calories/day, and continuation of prenatal vitamins or multivitamins is advised.[17] Mothers of twins or triplets who do not ingest sufficient calories for the extra energy needed for milk production may have increased mobilization of endogenous fat stores and earlier return to prepregnancy weight.[78]

Many twins or triplets are born prematurely and spend time in the newborn intensive care unit. In addition to information and support, breast pumping is recommended to stimulate and maintain milk production until the infants can use some or all of the mother's milk.

Food allergies

Heredity plays an important role in food allergies and atopic disease. Either skin manifestations of atopia or gastrointestinal symptoms may be related to food allergies. Several studies have attempted to evaluate the prevention of development of infant atopia and gastrointestinal disturbances by manipulating the maternal diet during pregnancy and lactation to avoid allergenic foods and by feeding the infant either breast or soy milk.[79] Many of these studies were not well designed and did not control for duration of exclusive breastfeeding.

Other studies suggested a decrease in the infant's gastrointestinal symptoms with a maternal diet devoid of cow's milk and egg proteins. Cow's milk, goat's milk, soy milk, and egg proteins in the maternal diet are secreted into the breast milk.[80, 81, 82] Jacobsson and colleagues[83] reported high levels of β-lactoglobulin in the milk of mothers whose infants had colic. After cow's milk was removed from the diet, the β-lactoglobulin levels were not detectable, and the colic resolved.

In addition to allergic problems with protein components of cow's milk, lactose intolerance in the mother is prevalent worldwide.[84] More than 80% of Oriental and Eskimo adults and 60–80% of Native Americans, blacks, and Hispanics are lactose intolerant.[84] Alternative sources of calcium, such as calcium-rich vegetables and supplemental calcium tablets, are recommended in the maternal diet during pregnancy and lactation.

Current recommendations have changed from recommending restrictions in the maternal diet to not recommending any maternal dietary restrictions in pregnancy or lactation. There remains some evidence that breastfeeding for the first 4 months of life in comparison to cow milk protein decreases risk of atopy in high risk children.[84] If there is not a strong family history of soy allergy, soy protein products may be used in the maternal diet during pregnancy and lactation.[85]

There is modest benefit of use of a casein hydrolysate or a partially hydrolyzed whey protein formula in the high risk infant not breastfed. Examples of casein hydrolysate formulas are: Nutramigen® or Pregestimil® (Mead Johnson Nutrition). Good Start® (Gerber) contains partially hydrolyzed whey protein.[86]

Cleft palate

It is difficult to feed the baby with a significant cleft palate exclusively at the breast. One strategy is to use a breast pump and then feed the infant using a cleft palate nurser. There are several organizations, such as the Cleft Palate Foundation that have websites with instructions as well as online support groups. The recommendation would be for the mother to consult a lactation or dysphagia specialist as ease of breastfeeding would vary according to the individual infant's anatomic defect.

Inborn errors of metabolism

PHENYLKETONURIA

Phenylketonuria is a common inborn error of metabolism, occurring in 1:10,000 white children.[87] Breastfeeding often was discouraged in the past, and the infant was fed a combination of a small, measured amount of standard formula and a special formula containing low levels of phenylalanine.[88] Human milk averages 41 mg/dl phenylalanine, compared with 75 mg/dl in standard infant formulas and 159 mg/dl in cow's milk.[88] With close monitoring, breastfeeding may be continued for the infant with PKU.

A comprehensive website from the University of Washington, Seattle, Washington describes protocols for feeding, information for both parents and professionals, recipes and contact information (depts.washington.edu.pku.resources/essentials.html). When the mother wants to breastfeed, several strategies may be used. They include weighing the infant before and after feeding to determine amount of breast milk ingested, offering a low phenylalanine formula after a certain number of minutes at the breast, checking daily blood levels of phenylalanine until the infant's level is stable, substituting low phenylalanine formula for one or two feedings a day and pumping milk at the feeding time to maintain the maternal milk supply, and placing low phenylalanine formula in a nursing supplementer. The supplementer allows the infant to nurse and receive the low phenylalanine formula simultaneously. The optimal blood level of serum phenylalanine that maintains adequate infant growth is less than 5 mg/dl for the first 6 months of life.[88]

Other than following the recommended daily allowances for lactation, no alteration in maternal diet is necessary for nursing an infant with PKU. Restricting the intake of maternal dietary protein does not lower the phenylalanine content of breast milk.

TYPE I HYPERLIPOPROTEINEMIA

This rare metabolic defect is associated with a defect of lipoprotein lipase activity. This defect results in an inability to clear any dietary fat, and levels of serum chylomicrons and serum triglycerides can be as high as 10,000 mg/dl.[23]

The average fat content of 24-hour pooled milk samples varies from 2.10 to 3.33%.[26, 28] At 3% fat content, the infant could be fed a maximum of 660 ml or 22 oz of human milk each day if a dietary fat restriction of 20 g daily was desired. The remainder of the intake would need to come from a nonfat formula. Each infant must be managed on an individual basis, depending on the fat content of the mother's milk and the feeding technique. The infant could be allowed to nurse for a specific period, and triglyceride levels could be obtained frequently, with nursing time adjusted accordingly. Another alternative, although cumbersome, is to pump the breast and give a measured amount of human milk fortified with nonfat dry milk and another carbohydrate source, or one of the commercially available products low in fat (Abbott® Nutrition or Mead Johnson Nutrition®) to the infant in a bottle. The infant requires careful monitoring for any symptoms of linoleic acid deficiency.

OTHER INBORN ERRORS OF METABOLISM

There are over 20 specialty infant formulas for inborn errors of metabolism. They are designed for infants with hypercalcemia, urea cycle disorders, homocystinuria, hypermethionemia, maple syrup urine disease, propionic or methylmalonic acidemia, glycogen storage disorders, need for a ketogenic diet or cholestasis, chylothorax and other disorders. With some of these a measured quantity of human milk may be used under supervision of a pediatric specialist in this area. More detailed information can be obtained from the websites of Abbott Nutrition or Mead Johnson Nutrition.

CYSTIC FIBROSIS

Cystic fibrosis is a common inherited enzyme defect, occurring in 1:1500 to 1:2000 live, white births. Eighty-five per cent of affected infants have some pancreatic impairment. Regardless of the feeding method, these infants usually need supplemental fat-soluble vitamins (aqueous preparations of vitamins A, E, D, and K) and exogenous pancreatic enzymes.[23] Maternal diet does not need to be modified in the unaffected mother wanting to nurse an infant with cystic fibrosis.

Drugs and chemicals in breast milk

To alter the practice of weaning as a precaution during drug therapy, information must be available to permit accurate evaluation of the risks and benefits of therapy to the mother and infant. Older studies often were contradictory, with most human data including only a small number of subjects or a single case report. Single determinations of a drug in breast milk are of limited value. Only within the last 10 years have sound pharmacokinetic principles been applied to drug or chemical excretion in human breast milk. Most drugs in breast milk are found in concentrations equal to or lower than maternal plasma levels.

Many important drugs have not been studied adequately, and information regarding their short- or long-term effects in infants often is lacking. When publishing data, manufacturers sometimes use such words as *may* or *might* when referring to the possible effect of the drug on the nursing infant. Often, these words are understood to mean that the drug is contraindicated in nursing mothers. Neonatal effects are thought to be negligible with antibiotic exposure, except for allergic sensitization, candidal infection, or diarrhea. Cardiovascular drugs often do not cause adverse effects on the newborn at maternal therapeutic doses, but product information on newer medications should always be checked. Gastrointestinal drugs may cause diarrhea or colic. Effects from exposure to psychoactive substances in breast milk are unknown, but may be of concern. Long-term antihistamine use may cause sedation or decreased feeding. Concentrations of hormones and synthetic substances such as thyroid preparations are thought to be too small to be clinically significant. Information about specific drugs may be found in standard textbooks or on-line sites.[89, 90] The United States National Library of Medicine has a toxicology data network with a subsection on drugs and lactation – LactMed (TOXNET.NLM.NIH.GOV). A mobile application is available from Texas Tech University Health Sciences Center, Infant Risk Center Mobile App, www.infantrisk.com.

Volatile oils, such as in garlic, onion, and melons, may be poorly tolerated by the infant.[60] Artificial colors and dyes used in beverages, gelatin desserts, and other foods can color the milk.[91] Lawrence[60] reported cases of green milk caused by a sports drink colored with food dye, kelp, seaweed, and colored vitamin tablets. Such color changes do not affect the nutritional content of the milk. Excessive maternal consumption of caffeine and methylxanthines (several cups of coffee or tea each day) causes hyperstimulation in the nursing infant.[92] Herbal teas may contain natural coumarins or other potent pharmacologic and psychogenic compounds that could cause bleeding or other problems.[93] It is not known whether significant amounts of these compounds are secreted into human milk in women who drink herbal teas regularly.

Women with a high exposure to agricultural chemicals, such as polychlorinated biphenyl (PCB), may have blood levels 10–100 times those of nonexposed mothers.[94] Detectable levels in their milk usually are lower than the levels found in cow's milk. The breastfed infants of these mothers have PCB residue in the blood. Levels in the infant relate directly to the duration of breastfeeding rather than to maternal serum PCB concentration.[94] No significant medical problems in these infants have been seen, and no infants were diagnosed with chronic PCB poisoning. Testing of human milk for PCB content is not required or recommended unless there has been an unusually high exposure or the area has been designated by the state health department as heavily contaminated.

POTENTIAL CONTRAINDICATIONS TO BREASTFEEDING

Often, questions are asked about the suitability of breast milk in meeting the infant's nutritional needs under a variety of infant and maternal conditions. The following situations may result in temporary or complete discontinuation of breastfeeding.

Cancer of the breast

If breastfeeding means that the mother may delay definitive treatment, it is not recommended. A positive family history for breast cancer is not a contraindication to breastfeeding.[95]

Other cancer

During chemotherapy, other than that with prednisone, the mother's milk may be pumped and discarded for the duration of chemotherapy. Breastfeeding can be resumed after drug levels no longer are found in the milk, or until the time since the last dose exceeds four half-lives of the drug.

Tuberculosis

Sputum-positive tuberculosis is a contraindication to breastfeeding until the mother is under effective treatment for at least 1 week and the infant is receiving isoniazid prophylaxis.[96] Milk may be pumped and discarded until this time.

Hepatitis B and C

Hepatitis B can be transmitted to the infant transplacentally during pregnancy, by the fecal–oral route during delivery, and through breast milk.[96, 97, 98] For mothers who have active hepatitis B during pregnancy the American Academy of Pediatrics Committee on Infectious Disease has taken the position that “breastfeeding should be avoided if artificial milk formulas and adequate refrigeration facilities are available. However, breastfeeding is indicated for infants living in areas of the world where hepatitis, type B, infection is highly endemic and artificial formulas and refrigeration are not available.”[96]

Other authors have not found hepatitis B in unconcentrated breast milk specimens from women who were carriers but were not actively infected.[97, 98] Krugman[99] noted that the use of vaccines against viral hepatitis so substantially reduced its incidence that the risk associated with breastfeeding by carrier mothers may be significantly less than previously thought. The American Academy of Pediatrics does not consider breastfeeding contraindicated in mothers infected with hepatitis C antibody or hepatitis C virus-RNA-positive blood.[2]

Herpes simplex

Fatal newborn cases of herpes simplex type 1 and herpes simplex type 2 involving maternal breast lesions have been reported.[96, 100, 101] If suspicious breast lesions are present, the mother should empty her breasts and discard the milk until lesions have resolved.

Acquired immune deficiency syndrome

Case studies report possible transmission of acquired immune deficiency syndrome retrovirus through human milk.[102, 103] Women in high-risk groups (*e.g.*, intravenous drug abusers, those born in areas of high incidence of heterosexual transmission, those who have been sexual partners of affected men) should be excluded from donating human milk. Seropositive women should be advised against breastfeeding their newborns in areas of the world where alternate, adequate food source is available and affordable for the infant.[96]

Radioactive drugs

Interruption of breastfeeding is necessary during exposure to diagnostic radioactive isotopes. Milk should be pumped and discarded during the first four half-lives of the drug. For sodium pertechnetate technetium-99m, iodohippurate sodium iodine-131, and similar compounds, the infant should be fed immediately before the administration of the radionuclide. The next three milk fractions should be discarded before nursing is resumed.[104] Only the first milk fraction after radionuclide administration should be discarded for red blood cell labeled (technetium-99m), petetic acid (technetium-99m), methylene diphosphonate (technetium-99m), and edetic acid (chromium-57).[104, 105]

When radionuclide compounds are used for treatment, breast milk also should be discarded for four half-lives. For iodine-131, discarding milk for four half-lives (half-life of 8 days) causes a 4-week interruption of breastfeeding.[106]

Oral contraceptives

The advisability of recommending oral contraceptives to lactating women continues to be debated, both for their maternal and infant effects. Lonnerdal and associates[107] reported significant differences in some protein components of human milk and a decrease in total volume among women taking oral contraceptives compared with women not using oral contraceptives.[108] However, even with these differences, nutrient composition of the breast milk was within normal limits, and no infants had clinical signs or nutritional deficiencies.

Stefan and Nygren[108] reported that concentrations of ethinyl estradiol in breast milk obtained from women taking oral contraceptives were approximately 1% of the dose taken. They estimated that an oral contraceptive containing 50 µg of ethinyl estradiol excretes 10 ng of ethinyl estradiol per 600 ml breast milk expressed. Today, most oral contraceptives have 30 µg or less of ethinyl estradiol or equivalent.

Roepke and Kirksey[109] found that women who took oral contraceptives for longer than 30 months before their pregnancy had substantially reduced reserves of vitamin B_6 during pregnancy and lactation. Some authors suggest that supplemental vitamin B_6 be given during pregnancy to women with a history of long-term use of oral contraceptives.[109]

Infant galactosemia

Galactosemia is an absolute contraindication to breastfeeding because the chief carbohydrate source in milk is lactose. Galactosemia occurs in only 1:60,000 live births.[110] Use of human or cow's milk or other products containing lactose will result in hepatomegaly, jaundice, cataract formation, and mental retardation in the infant. Meat base or casein hydrolysate formulas are used to meet nutritional requirements.[53]

CONCLUSIONS

Most women who deliver an infant have adequate nutritional stores for breastfeeding. The maternal diet can influence the nutrient content of breast milk, particularly the volume of milk produced, its protein content, its water-soluble vitamin content, and its fatty acid composition.

Vitamin and mineral supplementation of the maternal diet may not be necessary, except for the strict vegetarian or malnourished mother. Many physicians recommend the nursing mother continue her prenatal vitamins while lactating since the quality of the maternal diet may not be easy to ascertain. Special situations, such as diabetes, gastrointestinal problems, and inborn errors of metabolism, do not preclude breastfeeding if recommended adjustments to the maternal diet are made. The nutritional needs of infants weighing less than 1500 g or infants with special problems may be partially or fully met by breastfeeding. Specific adjustments to the maternal or infant diet may be required.

Many chemicals and drugs are excreted into breast milk. Seldom is breastfeeding contraindicated because of drugs or environmental contaminants, although an awareness of potential effects may make the mother avoid unnecessary exposure to these substances. Breastfeeding may have to be suspended temporarily when certain radionuclides are used for diagnosis or treatment, or while the mother is receiving chemotherapy. Afterward, it may be resumed.

Infectious agents, such as those of hepatitis, herpes, tuberculosis, or acquired immune deficiency syndrome, may be transmitted to the infant through breast milk. Temporary or permanent cessation of breastfeeding may be recommended. The only absolute contraindication to breastfeeding is galactosemia in the infant.

Special maternal or infant needs requiring dietary changes on either part sometimes are used as reasons to discourage breastfeeding. For a motivated mother who wants to nurse her infant, the specific recommendations in this chapter are designed to help her to provide for both her own and her infant's nutritional needs. These recommendations are intended to be used to promote rather than discourage breastfeeding.

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