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Nutritional Goals and Requirements

Introduction

Due to nutrition's direct impact on health and disease, nutritional goals and requirements for patients under medical care should be set as clearly as possible. These goals and requirements are constantly revised, following the progressive understanding of the quantitative and qualitative role of nutrients in biological pathways and clinical outcomes. This chapter describes current nutritional goals and requirements in health and disease.

I. Nutritional Goals

A. Nutritional goals are different for different interventional applications. For example, goals of nutrition support for therapeutic aims are often different from goals for prevention of nutrient deficiency, which, in turn, may be different from goals for prevention of chronic disease.

B. Nutrition plays an important role in disease evolution and significantly affects patient response to disease, and consequently outcomes. With regard to the role of nutrition in disease evolution, it is well recognized that
   1. Malnutrition and malabsorption of macro- and/or micronutrients contribute to many disease outcomes (malnutrition: cancer, acute and chronic infections, etc; malabsorption: gastrointestinal diseases such as celiac disease or inflammatory bowel disease, hereditary diseases such as cystic fibrosis, etc). For example, survival is typically shorter in cancer patients who have already lost weight prior to beginning chemotherapy.[1] Another example of how malnutrition affects disease outcome is provided by children with Crohn's disease.[2] Malnutrition in these children can contribute to growth failure and delayed sexual maturation.
   2. Malnutrition increases both morbidity and mortality. Hospitalized patients are at risk (up to 65%) of developing malnutrition. No major changes in this percentage have been detected over the years.[3,4] The vicious circle of malnutrition and infections has been well documented.

C. Reversal or alteration of disease outcomes is possible through appropriate nutrition support[3,4]:
   1. The clinical course of disease may be improved through avoiding or correcting macro- and micronutrient deficiencies. Improvements involve anthropometric parameters and body metabolism.
   2. Morbidity and mortality are less likely and the need for hospitalization and further treatments may be reduced, which has implications for cost containment.

D. Benefits from nutritional therapy have been detected in both "healthy" children and children receiving treatments for various diseases either in the hospital or at home. Overall pediatric nutritional goals can be summarized as follows:
   1. To avoid limitations in the rate of growth and reverse weight loss or extreme conditions such as failure to thrive. In the presence of a disease, ponderal and/or statural growth are usually affected—the former in acute conditions, both in chronic ones. Proper nutritional intervention allows catch-up growth.[5–7]
   2. To maintain positive nitrogen balance, necessary for growth, tissue repair, and subsequent multiorgan functioning. Children are at greater risk than adults of protein wasting because of a proportionally higher basal metabolic rate and protein turnover.[8,9] Children can lose as much as one third of their lean body mass in 3 to 5 days after caloric stores are depleted.[10] Malnutrition can lead to progressive muscle weakness, altered respiratory function, impaired immune response, and other hazards of debilitation, including cellular and mitochondrial impairments.
   3. To reduce short- and long-term morbidity (eg, infectious episodes of various origins such as respiratory and intravenous [IV] catheter-related infections or postoperative complications) and mortality. Evidence in this regard exists for both in- and outpatients suffering from different diseases (eg, human immunodeficiency virus, cancer requiring bone marrow transplant).[11,12]
   4. To avoid or diminish the rate of long-term disabilities. Cognitive and behavioral development is influenced by adequate nutrition. For instance, extreme situations such as failure to thrive—as well as singular deficiencies regarding iron, iodine, zinc, and so forth—have been associated with poor cognitive and behavioral performances in children of different ages. Energy and nutrients such as polyunsaturated fatty acids (PUFA) are also implicated in cognitive and behavioral performance.[13–15]
   5. To reduce costs for the patient and for the health care system. With the advent of home-based nutrition support and the reduction in complication rates, patients tend to have briefer hospitalizations. The choice of nutrition intervention has a profound impact on costs. A report on home nutrition support showed enteral nutrition (EN) to cost, on average, one sixth of home parenteral nutrition (PN) and to halve the hospital admissions/year/patient rate.[16]
   6. To improve quality of life. Although difficult to assess and quantify, quality of life appears to be enhanced, especially during home nutrition support. Happiness, activity, sense of freedom, and willingness to socialize were reported to be improved in children on both home EN and PN.[17,18]

E. Goals of nutrition support in adults
   1. The primary goal of nutrition support in adults should be to improve clinical outcome. To achieve this goal, provision of nutrition support is based on two different rationales:
      a) To prevent starvation-induced complications (eg, death, infection). This rationale is indisputable and includes patients who, without nutrition support, would eventually die from starvation because they cannot eat.
      b) To alter favorably the natural history or treatment of a specific disease process.
         (1) This goal is based on correcting nutritional or metabolic deficiencies that arise from a disease or treatment so that outcome will improve.
         (2) The role of nutrition support in this scenario is controversial because improvements in prognostic markers such as serum protein concentrations, nitrogen balance, and weight gain have not consistently been accompanied by clinical benefits.[19–21]
   2. Nutrition therapy should be directed toward a specific objective, with the intent of improving outcome. Depending on the patient's nutritional status and clinical condition, this objective may be as follows:
      a) To diminish the rate of weight loss and body protein turnover. This is the goal in markedly catabolic patients (eg, severely injured patients).
      b) To maintain body weight and lean body mass. This is the goal in patients who cannot eat for indefinite or long periods: patients with certain intestinal disorders (eg, short-bowel syndrome, long-term obstruction), permanent neurologic impairment, or oropharyngeal dysfunction.
      c) To achieve weight gain and anabolism. This is the goal in depleted patients.

II. Overall Nutritional Requirements

A. The human body requires the daily provision of macronutrients (carbohydrates, fats, and proteins) and micronutrients (vitamins and trace elements) along with water and electrolytes. Macronutrients have an energetic and structural-functional role, while micronutrients are vital regulators of cellular, metabolic, or structural components. Nutrient requirements have been established according to age, gender, weight, and/or height.

B. For patients under medical care, nutrients can be delivered enterally and/or parenterally. The enteral route includes the physiological route of ingestion of food by mouth as well as the introduction of nutrients directly into the stomach or duodenum/jejunum by enteric tubes or stoma. Nutritional requirements depend on the patient's health status. Nutritional requirements for healthy people refer specifically to food ingested orally. Those for people using PN are set for people with acute or chronic illness that renders their gastrointestinal tract either nonfunctional or inaccessible. The requirements for healthy people or for people using PN can indirectly be applied to EN, but only partially and with adjustments. Recommendations for the enteral and the parenteral requirements can overlap.

C. Given extreme inter- and intrapersonal variability and difficulties in assessing nutrient requirements in studies on healthy subjects, suggested intakes are reference standards and are continuously revised to reflect advances in knowledge. Requirements have been extensively investigated for energy, protein, and some micronutrients. The list is growing, however, and other nutrients such as specific lipids and fibers are now included. For each nutrient, specific indicators are used to set the requirements.

D. Energy is measured in calories (in the United States) with specific respect to its individual components:
   1. Basal metabolic rate (BMR): the energy necessary to allow normal function at the cellular, organ, and systemic levels, and to maintain homeostasis, body temperature, and heart and respiratory rate when the body is in a fasted state for 12 hours, awake, and in a thermoneutral environment. BMR decreases proportionally with age.[22] Approximately two thirds of BMR is used by the fat-free mass in both adults and children.[23] More specifically, BMR is directly proportional to metabolically active organ mass such as heart, central nervous system, liver, and kidneys in infants and children, and to metabolically active muscle mass in adults.[24] BMR at rest, but not fasted, is called resting energy expenditure (REE). REE and BMR are often used interchangeably, even though the former can be approximately 10% higher than the latter. In young infants, growth may account for as much as 25% to 33% of total energy expenditure.
   2. Thermic effect of food (TEF): the energy required to allow digestion, absorption, and storage of nutrients. TEF is influenced by energy intake, time of delivery, and meal composition for both EN and PN.[25] The highest thermic effect is seen for proteins (protein synthesis from amino acids requires 25% to 57% of their energy content), followed by carbohydrates (glycogen from glucose requires 4%) and lipids (lipids from lipids or glucose require 2% and 28%, respectively).[26] Metabolic response to food (TEF) may account for 5% to 10% of energy expenditure.
   3. Losses: the energy lost in stool and urine.
   4. Activity: the energy required for physical activity. Activity requirements are expressed as percentage increases over BMR requirements. With regard to activity, percentage increases over BMR requirements can range from 5% to 10% of the daily energy expenditure in premature neonates and up to 50% in 8- to 12-year-old children. These values decrease with illnesses and hospitalization. Activity typically represents about a 5% increase over BMR in hospitalized adults but can be much higher.[27]
   5. Growth: the energy cost for new tissue to be generated. It is approximately 5 kcal/g of body weight, ranging from 3 to 6 kcal/g according to type of tissue. Except in young infants, growth represents a very small part of the total energy requirement.[28]
   6. Illness/stress: any amount of energy to overcome other nonphysiologic or "stress" conditions, usually expressed by a BMR correction factor.
   7. The sum of the first five energy components above is called total energy expenditure (TEE). Each component should not be seen as a separate contributor to TEE, as they are all intertwined and subject to wide variability.
   8. The minimum level of energy compatible with health is termed *maintenance energy requirement.*

E. Proteins (nitrogen) are critical for body homeostasis. Appropriate nitrogen and energy intakes along with body metabolism help maintain nitrogen balance. In disease states, due to higher turnover and catabolism of endogenous proteins, this balance may become negative. Although proteins are not one of the two major macronutrients for supplying energy, they can be used for energy when energy intake is insufficient.

F. Lipids are energy dense, facilitate the absorption of fat-soluble vitamins and their precursors, and are structural components of cell membranes and some hormones. They consist of saturated and unsaturated (mono- and polyunsaturated) fatty acids, phospholipids, and

cholesterol. Among these, only the PUFA (omega-3 and omega-6) are essential components of the diet, as humans cannot synthesize them. For this reason, dietary reference intakes have been set only for PUFA. For the others, only limitations of daily intakes are available. The recent attention to PUFA is due to their immunomodulatory effects: anti-inflammatory effects in the omega-3 series and pro-inflammatory effects in the omega-6 series, through modulation of different prostaglandins, thromboxanes, leukotrienes, and lipoxins.[29] Other PUFA functions include alteration in membrane fluidity, additional immunomodulatory effects through intracellular signal transduction and changes in gene expression, and modifications of the intestinal bacterial ecosystem due to a hypothesized disruption of the wall membrane.[29] They are also important for development and maintenance of the eye and brain.

G. Fiber requirements have been set because of the recently recognized importance of functional fibers. All fibers are nondigestible carbohydrates, but functional fibers are defined as those that have beneficial physiological effects in humans. These beneficial effects include laxation, improvement in blood lipid concentrations, and reduction in glycemic response. Different functional fibers demonstrate differing effects on these physiological responses.

H. Micronutrient requirements remain largely empirical due to assessment problems and lack of knowledge. Vitamin requirements are better characterized than those of trace elements.

III. Nutritional Requirements for Health and Disease (Enteral and Parenteral Nutrition)

A. Premature infants

1. The goal is to achieve a postnatal growth rate approximating normal fetal intrauterine growth rates (weight, length, and head circumference). This is not usually possible in the first 1 to 2 weeks of life. Growth parameters are routinely plotted on Babson-Benda or Lubchenco growth grids to determine trends. Weight gain should approximate 10–20 g/kg/day for preterm infants After reaching 2.5 kg, daily weight gain is around 20 to 30 g/day. Length and head circumference gains are expected to be between 0.7 and 1 cm/week.[30] The goal is accretion of protein, fat, and minerals approximating normal fetal intrauterine accretion rates.
2. EN and PN requirements are shown in Table 2-1.[31–39]
   a) Energy. Actual energy needs are affected by weight, gestational age, postnatal age, gender, environment, feeding regimen and composition, activity, rate of growth, and development. Energy needs increase with fever, cardiac failure, major surgery, severe sepsis, long-term growth failure, protein-calorie malnutrition, and chronic lung disease (bronchopulmonary dysplasia [BPD]). Energy intake below or above requirements may lead to growth retardation or excessive fat accumulation, respectively.
      (1) EN. The energy requirement for premature infants is approximately 120 kcal/kg/day (50 kcal/kg for maintenance plus 70 kcal/kg for a daily weight gain of 15 g/kg), with a range of 105 to 130 kcal/kg/day. Most energy components are extrapolated from the norm to provide adequate energy for catch-up growth, high energy costs of thermoregulation and body functions, and inefficient utilization of ingested nutrients.
      (2) PN. Because energy is not required for digestion, there are no absorptive losses, activity is limited, and cold stress is reduced, energy requirements for PN are lower than for EN. After the first 2 weeks of life, energy intake of 90 to 120 kcal/kg/day promotes weight gains approximating the intrauterine growth rate. Greater weight gains associated with greater energy intakes are thought to reflect fat deposition.[35] In conditions such as BPD, 150 kcal/kg/day may be required. Both carbohydrate and fat are provided as energy sources to provide a balanced PN formulation. Provision of fat in addition to carbohydrate for energy decreases the volume needed for the PN formulation, decreases the respiratory quotient, may help avoid fatty infiltration of the liver, and prevents deficiency of essential fatty acids.
   b) Protein. The protein requirement varies according to body weight and is highest in the most immature infants. Provision of amino acids is necessary to reverse the 1% daily loss of endogenous protein stores by premature infants. The protein loss begins the first day after birth. Clinical conditions including surgery, necrotizing enterocolitis, sepsis, and BPD may increase protein requirements.
      (1) Net protein utilization depends on energy intake. Protein utilization ensures growth and minimizes complications. High rates of protein utilization (protein not used exclusively as an energy source) are achieved with 150 to 200 nonprotein kcal per g of nitrogen (24–32 nonnitrogen kcal per g of protein). If energy intake is deficient (<150 nonprotein kcal per g of nitrogen), endogenous proteins are oxidized to produce the needed energy and nitrogen balance becomes negative. If protein intake is suboptimal, increasing energy intake will spare protein for lean tissue gain, but only up to a certain level. Above this level, protein gain plateaus.
      (2) Conditionally essential amino acids for preterm infants include tyrosine, cysteine, and taurine in addition to the other amino acids essential for term infants.
      (3) EN. The protein requirement for appropriate growth in premature infants is estimated at 2.5 to 4 g/kg/day, which is primarily devoted to preserving or depositing lean body mass. Excessive protein administration (>6 g/kg/day) has been associated with adverse effects, including azotemia, pyrexia, and lower IQ scores. Inadequate (<2.5 g/kg/day) protein intake is associated with slow growth and decreased nitrogen retention.[31]
         (a) Human milk varies with stage of lactation. Early milk is 60% to 90% whey protein and 10% to 40% casein. Within 1 to 2 weeks, the ratio becomes closer to 50:50.
         (b) Formulas designed for premature infants or fortified human milk are required to provide adequate protein. Standard infant formulas do not provide adequate protein.
      (4) PN. The protein requirement to approximate intrauterine nitrogen accretion is estimated at 3 to 4 g/kg/day, with a minimum concomitant delivery of 60 to 90 nonprotein kcal/kg/day. Azotemia may result from administration of >4 g/kg/day in low birth weight infants. Current practice is to initiate amino acids just after birth at variable doses of 1 to 3 g/kg/day. Doing so could decrease subsequent protein requirements for catch-up growth. The target for normalization of plasma amino acids during PN is generally set at the postprandial amino acid concentrations for the term breast-fed infant. For this reason, specific amino acid formulations have been designed with the addition of taurine, glutamate, aspartate, and cysteine; the reduction

TABLE 2-1. Guidelines for Daily Nutrient Intakes of Enterally or Parenterally Fed Preterm Infants[31–39]

Nutrient	Unit measurement	Suggested enteral intake	Suggested parenteral intake
Fluid	mL/kg/day	120–200	100–150
Energy	kcal/kg/day	105–130	90–120
Protein	g/kg/day	2.5–4	3–4
Carbohydrate	40%–50% total energy	6–15 mg/kg/minute	
Fat	40%–55% total energy		
	g/kg/day	5–7	1–3
Minerals			
Calcium	mg/kg/day	100–220	40-80
Phosphorus	mg/kg/day	60–140	31-62
Magnesium	mg/kg/day	8–15	3.6-6
Iron	mg/kg/day	2–4	—
Sodium	mEq/kg/day	2–7	2–5
Potassium	mEq/kg/day	2–3	2–4
Chloride	mEq/kg/day	2–7	As needed to maintain acid-base balance
Zinc	mcg/kg/day	600–3000	400
Copper	mcg/kg/day	110–160	20
Iodine	mcg/kg/day	30–60	1
Selenium	mcg/kg/day	1.3–4.5	1.5-2
Chromium	mcg/kg/day	0.1–2.25	0.05-0.2
Molybdenum	mcg/kg/day	0.3	0.25
Manganese	mcg/kg/day	0.75–7.5	1
Vitamins			
Vitamin A*	IU/kg/day max 700 mcg/day)	700–1500	1643; max 2300 IU/day (500 mcg/kg/day,
Vitamin D**	IU/day 10 mcg/day	400	160; max 400 IU/day (4 mcg/day; max
Vitamin E***	IU/day	6–12	2.8; max 7 IU/day (2.8 mg; max 7 mg/day)
Vitamin K	mcg/kg/day	8–10	80; max 200 mcg/day
Thiamine	mcg/kg/day	180–240	350; max 1200 mcg/day
Riboflavin	mcg/kg/day	250–360	150; max 1400 mcg/day
Niacin	mg/kg/day	3.6–4.8	6.8; max 17 mg/day
B_6	mcg/kg/day	150–210	180; max 1000/day
B_{12}	mcg/kg/day	0.30	300; max 1000/day
Folic acid	mcg/kg/day	25–50	56; max 140/day
Biotin	mcg/kg/day	3.6–6	6; max 20/day
Pantothenic acid	mg/kg/day	1.2–1.7	2; max 5/day
Vitamin C	mg/kg/day	18–24	25; max 80/day
Carnitine	mg/kg/day	—	10–30

*Vitamin A (retinol) 0.3 mcg = 1 IU.
**Vitamin D 0.025 mcg = 1 IU.
***Vitamin E 1 mg = 1 IU.
The following conversion factors apply to: Ca 40 mg=1 mmol=2 mEq; P 31 mg=1 mmol; Mg 24 mg=1 mmol=2 mEq; Na 23 mg=1 mmol= 1 mEq; K 39 mg=1 mmol= 1 mEq; Cl 35 mg=1 mmol= 1 mEq.

of methionine, glycine, and alanine; and an increase of arginine and leucine. The N-acetyl-L-tyrosine salt is a more soluble form of tyrosine. Cysteine, along with glutamine and glycine, is a precursor of glutathione. These formulations have been demonstrated to improve weight gain, nitrogen balance, and mineral solubility.

c) Carbohydrate. Carbohydrate delivery is recommended to be 40% to 50% of the total caloric intake. Infants with chronic lung diseases benefit from as little as 35% of energy as carbohydrates.
   (1) EN. The carbohydrate composition of preterm infant formulas is generally equally divided between lactose and glucose polymers.
      (a) Glucose polymers may be digested more effectively than lactose by premature infants early in life.
      (b) Glucose polymers contribute fewer osmotic particles to formula than do individual glucose molecules.
      (c) Lactose appears to lower intestinal pH, facilitating absorption of some minerals (eg, calcium) and development of normal flora.
      (d) Functional fibers or prebiotics such as galactooligosaccharide and oligofructose may improve the intestinal ecosystem (development of beneficial flora such as *Lactobacillus* and *Bifidobacterium,* change in pH, enterocyte and immune system maturation). Oligosaccharides are present in breast milk but not current North American formulas.
   (2) PN. Carbohydrate is provided as dextrose (D-glucose) in the monohydrate form at 3.4 kcal/g. Dextrose is the major contributor to the osmolarity of the PN formulation.
      (a) Current practice is to initiate glucose approximating the rate of endogenous glucose production (6 mg/kg/minute for infants weighing <1000 g; 8 mg/kg/minute for infants weighing >1000 g) with stepwise advancements of 1 to 2 mg/kg/minute to a maximum of 15 mg/kg/minute to optimize glucose tolerance. Serum and urine glucose monitoring provides an indication of acute intolerance reflected as hyperosmolarity and osmotic diuresis. Glucose delivery of >26 mg/kg/minute may result in fatty infiltration of the liver.
      (b) Nonprotein calories need to be balanced between glucose and fat. Glucose without fat increases water retention and may thereby worsen existing respiratory compromise. Glucose alone may exacerbate fatty infiltration of the liver.

d) Lipids. Fat delivery is recommended to be at 40% to 55% of total calories. The essential fatty acid requirement is estimated at approximately 3–12% of total calories.
   (1) EN. The lipid requirement is 4.5 to 6 g/100 kcal, or 5 to 7 g/kg/day.
      (a) The recommended omega-6 (C18:2ω-6) to omega-3 (C18:3ω-3) ratio ranges from 5:1 to 15:1, while the ratio of their derivatives, docosahexaenoic acid (DHA) (C22:6ω-3) to arachidonic acid (ARA)(C20:4ω-6), ranges from 1:1 to 1:2.7. Inclusion of one international unit of vitamin E per g of linoleic acid will prevent peroxidation of unsaturated lipids in food and tissues. PUFA content has been revised in some formulas to include DHA and ARA.
      (b) Premature infants (especially if <34 weeks of gestational age) may absorb and use medium-chain triglycerides (MCT) more effectively than long-chain ones, because their concentration of bile salts is low. Formulas for premature infants include both MCT and long-chain triglycerides in various concentrations. The European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) has recommended limiting the amounts of MCT to <40% of total calories in preterm formula.[40] MCT do not provide essential fatty acids and do not promote the absorption of minerals. Therefore, essential fatty acids and fat-soluble vitamins have to be supplied when formulas with high MCT content (>80%) are used.
   (2) PN. Lipids are provided as IV fat emulsions (IVFE) (see Chapter 7) at a dose of 1 to 3 g/kg/day (30%–60% of nonprotein calories when full calories are administered). Lipids should be provided from the first day of life, because premature infants do not have essential fatty acid stores. Serum triglycerides should be monitored, with values <200 mg/dL considered acceptable. A continuous infusion and 20% IVFE promote optimal metabolic tolerance. No adverse effects have been observed in terms of lung dysfunction.

e) Fluids. Fluid requirements are generally higher for EN than PN and should take into account the following points:
   (1) Diuresis during the first 1 to 2 weeks of life results in a 5% to 15% weight loss in premature infants. Fluids must be adjusted accordingly, based on urine parameters (maintenance of specific gravity between 1.010 and 1.016 g/mL, flow 2–3 mL/kg/hour by day 3 and up to 6 mL/kg/hour later, osmolality 200–400 mOsm/kg of water) and normal serum sodium values.
   (2) Higher fluid intake may be required to meet energy needs after 2 weeks of life. Tolerance to increased fluids depends on the clinical condition (eg, BPD and patent ductus arteriosus are exacerbated by excessive fluid intake). Premature infants are susceptible to both dehydration and fluid overload.
   (3) The infant's environment and other factors directly affect fluid requirements. Examples that increase requirements are exposure to radiant warmers, phototherapy, fluid losses (diarrhea, glycosuria), or respiratory distress. Examples that decrease requirements are oliguria and conditions of neutral thermal range or high ambient humidity.
   (4) EN. Ranges are 120 to 200 mL/kg/day or 100 to 160 mL/100 kcal. Infants weighing <1000 g preferably require 150 to 200 mL/kg/day. Infants weighing >1000 g require 120 to 150 mL/kg/day.
   (5) PN. Infants weighing <1000 g require 150 mL/kg/day; infants weighing >1000 g require 100 to 150 mL/kg/day. Some infants require >150 mL/kg/day, depending on their environmental situation.

f) Vitamin, mineral, and trace element recommendations for EN and PN have been developed for premature infants (Table 2-1).[31–39] PN requirements are generally lower than EN requirements.
   (1) Vitamins. Preterm infants do not have fat-soluble vitamin reserves at birth. Requirements may change based on the quality and quantity of nutrient intake.
      (a) EN. In general, specific formulas and fortified breast milk supply adequate amounts. Most water-soluble

vitamins are affected by macronutrient intake and exposure to environmental factors. For instance, exposure to light or phototherapy destroys riboflavin.

(b) PN. A preterm parenteral multivitamin preparation has not yet been developed. Current practice is to use 2 mL/kg/day of a pediatric multivitamin to a maximum of 5 mL/day. The American Society for Clinical Nutrition recommends intakes of 500 mcg/kg/day vitamin A and approximately 3 mg/kg/day of vitamin E, and these should be started just after birth.[37] When other intakes are compared with estimates, at the current doses, water-soluble vitamins largely cover the recommended needs. Ascorbic acid and riboflavin are given in excess.

(2) Minerals. Premature infants require higher calcium, phosphorus, and magnesium intakes than do term infants to promote intrauterine accretion rates and to prevent osteopenia. An infant in utero accrues 75% of its total body calcium from gestation weeks 24 to 40. Drugs such as corticosteroids, furosemide, theophylline, and caffeine cause calcium loss. Due to high urinary sodium losses during the first 3 weeks of life, premature infants require more sodium. Therefore, 5 to 7 mEq/kg/day of sodium are recommended in infants <32 weeks gestational age, while 3 to 5 mEq/kg/day are more appropriate for less premature infants. After that critical time and upon stabilization and growth, premature infants require 2 to 4 mEq/kg/day of sodium along with equal amounts of chloride and potassium. Some of the anion is commonly provided as acetate to decrease the likelihood of metabolic acidosis.

(a) EN. The following points are emphasized:

i) Mineral bioavailability averages 60% for calcium, 70% for phosphorus, and 50% for magnesium. Mineral absorption is improved with the addition of MCT, lactose, enrichment with vitamin D and minerals, and appropriate quantity of calcium and phosphorus.

ii) Standard infant formulas and unfortified human milk do not provide enough calcium and phosphorus to meet the mineral needs of preterm infants. Fortified human milk or formulas specifically designed for premature infants provide higher calcium and phosphorus delivery and appropriate amounts of sodium, potassium, and chloride (see Chapter 4).

iii) Preterm infants require more iron. Iron requirements are between 2 and 4 mg/kg/day, to be started within 2 months of age or at doubling of weight. Iron absorption is enhanced in premature infants. Formulas specifically for premature infants are iron fortified (see Chapter 4).

(b) PN. Specific IV recommendations are as follows: A calcium-phosphorus ratio of 1.3:1 (≥1:1 molar) replicates the fetal mineral accretion ratio and allows for the highest retention of both minerals, provided they are supplied together and daily. Addition of calcium and phosphorus to PN is limited by solubility (see Chapter 7). Cysteine HCl increases calcium/phosphorus solubility. It is frequently impossible to provide adequate amounts of these minerals for prevention of osteopenia in infants requiring long-term PN. Long-term diuretic use or aluminum contamination of the components of PN formulations may further deplete calcium reserves. At birth, the magnesium level is elevated and, upon its normalization, IV supplementation can start.

(3) Trace elements. Zinc and copper are required for growth. Deficiencies of zinc (alteration of the intestine, skin, immunity, and growth) and copper (hypochromic anemia, osteoporosis, and neutropenia) can occur. Zinc requirements may increase in infants with high stool output, gastrointestinal fluid losses, or renal failure.

(a) EN. Zinc and copper have a limited absorption rate: 36% and 60% from fortified human milk and preterm formula for zinc, and 10% to 30% for copper. They exhibit competition for absorption and may be involved in drug-nutrient interactions. Recommendations for zinc are 600 to 1500 (up to 3000) mcg/kg/day and for copper 110 to 160 mcg/kg/day.

(b) PN. Copper and manganese need to be omitted in the presence of cholestasis as indicated by direct bilirubin > 2 mg/dL. Selenium, chromium, and molybdenum need to be omitted in infants with renal dysfunction.

g) Other. Carnitine: Premature infants receiving exclusively PN need carnitine to allow fat oxidation at the mitochondria. Estimates range from 10 and 20, with supplementation up to 30 mg/kg/day without risk of side effects.

B. From infancy to adolescence

1. The child's age-specific regular growth and development are the final tests of nutritional needs. Appetite and self-selection usually result in adequate nutrient intake for the normal, healthy child. When illness or physical disability prevent adequate nutrient intake, requirements must be artificially determined considering the disease factor involved. In this case, ongoing reassessments of many nutrients are essential, especially for energy expenditure. For healthy children and adults, a joint committee of the governments of Canada and the United States, after reassessing the previous recommended dietary allowances (RDAs) plus the qualities of subsequent studies, has developed dietary reference intakes (DRI) (full reports are available at www.nap.edu). DRI define the levels of nutrient intake that are necessary to achieve good health and avoid adverse effects. These levels, obtained after selecting specific indicators, are age-specific and identify first and second semesters (0–6 months and 7–12 months) of life, infants, toddlers, children, and adolescents. No similar age-specific nutritional recommendations are available for sick children nourished either enterally or parenterally. DRI include the RDA plus three other reference values[41,42]:

a) Adequate intake (AI): the usual intake at or above which there is a low probability of inadequacy (replaces RDA when RDA cannot be determined)

b) Tolerable upper level (UL): the average daily nutrient intake level above which adverse effects may arise

c) Estimated average requirement (EAR): the average daily nutrient intake level that meets the requirements of half the healthy individuals of a specific age and gender

2. Energy needs. Pediatric energy needs originate from maintenance, activity, and growth. Each component is subject to age variability because maintenance progressively declines from birth to adolescence, activity increases during childhood, and growth has two major spikes during infancy and adolescence.

TABLE 2-2. Criteria and Dietary Reference Intake Values for Energy by Active Individuals by Life Stage Group*[43]

Life stage group	Active PAL EER (kcal/day)		
	Criterion	Male	Female
0–6 mos	Energy expenditure plus energy deposition	570	520 (3 mos)
7–12 mos	≤	743	676 (9 mos)
1–2 yrs	≤	1046	992 (24mos)
3–8 yrs	≤	1742	1642 (6 yrs)
9–13 yrs	≤	2279	2071 (11 yrs)
14–18 yrs	≤	3152	2368 (16 yrs)

EER = estimated energy requirement; PAL = physical activity level.
*For healthy, moderately active Americans and Canadians.
Printed with permission from the Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients).* Washington, DC: National Academy Press; 2002.

TABLE 2-3. Equations for Predicting REE from Body Weight[45]

Sex and age range (yrs)	Equation to derive REE (kcal/day)
Male	
0– < 3	(60.9 x wt) – 54
3– <10	(22.7 x wt) + 495
10–18	(17.5 x wt) + 651
Female	
0– < 3	(61 x wt) – 51
3– <10	(22.5 x wt) + 499
10–18	(12.2 x wt) + 746

REE, resting energy expenditure; wt = weight in kilograms.
Printed with permission from World Health Organization. Energy and Protein Requirements Technical Report Series, No 724. Geneva, Switzerland: World Health Organization; 1985.

a) EN
   (1) Energy needs for healthy infants/children/adolescents. The estimated requirement is defined as the average dietary energy intake that is predicted to maintain energy balance in healthy individuals of a defined age, gender, weight, height, level of physical activity, and deposition of new tissues. Physical activity is classified into four levels (sedentary, low active, active, and very active) with different coefficients. The activity-level coefficient is approximately 1.25 to 1.4. Estimates have been extrapolated from reported energy intakes and body mass index data, factorial approaches, and measurements of energy expenditure by double-labeled water. Table 2-2 summarizes the recommended energy intake.[43]
   (2) Energy needs for stressed infants/children/adolescents. See PN section.
b) PN
   (1) In the presence of illness or disability, DRI may not apply secondary to decrease in activity or growth or change in thermic effect of food. Energy expenditure may shift from growth to the needs of acute illness.[44]
   (2) The starting point for the estimation of an individual's energy expenditure is the BMR or the REE. Approaches for estimating BMR or REE differ according to the number of variables included (eg, age, sex, weight, height.) The World Health Organization equations are two examples of energy expenditure estimates based on weight, age, and/or sex (see Tables 2-3 and 2-4).[45–47]

TABLE 2-4. Basal Metabolic Rate Requirement in kcal/Day Based on Body Weight[46,47]

Kg	Male	Female	Kg	Male	Female	Kg	Male	Female	Kg	Male	Female
3	150 (120*)	136 (144*)	16	750	747	38	1305	1207	62	1660	1572
4	210 (191*)	205 (191*)	17	780	775	40	1340	1241	64	1690	1599
5	270	274	18	810	802	42	1370	1274	66	1725	1626
6	330	336	19	840	827	44	1400	1306	68	1765	1653
7	390	395	20	870	852	46	1430	1338	70	1785	1679
8	445	448	22	910	898	48	1460	1369	72	1815	1705
9	495	496	24	980	942	50	1485	1399	74	1845	1731
10	545	541	26	1070	984	52	1505	1429	76	1870	1756
11	590	582	28	1100	1025	54	1555	1458	78	1900	1781
12	625	620	30	1140	1063	56	1580	1487	80	1935	1805
13	665	655	32	1190	1101	58	1600	1516	82	1970	1830
14	700	687	34	1230	1137	60	1630	1544	84	2000	1855
15	725	718	36	1270	1173						

*From reference 46. These values differ from those in reference 47. Printed with permission from World Health Organization. Energy and Protein Requirements Technical Report Series, No 522. Geneva, Switzerland: World Health Organization; 1973.

Table 2-5. Daily Energy Requirements for Pediatric Patients on Parenteral Nutrition[38]

Age	kcal/kg
<6 mos	85–105
6–12 mos	80–100
>1–7 yrs	75–90
>7–12 yrs	50–75
>12–18 yrs	30–50

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(3) Illness tends to decrease activity but may increase energy expenditure. Therefore, estimates of BMR or REE (Tables 2-3 and 2-4) must be corrected by a factor of 0.7 for starvation, 1 to 1.2 for minimal stress, 1.2 to 1.5 for moderate stress, and 1.5 to 2 for severe stress.

(4) Indirect calorimetry may be used to determine the actual energy expenditure of a specific child with greater accuracy. Measurements of resting metabolic expenditure can be adjusted for activity and other factors as needed. This determination may help to reduce the likelihood of under- or overfeeding. See Chapter 22.

(5) Energy estimates for pediatric patients on PN are provided by A.S.P.E.N. (Table 2-5).[38] Regardless of the energy recommendations used, calorie distribution among lipids, carbohydrates, and proteins should be carefully prescribed.

3. Protein needs

a) EN

(1) Healthy infants/children/adolescents. DRI values may be used to determine protein needs. Acceptable protein intake should range between 10% and 20% of total calories. These values are based on a combination of intake, growth, nitrogen accretion, and nitrogen balance data. AI (or RDA) and EAR are also provided (Table 2-6).[43]

(2) Stressed infants/children/adolescents. See PN section.

b) PN

(1) In the stressed child, protein requirements are increased. Rates of catabolism and synthesis of proteins are higher. Protein recommendations are listed in Table 2-7.[38]

(2) Provision of approximately 12% to 16% of calories as protein minimizes negative nitrogen balance.

(3) To maximize protein utilization and avoid gluconeogenesis, appropriate calorie distribution and intake are essential. A nonprotein calorie-to-nitrogen ratio of 150:1 to 300:1 is most likely to achieve positive nitrogen balance. The ratio should be determined based on age, metabolic stress, nutritional intake and status, and ongoing losses.

(4) 1 g/kg/day daily advances in protein intake are suggested, after starting at an initial rate of 0.5 g/kg/day.

(5) All formulations contain crystalline amino acids.

(a) Children under 1 year of age have special amino acid requirements, and therefore the IV formulations used are as discussed under the PN section for premature infants. In patients older than 1 year, adult formulations can be used. These formulations are designed to

Table 2-6. Criteria and Dietary Reference Intake Values for Protein by Life Stage Group[43]

		AI or RDA for Reference Individual (g/day)		EAR (g/kg/day)		RDA (g/kg/day)			
Life stage Ggroup	Criteria	Male	Female	Male	Female	Male	Female	AI (g/kg/day)	AMDR %
0–6 mos	Average consumption of protein from human milk	9.1 (AI)	9.1 (AI)		1.52	ND			
7–12 mos	Nitrogen equilibrium + protein deposition	13.5 (AI)	13.5 (AI)	1.10	1.10	1.50	1.50	ND	
1–3 yrs	"	13.0	13.0	0.88	0.88	1.10	1.10	5–20	
4–8 yrs	"	19.0	19.0	0.76	0.76	0.95	0.95	10–30	
9–13 yrs	"	34.0	34.0	0.76	0.76	0.95	0.95	10–30	
14–18 yrs	"	52.0	46.0	0.73	0.71	0.85	0.85	10–30	
>18 yrs	Nitrogen equilibrium	56.0	46.0	0.66	0.66	0.80	0.80	10–35	

AI, adequate intake (the observed average or experimentally determined intake by a defined population or subgroup that appears to sustain a defined nutritional status, such as growth rate, normal circulatory nutrient values, or other functional indicators of health; used if sufficient scientific evidence is not available to derive an EAR; for healthy infants receiving human milk, the AI is the mean intake; not equivalent to an RDA); AMDR, acceptable macronutrient distribution range (the intake for a particular energy source associated with a reduced risk of chronic disease while providing intakes of essential nutrients); EAR, estimated average requirement (the intake that meets the estimated nutrient needs of half of the individuals in a group); ND, not determinable; RDA, recommended dietary allowance (the intake that meets the nutrient need of almost all [97%–98%] individuals in a group).

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Table 2-7. Daily Protein Requirements for Children on Parenteral Nutrition with Normal Organ Function[38]

Age	g/kg
Neonates	3–4
Infants (1-12 months)	2–3
Children (above 10 kg or 1 through 10 years)	1–2
Adolescents (11 through 17 years)	0.8–1.5

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meet the amino acid requirements of orally fed adults and contain high levels of methionine, glycine, and phenylalanine and low levels of branched-chain amino acids, cysteine, and tyrosine.

(b) Glutamine, a primary fuel for intestinal mucosa and immune cells and precursor for nucleotide synthesis and the antioxidant glutathione, seems to improve nitrogen balance, gut barrier functions, and mortality and morbidity in selected patients. Limited stability in PN still limits its use in the United States.

4. Carbohydrate. Without carbohydrate in the diet, lipolysis, limited ketone accumulation, and transient protein breakdown may occur. Fifty to 100 g per day of carbohydrate usually prevents or minimizes these effects.
   a) EN. The subcommittee on the 10th edition of the RDA recommended that beyond infancy, greater than 50% of energy needs be given as carbohydrate to limit fat and possibly protein intake in the diet.[41] The acceptable carbohydrate intake as a percentage of energy should be 45% to 65% of total calories in all age groups. EAR for carbohydrates has been established only for older adolescents and adults, based on the average amount of glucose used by the brain. Pediatric data have been extrapolated from adults (Table 2-8).[43]
   b) PN. Carbohydrates should comprise 40% to 60% of the total caloric intake. Dextrose monohydrate is used as the major source of energy in PN and contributes to PN osmolality. Glucose infusion rates of 5 to 13 mg/kg/minute are generally tolerated. Above 14 mg/kg/minute, complications such as liver fatty infiltration, hypertriglyceridemia, hyperglycemia, and excessive carbon dioxide production may occur. In general, the infusion rate usually starts at 5 to 7 mg/kg/minute and advances daily by 2 to 4 mg/kg/minute.
5. Fat. Fat requirements range from 25% to 55% of total calories, with a minimum requirement of 3% to 4% of calories as essential fatty acids (1%–3% as linoleic and close to 1% as linolenic acid).
   a) EN. Fat does not have DRI values, with few exceptions (AI for infants of 31 g/day in the age range 0–6 months and 30 g/day from 7–12 months, obtained from average consumption data of total fat from human milk). More detailed recommendations are available for the essential PUFA (Table 2-9).[43] The American Academy of Pediatrics Committee on Nutrition and the National Cholesterol Education Program have agreed that fat and cholesterol should not be restricted in children less than 2 years of age. In children over 2 years of age, the American Academy of Pediatrics recommends 30% of calories from fat, with less than 10% from saturated fat, and less than 300 mg of cholesterol daily. Acceptable enteral fat intake as a percentage of energy is 25% to 30% (up to 55% in infants).

Table 2-8. Criteria and Dietary Reference Intake Values for Carbohydrate by Life Stage Group[43]

Life stage group	Criteria	EAR (g/day)		RDA (g/day)		AI (g/day)	AMDR %
		Male	Female	Male	Female		
0–6 mos	Average content of human milk					60	ND
7–12 mos	Average intake from human milk plus complementary foods					95	ND
1–3 yrs	Extrapolation from adult data	100	100	130	130		45–65
4–8 yrs	Extrapolation from adult data	100	100	130	130		45–65
9–13 yrs	Extrapolation from adult data	100	100	130	130		45–65
14–18 yrs	Extrapolation from adult data	100	100	130	130		45–65
>18 yrs	Brain glucose use	100	100	130	130		45–65

AI, adequate intake (the observed average or experimentally determined intake by a defined population or subgroup that appears to sustain a defined nutritional status, such as growth rate, normal circulatory nutrient values, or other functional indicators of health; used if sufficient scientific evidence is not available to derive an EAR; for healthy infants receiving human milk, the AI is the mean intake; not equivalent to an RDA); AMDR, acceptable macronutrient distribution range (the intake for a particular energy source associated with a reduced risk of chronic disease while providing intakes of essential nutrients; reflects the source of kcal to maintain body weight); EAR, estimated average requirement (the intake that meets the estimated nutrient needs of half of the individuals in a group); ND, not determinable; RDA, recommended dietary allowance (the intake that meets the nutrient need of almost all [97%–98%] individuals in a group).

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Table 2-9. Criteria and Dietary Reference Intake Values for PUFA by Life Stage Group[43]

		Linoleic Acid			Linolenic Acid		
		AI (g/day)			AI (g/day)		
Life stage group	Criteria	Male	Female	AMDR %	Male	Female	AMDR %
0–6 mos	Average consumption of total fat from human milk	4.4	4.4	ND	0.5	0.5	ND
7–12 mos	Average consumption of total fat from human milk and complementary foods	4.6	4.6	ND	0.5	0.5	ND
1–3 yrs	Median intake of specific PUFA from CSFII	7.0	7.0	5–10	0.7	0.7	0.6–1.2
4–8 yrs	Median intake of specific PUFA from CSFII	10.0	10.0	5–10	0.9	0.9	0.6–1.2
9–13 yrs	Median intake of specific PUFA from CSFII	12.0	10.0	5–10	1.2	1.0	0.6–1.2
14–18 yrs	Median intake of specific PUFA from CSFII	16.0	11.0	5–10	1.6	1.1	0.6–1.2

AI, adequate intake (the observed average or experimentally determined intake by a defined population or subgroup that appears to sustain a defined nutritional status, such as growth rate, normal circulatory nutrient values, or other functional indicators of health; used if sufficient scientific evidence is not available to derive an EAR; for healthy infants receiving human milk, the AI is the mean intake; not equivalent to an RDA); AMDR, acceptable macronutrient distribution range (the intake for a particular energy source associated with a reduced risk of chronic disease while providing intakes of essential nutrients; reflects the source of kcal to maintain body weight); CSFII, Continuing Survey of Food Intake by Individuals; ND, not determinable; PUFA, polyunsaturated fatty acids.

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b) PN

(1) High glucose loads expose the patient to fatty liver infiltration and possibly metabolic and respiratory stresses. The minimum fat requirement is determined by essential fatty acid need, and the daily maximum is 50% to 60% of energy. Fats provide concentrated energy and decrease IV osmolality. Fat emulsion infusion rate starts at 1 g/kg/day with increments of 0.5 to 1 g/kg/day. A 20% fat emulsion supplies 2 kcal/mL. Continuous infusions are better tolerated.

(2) Fat emulsion formulations come from soybean oil, safflower oil, or both, with different long-chain fatty acid (LCFA) content. The combination of MCT with LCFA formulations are under investigation. MCT are better hydrolyzed, with less storage in the body.

6. Fiber. AI estimates are available exclusively for EN. Recommendations are shown in Table 2-10.[43]
7. Vitamins and minerals

a) EN

(1) The DRI provide recommendations based on dietary intakes, a factorial approach of nutrient retention, and estimates of physiological needs extrapolated from previous studies in adults or children (see Tables 2-11 and 2-12).[42,48–50] Upper Levels are also available for most vitamins and minerals. Requirements are usually met by eating a variety of foods. The nutrient content of enteral formulations mirrors these recommendations.

(2) Administration of vitamin K to newborn infants is recommended for the prevention of hemorrhagic disease. Breastfed or formula-fed infants receive one intramuscular dose of 0.5 to 1.0 mg at birth or later, or multiple oral doses of 1.0 to 2.0 mg.

Table 2-10. Criteria and Dietary Reference Intake Values for Total Fiber by Life Stage Group[43]

		AI (g/day)	
Life stage group	Criteria	Male	Female
0–6 mos	—	ND	ND
7–12 mos	—	ND	ND
1–3 yrs	Intake level shown to provide the greatest protection against coronary heart disease (14 g/1000 kcal of required energy) ? median energy intake level (kcal/1000 kcal/day)	19	19
4–8 yrs	"	25	25
9–13 yrs	"	31	26
14–18 yrs	"	38	26
19–50 yrs	"	38	25
>51 yrs	"	30	21

AI, adequate intake (the observed average or experimentally determined intake by a defined population or subgroup that appears to sustain a defined nutritional status, such as growth rate, normal circulatory nutrient values, or other functional indicators of health; used if sufficient scientific evidence is not available to derive an EAR; for healthy infants receiving human milk, the AI is the mean intake; not equivalent to an RDA); ND, not determinable.

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Table 2-11. Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals, Vitamins

Food and Nutrition Board, Institute of Medicine, National Academies

Life stage group	Vit A (μg/d)[a]	Vit C (mg/d)	Vit D (μg/d)[b,c]	Vit E (mg/d)[d]	Vit K (μg/d)	Thia- (mg/d)	Ribo- (mg/d)	Niacin (mg/d)[e]	Vit B_6 (mg/d)	Folate (μg/d)[f]	Vit B_{12} (μg/d)	Panto-thenic acid (mg/d)	Biotin (μg/d)	Choline (mg/d)[g]
Infants														
0–6 mo	400*	40*	5*	4*	2.0*	0.2*	0.3*	2*	0.1*	65*	0.4*	1.7*	5*	125*
7–12 mo	500*	50*	5*	5*	2.5*	0.3*	0.4*	4*	0.3*	80*	0.5*	1.8*	6*	150*
Children														
1–3 y	**300**	**15**	5*	**6**	30.0*	**0.5**	**0.5**	**6**	**0.5**	**150**	**0.9**	2*	8*	200*
4–8 y	**400**	**25**	5*	**7**	55.0*	**0.6**	**0.6**	**8**	**0.6**	**200**	**1.2**	3*	12*	250*
Males														
9–13 y	**600**	**45**	5*	**11**	60.0*	**0.9**	**0.9**	**12**	**1.0**	**300**	**1.8**	4*	20*	375*
14–18 y	**900**	**75**	5*	**15**	75.0*	**1.2**	**1.3**	**16**	**1.3**	**400**	**2.4**	5*	25*	550*
19–30 y	**900**	**90**	5*	**15**	120.0*	**1.2**	**1.3**	**16**	**1.3**	**400**	**2.4**	5*	30*	550*
31–50 y	**900**	**90**	5*	**15**	120.0*	**1.2**	**1.3**	**16**	**1.3**	**400**	**2.4**	5*	30*	550*
51–70 y	**900**	**90**	10*	**15**	120.0*	**1.2**	**1.3**	**16**	**1.7**	**400**	**2.4**[h]	5*	30*	550*
> 70 y	**900**	**90**	15*	**15**	120.0*	**1.2**	**1.3**	**16**	**1.7**	**400**	**2.4**[h]	5*	30*	550*
Females														
9–13 y	**600**	**45**	5*	**11**	60.0*	**0.9**	**0.9**	**12**	**1.0**	**300**	**1.8**	4*	20*	375*
14–18 y	**700**	**65**	5*	**15**	75.0*	**1.0**	**1.0**	**14**	**1.2**	**400**[i]	**2.4**	5*	25*	400*
19–30 y	**700**	**75**	5*	**15**	90.0*	**1.1**	**1.1**	**14**	**1.3**	**400**[i]	**2.4**	5*	30*	425*
31–50 y	**700**	**75**	5*	**15**	90.0*	**1.1**	**1.1**	**14**	**1.3**	**400**[i]	**2.4**	5*	30*	425*
51–70 y	**700**	**75**	10*	**15**	90.0*	**1.1**	**1.1**	**14**	**1.5**	**400**	**2.4**[h]	5*	30*	425*
> 70 y	**700**	**75**	15*	**15**	90.0*	**1.1**	**1.1**	**14**	**1.5**	**400**	**2.4**[h]	5*	30*	425*
Pregnancy														
14–18 y	**750**	**80**	5*	**15**	75.0*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	**2.6**	6*	30*	450*
19–30 y	**770**	**85**	5*	**15**	90.0*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	**2.6**	6*	30*	450*
31–50 y	**770**	**85**	5*	**15**	90.0*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	**2.6**	6*	30*	450*
Lactation														
14–18 y	**1,200**	**115**	5*	**19**	75.0*	**1.4**	**1.6**	**17**	**2.0**	**500**	**2.8**	7*	35*	550*
19–30 y	**1,300**	**120**	5*	**19**	90.0*	**1.4**	**1.6**	**17**	**2.0**	**500**	**2.8**	7*	35*	550*
31–50 y	**1,300**	**120**	5*	**19**	90.0*	**1.4**	**1.6**	**17**	**2.0**	**500**	**2.8**	7*	35*	550*

Note: This table (taken from the DRI reports, see www.nap.edu) presents Recommended Dietary Allowances (RDAs) in **bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). RDAs and AIs may both be used as goals for individual intake. RDAs are set to meet the needs of almost all (97 to 98 percent) individuals in a group. For healthy breastfed infants, the AI is the mean intake. The AI for other life stage and gender groups is believed to cover needs of all individuals in the group, but lack of data or uncertainty in the data prevent being able to specify with confidence the percentage of individuals covered by this intake.

[a] As retinol activity equivalents (RAEs). 1 RAE = 1 μg retinol, 12 μg β-carotene, 24 μg β-carotene, or 24 μg β-cryptoxanthin. The RAE for dietary provitamin A carotenoids is twofold greater than retinol equivalents (RE), whereas the RAE for preformed vitamin A is the same as RE.

[b] As cholecalciferol. 1 μg cholecalciferol = 40 IU vitamin D.

[c] In the absence of adequate exposure to sunlight.

[d] As α-tocopherol. α-Tocopherol includes *RRR*-α-tocopherol, the only form of α-tocopherol that occurs naturally in foods, and the *2R*-stereoisomeric forms of α-tocopherol (*RRR-, RSR-, RRS-,* and RSS-α-tocopherol) that occur in fortified foods and supplements. It does not include the *2S*-stereoisomeric forms of α-tocopherol (*SRR-, SSR-, SRS-,* and *SSS*-α-tocopherol), also found in fortified foods and supplements.

[e] As niacin equivalents (NE). 1 mg of niacin = 60 mg of tryptophan; 0–6 months = preformed niacin (not NE).

[f] As dietary folate equivalents (DFE). 1 DFE = 1 μg food folate = 0.6 μg of folic acid from fortified food or as a supplement consumed with food = 0.5 μg of a supplement taken on an empty stomach.

[g] Although AIs have been set for choline, there are few data to assess whether a dietary supply of choline is needed at all stages of the life cycle, and it may be that the choline requirement can be met by endogenous synthesis at some of these stages.

[h] Because 10 to 30 percent of older people may malabsorb food-bound B12, it is advisable for those older than 50 years to meet their RDA mainly by consuming foods fortified with B12 or a supplement containing B12.

[i] In view of evidence linking folate intake with neural tube defects in the fetus, it is recommended that all women capable of becoming pregnant consume 400 μg from supplements or fortified foods in addition to intake of food folate from a varied diet.

[j] It is assumed that women will continue consuming 400 μg from supplements or fortified food until their pregnancy is confirmed and they enter prenatal care, which ordinarily occurs after the end of the periconceptional period—the critical time for formation of the neural tube.

Table 2-12. Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals, Elements
Food and Nutrition Board, Institute of Medicine, National Academies

Life stage group	Calcium (mg/d)	Chromium (µg/d)	Copper (µg/d)	Fluoride (mg/d)	Iodine (µg/d)	Iron (mg/d)	Magnesium (mg/d)	Manganese (mg/d)	Molybdenum (µg/d)	Phosphorus (mg/d)	Selenium (µg/d)	Zinc (mg/d)	Potassium (g/d)	Sodium (g/d)	Chloride (g/d)
Infants															
0–6 mo	210*	0.2*	200*	0.01*	110*	0.27*	30*	0.003*	2*	100*	15*	2*	0.4*	0.12*	0.18*
7–12 mo	270*	5.5*	220*	0.5*	130*	**11.0**	75*	0.6*	3*	275*	20*	**3**	0.7*	0.37*	0.57*
Children															
1–3 y	500*	11.0*	**340**	0.7*	**90**	**7.0**	**80**	1.2*	**17**	**460**	**20**	**3**	3.0*	1.0*	1.5*
4–8 y	800*	15.0*	**440**	1.0*	**90**	**10.0**	**130**	1.5*	**22**	**500**	**30**	**5**	3.8*	1.2*	1.9*
Males															
9–13 y	1,300*	25.0*	**700**	2.0*	**120**	**8.0**	**240**	1.9*	**34**	**1,250**	**40**	**8**	4.5*	1.5*	2.3*
14–18 y	1,300*	35.0*	**890**	3.0*	**150**	**11.0**	**410**	2.2*	**43**	**1,250**	**55**	**11**	4.7*	1.5*	2.3*
19–30 y	1,000*	35.0*	**900**	4.0*	**150**	**8.0**	**400**	2.3*	**45**	**700**	**55**	**11**	4.7*	1.5*	2.3*
31–50 y	1,000*	35.0*	**900**	4.0*	**150**	**8.0**	**420**	2.3*	**45**	**700**	**55**	**11**	4.7*	1.5*	2.3*
51–70 y	1,200*	30.0*	**900**	4.0*	**150**	**8.0**	**420**	2.3*	**45**	**700**	**55**	**11**	4.7*	1.3*	2.0*
> 70 y	1,200*	30.0*	**900**	4.0*	**150**	**8.0**	**420**	2.3*	**45**	**700**	**55**	**11**	4.7*	1.2*	1.8*
Females															
9–13 y	1,300*	21.0*	**700**	2.0*	**120**	**8.0**	**240**	1.6*	**34**	**1,250**	**40**	**8**	4.5*	1.5*	2.3*
14–18 y	1,300*	24.0*	**890**	3.0*	**150**	**15.0**	**360**	1.6*	**43**	**1,250**	**55**	**9**	4.7*	1.5*	2.3*
19–30 y	1,000*	25.0*	**900**	3.0*	**150**	**18.0**	**310**	1.8*	**45**	**700**	**55**	**8**	4.7*	1.5*	2.3*
31–50 y	1,000*	25.0*	**900**	3.0*	**150**	**18.0**	**320**	1.8*	**45**	**700**	**55**	**8**	4.7*	1.5*	2.3*
51–70 y	1,200*	20.0*	**900**	3.0*	**150**	**8.0**	**320**	1.8*	**45**	**700**	**55**	**8**	4.7*	1.3*	2.0*
> 70 y	1,200*	20.0*	900	3.0*	**150**	**8.0**	**320**	1.8*	**45**	**700**	**55**	**8**	4.7*	1.2*	1.8*
Pregnancy															
14–18 y	1,300*	29.0*	**1,000**	3.0*	**220**	**27.0**	**400**	2.0*	**50**	**1,250**	**60**	**13**	4.7*	1.5*	2.3*
19–30 y	1,000*	30.0*	**1,000**	3.0*	**220**	**27.0**	**350**	2.0*	**50**	**700**	**60**	**11**	4.7*	1.5*	2.3*
31–50 y	1,000*	30.0*	**1,000**	3.0*	**220**	**27.0**	**360**	2.0*	**50**	**700**	**60**	**11**	**4.7***	**1.5***	**2.3***
Lactation															
14–18 y	1,300*	44.0*	**1,300**	3.0*	**290**	**10.0**	**360**	2.6*	**50**	**1,250**	**70**	**14**	5.1*	1.5*	2.3*
19–30 y	1,000*	45.0*	**1,300**	3.0*	**290**	**9.0**	**310**	2.6*	**50**	**700**	**70**	**12**	5.1*	1.5*	2.3*
31–50 y	1,000*	45.0*	**1,300**	3.0*	**290**	**9.0**	**320**	2.6*	**50**	**700**	**70**	**12**	5.1*	1.5*	2.3*

Note: This table presents Recommended Dietary Allowances (RDAs) in bold type and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). RDAs and AIs may both be used as goals for individual intake. RDAs are set to meet the needs of almost all (97 to 98 percent) individuals in a group. For healthy breastfed infants, the AI is the mean intake. The AI for other life stage and gender groups is believed to cover needs of all individuals in the group, but lack of data or uncertainty in the data prevent being able to specify with confidence the percentage of individuals covered by this intake.
Sources: Dietary Reference Intakes for Calcium, Phosphorous, Magnesium, Vitamin D, and Fluoride (1997); Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline (1998); Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids (2000); Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001); and Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate (2004). These reports may be accessed via http://www.nap.edu.

(3) Vitamin D supplementation (200–400 international units/d) is recommended for breast-fed infants and older infants (>6 months), especially those with limited exposure to sunlight.
(4) Iron-fortified formula should be provided to infants who are not breast-fed. The breast-fed infant should be provided with an additional source of iron such as iron-fortified cereal by 4 to 6 months of age. Other sources of iron in addition to cereal may be beneficial after 6 months of age.

b) PN
(1) Guidelines for the provision of IV vitamins and trace elements in pediatrics follow the indications of the

Subcommittee on Pediatric Parenteral Nutrient Requirements from the Committee on Clinical Practice Issues of the American Society for Clinical Nutrition and A.S.P.E.N.[36–38]

(2) The multivitamin needs of term infants are commonly met by a pediatric multivitamin at 2 mL/kg up to a maximum of 5 mL/day (dose used in children up to 11 years old). For children over 11 years of age, the adult version of multivitamins will meet estimated requirements plus the addition of vitamin K (2–4 mg/week or 1 mg/day).[51] See Chapter 8, Table 8-6, for PN multivitamins.

(3) The trace element needs are described in Chapter 8, Table 8-7.

(4) If the patient is to be on PN for >1 month, supplemental selenium and possibly molybdenum should be added. Selenium should be provided at 2 to 3 mcg/kg/day (maximum: 40–60 mcg/day), while molybdenum requirements may be met by providing 0.25 mcg/kg/day (maximum: 5 mcg/day). Also, carnitine can become deficient in long-term PN patients receiving all their calories from PN. The recommended IV intake is 10 to 30 mg/kg/day (maximum 100 mg/day).

(5) If liver or renal complications occur, some trace element regimens have to be reformulated for PN patients (see Section III.A.2.f).(3).(b)).

8. Fluids and electrolytes. Body homeostasis is maintained by fluids, which are the bulk of body weight in children (60%–70%) and especially in neonates (up to 80%). To maintain water and electrolyte homeostasis and to allow metabolic processes (including the effects of insensible and sweat losses), a certain amount of fluid has to be introduced daily regardless of health conditions. Maintenance is mainly dependent on TEE and environmental temperature, whereas deficit replacements seem to be directly related to the size of the deficit and the body mass. Factors such as losses and organ dysfunction may require volume individualization. New DRI for some electrolytes can be found in Table 2-12.[52]

a) Fluid maintenance requirements can be computed following the A.S.P.E.N. recommendations based on the Holliday-Segar method. The Holliday-Segar formula estimates fluid needs by calculating energy expenditure and relating this to water losses and water of metabolism. The formula is based on energy expenditure for bed rest and therefore may not be adequate for highly active children:

(1) 2 to 10 kg, 100 mL/kg

(2) 10 to 20 kg, 1000 mL + 50 mL/kg for each kg over 10

(3) 20 kg and up, 1500 mL + 20 mL/kg for each kg over 20[38]

b) Another method, based on body surface area, can be accurate for children of abnormal height for weight: 1500 to 1700 mL/m^2/day.[53]

c) Based on caloric intake, infant and child fluid needs are, respectively, 1.5 and 1 mL/kcal of energy expenditure.

d) PN electrolyte recommendations are outlined in Chapter 8, Table 8-2.[38,54] Addition of calcium and phosphorus to PN is limited by solubility.

C. Adults

1. Energy requirements

a) Estimated energy requirement (EER) as defined by the Institute of Medicine (IOM) for healthy adults is the dietary energy intake predicted to maintain energy balance in a healthy adult of a defined age, gender, weight, height, and level of physical activity consistent with good health.[43] EER equations for men and women are given in Table 2-13.[43]

Table 2-13. EER for Healthy Adults[43]

Men age 19 years and older:

EER = 662 – 9.53 (age in yrs) + PA (15.91 × weight in kg) + 539.6(height in m)

PA = 1.00 for sedentary men

PA = 1.11 for low-activity men

PA = 1.25 for moderate-activity men

PA = 1.49 for high-activity men

Women age 19 years and older:

EER = 354 – 6.91 (age in yrs) + PA (9.36 × weight in kg) + 726 (height in m)

PA = 1.00 for sedentary women

PA = 1.12 for low-activity women

PA = 1.27 for moderate-activity women

PA = 1.45 for high-activity women

Harris-Benedict equations

Men	66.42 + 13.75 (weight in kg) + 5.00 (height in cm) – 6.78 (age in yrs)
Women	655.1 + 9.65 (weight in kg) + 1.85 (height in cm) – 4.68 (age in yrs)

EER, estimated energy requirements; PA = physical activity coefficient. Printed with permission from Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients).* Washington, DC: National Academy Press; 2002.

b) Energy requirement may be measured by indirect calorimetry if equipment is available; this measurement may be particularly valuable in the critically ill patient. The value derived is REE, which is the energy expended at rest (not necessarily fasting). Then appropriate factors can be applied to account for physical activity.

c) In the absence of indirect calorimetry capability, various methods are used to estimate energy requirements of sick patients.[55,56]

(1) Harris-Benedict equations (Table 2-13) derived from healthy adults, adjusted for activity and stress, have been widely applied to sick patients to predict REE.

(2) Alternatively, more recently, regression equations based on sick populations have been derived; two of the more commonly used are the Ireton-Jones equations (Table 2-14).[57] These equations already factor in the stress level of the patient.

(3) Also frequently used is the simple calculation of energy requirement based on kcal per kg body weight. The typical range is 20 to 35 total kcal per kg body weight per day.[36]

(4) With most of these methods, the question of what body weight to use in a patient who is significantly above ideal body weight must be addressed. See Chapter 28 for a discussion of this topic.

(5) Another source of confusion when applying these equations is whether to express energy requirements in terms of total kcal or nonprotein kcal. In the early days of PN,

Table 2-14. Ireton-Jones Equations for Estimation of Energy Requirements of Hospitalized Patients[57]

Spontaneously breathing patients:

kcal/day = 629 – 11 (age in yrs) + 25 (weight in kg) – 609(O)*

Ventilator-dependent patients:

kcal/day = 1784 – 11 (age in yrs) + 5 (weight in kg) + 244(S)** + 239(T)*** + 804(B)****

*O stands for obesity (>30% above initial weight from 1959 Metropolitan Life Insurance tables or body mass index > 27 kg/m^2): use 1 if present and 0 if absent.
**S stands for sex: use 1 for male and 0 for female.
***T stands for diagnosis of trauma: use 1 if present and 0 if absent.
****B stands for diagnosis of burn: use 1 if present and 0 if absent.
Reprinted from Ireton-Jones C, Jones JD. Improved equations for predicting energy expenditure in patients: the Ireton-Jones equations. *Nutr Clin Pract.* 2002;17:29–31 with permission from A.S.P.E.N.

kcal requirements were often referred to in terms of nonprotein kcal, since it was felt that the protein supplied by the nutrient solution was being given not to act as an energy source for the body but rather as a substrate for synthesis of lean body mass. The recent trend is to express energy requirements in terms of total kcal, since the body does not distinguish that infused protein is not to be used as a fuel source.

d) Energy requirements of patients requiring nutritional support should generally be met through provision of a mixed fuel system, that is, one providing substantial kcal from both carbohydrate and fat. Carbohydrate should generally be provided at a rate not to exceed 7 g/kg/day (about 5 mg/kg/minute).[36] Fat should generally be provided at a rate not to exceed 2.5 g/kg/day; at least 1% to 2% of kcal should be derived from linoleic and 0.5% from alpha-linolenic acid to prevent essential fatty acid deficiency.[36] Many clinicians would limit fat infusion to closer to 1 g/kg/day, especially in critically ill and immunocompromised adults. The typical distribution of carbohydrate and fat in PN solutions is about 70% to 85% nonprotein kcal as carbohydrate and 15% to 30% nonprotein kcal as fat. Corresponding distributions for EN would be about 65% to 80% nonprotein kcal as carbohydrate and 20% to 35% nonprotein kcal as fat.
e) Carbohydrate in PN is provided exclusively as dextrose in the United States. Carbohydrate sources for EN are more varied. Starch or glucose polymers found in standard formulas require digestion to be absorbed. The formulas that require less digestive function typically contain oligosaccharides as the carbohydrate source.
f) Commercially available lipid for IV infusion in the United States is derived from soybean oil or a combination of soybean and safflower oils. These emulsions contain LCFAs. Use of MCT as an IV fat source remains investigational in the United States, although commercial products containing a blend of MCT and long-chain triglycerides for IV use are available in several other countries. Fat sources in standard adult EN formulas include vegetable oils such as soy or corn oil rich in PUFA. Canola oil is another common source of fat in enteral feeding products. MCT are a source of some of the fat in many enteral formulas and serve as a readily utilizable energy source.
g) Special considerations in the elderly. Both REE and physical activity decrease with age; the decrease in REE is primarily due to decrease in lean body mass and increase in fat mass with age. Individual differences in the elderly make estimation of energy requirements challenging.

2. Protein requirements
   a) The RDA for protein for healthy adults is 0.8 g/kg/day (Table 2-6).[43]
   b) Protein requirements for catabolic patients are generally higher, in the range of 1.2 to 2.0 g/kg/day.[36,38] About 25% to 30% of protein intake should typically be provided by essential amino acids.[36]
   c) Adequate kcal must be provided along with protein to ensure the proper utilization of protein.
   d) Patients with certain disease states such as renal failure and end-stage liver disease may require protein restriction (see disease-specific chapters 17, 23, 24 and 29).
   e) Provision of individual amino acids for specific situations may be beneficial, although general recommendations cannot yet be made.[36]
   f) Although there has been some suggestion that protein requirements may be increased in the elderly, the RDA for adults 50 years and older was set at the same level as for younger adults (0.8 g/kg/day).[43]
3. Fluid requirements
   a) Typical fluid requirements for adults are 20 to 40 mL/kg/day or 1 to 1.5 mL/kcal of energy expended.[36,38,41,52] Fluid supplied by nutritional support should be individualized on the basis of patient inputs and outputs and estimates of insensible losses.
   b) Fluid requirements of the elderly are similar to those quoted above. However, many elderly persons are underhydrated, due to impaired thirst mechanisms and inability to obtain or consume liquids by themselves, thus making attention to intake and output data critical in this population.[58] On the other hand, fluid may sometimes need to be restricted in the ill elderly due to underlying conditions such as congestive heart failure.
4. Electrolyte requirements
   a) Daily electrolyte requirements for generally healthy people receiving PN or EN as published by A.S.P.E.N. are shown in Table 2-15.[36,38] Note that some of these values for enteral electrolytes are slightly different from the AI and RDA values recently published by the IOM and presented in Table 2-12.
   b) The requirements of ill patients receiving these therapies can be much different, especially in the presence of organ dysfunction, thus necessitating close clinical and laboratory monitoring of these patients.
5. Vitamin requirements
   a) Vitamin requirements for patients receiving enteral feedings are based on the RDA or, if no RDA has been set for a particular vitamin, the AI.[42,48–50] See Table 2-11 for vitamin recommendations for healthy persons on oral diets; these recommendations can be extrapolated with caution to patients on enteral feedings.[36]
   b) Parenteral vitamin requirements are poorly defined. Current parenteral recommendations are largely based on guidelines adopted by the American Medical Association Department of Foods and Nutrition, which were approved by the Food and Drug Administration (FDA) in 1979.[59] Amendments to these

Table 2-15. Daily Adult Enteral and Parenteral Electrolyte Requirements Assuming Normal Age-Related Organ Function[36]

	Enteral	Parenteral
Sodium	500 mg (22 mEq)	1–2 mEq/kg
Potassium	2 g (51 mEq)	1–2 mEq/kg
Chloride	750 mg (21 mEq)	As needed to maintain acid-base balance
Acetate	—	As needed to maintain acid-base balance
Calcium	1200 mg (60 mEq)	10–15 mEq
Magnesium	420 mg (35 mEq)	8–20 mEq
Phosphorus	700 mg (23 mmol)	20–40 mmol

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recommendations were published by the FDA in 2000.[60] See Chapter 8, Table 8-4, for parenteral vitamin recommendations. Note that the parenteral vitamin recommendations are generally higher than the corresponding enteral recommendations, since the parenteral recommendations were intended for patients with increased requirements due to illness, although this assumption would lead to the question of whether the RDA and AI values for healthy adults (as in Table 2-11) are truly appropriate for extrapolation to very sick patients who receive tube feedings.

c) Measurement of serum vitamin concentrations or other biochemical markers of vitamin status may be useful in patients receiving long-term nutrition support or occasionally in patients receiving shorter-term therapies if the clinical condition suggests the possibility of a deficiency or excess.

d) Currently, US nutrient recommendations are being established for older adults in 51- to 70-year and over-70-year age categories. In the future, these categories may be further substratified.[61] Under the current scheme, requirements for vitamin D and vitamin B_6 are higher for adults 51 years old and over than for adults 19 to 50 years old.[42,48,50]

6. Trace elements

a) As with vitamin requirements, requirements for trace elements in patients receiving EN are generally set in accord with RDA or AI amounts. (see table 2-12)

b) Recommendations for parenteral chromium, copper, manganese, and zinc were set by the Nutrition Advisory Group of the Department of Foods and Nutrition, American Medical Association, in 1979 (Chapter 8, table 8-5).[62] The American Medical Association has not published updates to these recommendations; however, other definitive guidelines have set copper and manganese recommendations at levels significantly lower than those originally recommended and have also set a recommendation for the parenteral requirement for selenium.[36,38] Note that parenteral requirements for iodine and molybdenum are not well defined, and therefore these minerals are not routinely added to PN solutions. However, some commercially available multiple–trace element solutions contain these minerals. Many patients on long-term PN will require parenteral iron supplementation; many clinicians wait until laboratory abnormalities consistent with iron insufficiency develop before supplementing with parenteral iron.

c) Trace element RDAs and AIs are generally identical for older adults and younger adults. The two exceptions are the AI values for chromium, which are lower for adults 51 years old and older than for younger adults, and the RDA for iron, which is lower for postmenopausal women than for premenopausal women.

(Nutritional Requirements chapters from the 1st edition were contributed by Harry C. Sax, Wiley W. Souba, Nancy Baugh, Marilyn A. Recupero, and John A. Kerner Jr)

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