1 Nutritional Assessment, Dietary Requirements, Feed Supplementation

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Introduction

This text provides a practical approach to the dietary management of a range of paediatric disorders. The therapies outlined in Parts 2 and 3 describe the dietetic interventions and nutritional requirements of the infant, child and young person in a clinical setting, illustrating how normal dietary constituents are used alongside special dietetic products to allow for the continued growth of the child whilst controlling the progression and symptoms of disease. Nutrition for the healthy child and nutritional care in the community is addressed in Part 4.

The following principles are relevant to the treatment of all infants, children and young people and provide the basis for many of the therapies described later in the text.

Assessment of nutritional status

Assessment and monitoring of nutritional status should be included in any dietary regimen, audit procedure or research project where a modified diet has a role. Although the terms are used interchangeably in the literature, nutrition screening is a simple and rapid means of identifying individuals at nutritional risk which can be undertaken by a range of healthcare professionals, whereas nutrition assessment is a more detailed and lengthy means for nutrition experts, i.e. dietitians, to quantify nutritional status.

Nutrition screening

While nutrition screening tools can be used to identify all aspects of malnutrition (excess, deficiency or imbalance in macro and micro nutrients), they are generally used to identify protein energy undernutrition [1]. Despite the recommendations from benchmark standards and national and international guidelines that screening for nutrition risk be an integral component of clinical care for all [2–5], the development of nutrition screening tools for use with children has lagged behind work in the adult world. However, in recent years a number of child specific nutrition screening tools have been developed. Internationally the Nutrition Risk Score (Paris tool), the Subjective Global Nutrition Assessment (SGNA) and the Strongkids tool are available [6–8]. Each of these has strengths and limitations in terms of validity and reliability of the tool, the time taken to complete, and the level of skill required by individuals applying the tool.

Within the UK two child specific tools have been developed: the Screening Tool for the Assessment of

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Companion Website: www.wiley.com/go/shaw/paediatricdietetics

Table 1.1 Child specific screening tools developed and evaluated in the UK.

	STAMP	PYMS
Criteria utilised	Diagnosis Dietary intake Anthropometrics: weight and height centile	Diagnosis Dietary intake Weight loss Anthropometrics: BMI
Scored	High/medium/ low risk	High/medium/ low risk
Criterion validity		
Agreement with full nutritional assessment*	54%	46%
Positive predictive value†	55%	47%
Negative predictive value††	95%	95%
Training	30 minutes	60 minutes
Used by	Any trained healthcare professional	Registered nurses

STAMP, Screening Tool for the Assessment of Malnutrition in Paediatrics; PYMS, Paediatric Yorkhill Malnutrition Score; BMI, body mass index.
*Children identified as being at nutritional risk by tool and full nutritional assessment.
†The proportion of children identified as at risk by the tool who are actually at risk.
††The proportion of children identified as not at risk by the tool who are actually not at risk.

Malnutrition in Paediatrics (STAMP) and the Paediatric Yorkhill Malnutrition Score (PYMS) [9, 10]. Both of these tools have been evaluated in practice and comprise a number of elements that are scored to give a final risk score (Table 1.1). The reliability of each of these tools has been published, along with a number of other studies evaluating their use in a variety of clinical settings and conditions [11–13]. The main limitation of these evaluation studies is that they rely on the dietetic assessment of nutritional status as the 'gold standard' and the findings of studies comparing the tools to date have been equivocal. There is an ongoing multicentre Europe-wide study under the auspices of the European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) to evaluate a range of the tools available. Results have not yet been published, but it is hoped that this will form the scientific basis for future developments in this area [14].

Nutritional assessment

Nutritional assessment comprises anthropometric, clinical and dietary assessment, all of which should be used to provide as full a picture of the nutritional status of the individual as possible; no one method will give an overall picture of nutritional status. Within these areas there are several assessment techniques, some of which should be used routinely in all centres, whilst others are better suited to specialist clinical areas or research. This chapter provides a brief overview of the common techniques and sources of further information.

Anthropometry

Measurement of weight and height (or length) is critical as the basis for calculating dietary requirements as well as monitoring the effects of dietary intervention. It is important that all measurements are taken using standardised techniques and calibrated equipment. Ideally staff taking measurements should receive some training on how to do this accurately. There are a variety of online resources to support training in anthropometric measurement of children.

Weight

Measurement of weight is an easy and routine procedure that should be done using a calibrated digital scale. Ideally infants should be weighed naked and children wearing just a dry nappy or pants; however, this is often not possible or appropriate. In these situations it is important to record if the infant is weighed wearing a clean dry nappy, and the amount and type of clothing worn by older children. A higher degree of accuracy is required for the assessment of sick children than for routine measurements in the community. Frequent weight monitoring is important for the sick infant or child, and local policies for weighing and measuring hospitalised infants and children should be in place. Recommendations for the routine measurement of healthy infants where there are no concerns about growth are given in Table 1.2 [15]. If there are concerns

Table 1.2 Recommendations for routine measurements for healthy infants and children.

Weight	Length/height	Head circumference
Birth	Birth	Birth or neonatal period
2 months	6–8 weeks if birth weight <2.5 kg or if other cause for concern	6–8 weeks
3 months		
4 months		
8 months		
Additional weights at parent's request; not more frequently than 2 weekly <6 months, monthly 6–12 months	No other routine measurement of length/height	No other routine measurement of head circumference
12–15 months		
School entry	School entry	

Source: Adapted from *Health for all Children* [15].

about weight gain that is too slow or too rapid, measurement of weight should be carried out more frequently.

Height

Height or length measurement requires a stadiometer or length board. Measurement of length using a tape measure is too inaccurate to be of use for longitudinal monitoring of growth, although an approximate length may be useful as a single measure. Under the age of 2 years supine length is measured; standing height is usually measured over this age or whenever the child can stand straight and unsupported. When the method of measurement changes from length to height there is likely to be a drop in stature; this is accounted for in the UK-WHO growth charts (p. 6). Measurement of length is difficult and requires careful positioning of the infant; positioning of the child is also important when measuring standing height. It is recommended to have two observers involved in measuring an infant or young child. It is good practice for sick infants to be measured monthly and older children at clinic appointments or on admission to hospital. Healthy infants should have a length measurement at birth but further routine stature checks are not recommended until the preschool check [15]. Whenever there are concerns about growth or weight gain a height measurement should be made more often.

Proxy measurements for length/height

In some cases it is difficult to obtain length or height measurements, e.g. in very sick or preterm infants and in older children with scoliosis. A number of proxy measurements can be used which are useful to monitor whether longitudinal growth is progressing in an individual, but there are no recognised centile charts as yet and indices such as body mass index (BMI) cannot be calculated. In younger adults arm span is approximately equivalent to height, but body proportions depend upon age and while there is some evidence that there is a correlation in older children and adolescents, this measurement may be of limited usefulness in children. Ulna length has been demonstrated to act as a good proxy for stature in adults although evidence in children is limited [16]. Measurements of lower leg length or knee–heel length have been used and are a useful proxy for growth [17]. Total leg length is rarely measured outside specialist growth clinics and is calculated as the difference between measured sitting height and standing height. A number of other measures have been used in children with cerebral palsy as a proxy for height (p. 780), but numbers are too small for reference standards to be established [18]. Formulas for calculating stature in children from proxy measurements are available [19].

Head circumference

Head circumference is generally considered a useful measurement in children under the age of 2 years. After this age head growth slows and is a less useful indicator of somatic growth. A number of genetic and acquired conditions, such as cerebral palsy, will affect head growth and measurement of head circumference will not be a useful indicator of nutritional status in these conditions. Head circumference is measured using a narrow, flexible, non-stretch tape. Accuracy is dependent on the skill of the observer and, as such, training and practice in this technique is a requirement.

Supplementary measurements

While the measurement of weight and length or height forms the basis of routine anthropometric assessment, there are a number of supplementary measurements which can be used. These include the proxy measurements for stature already mentioned and mid upper arm circumference (MUAC). This is a useful measurement in children under the age of 5 years, as MUAC increases fairly rapidly up until this age. Increases in MUAC are less likely to be affected by oedema than body weight; they can also provide a useful method of assessing changes in children with solid tumours and liver disease. There are age related standards for infants and children [19, 20]. Measurement of waist circumference and the index of waist to height can be helpful in the identification and monitoring of overweight and obesity [21–23]. Research has shown links with dyslipidaemias, insulin resistance and blood pressure although the evidence for benefit using waist circumference centiles over BMI centiles is limited [23].

When monitoring interventions, particularly those addressing undernutrition, it is important to determine if changes in weight are due to increases in fat mass or lean muscle mass. In order to fully differentiate between lean and fat, measurement of skinfold thickness (SFT) can be used. This can be unpleasant for young children and is not used as a routine anthropometric measurement in clinical practice, but it can provide valuable data in research studies. The equipment and technique are identical to those used in adults and the measurement is subject to the same high rates of inter-observer and intra-observer error. Reference data for infants and children are available [20] and arm muscle and arm fat area can be calculated. Full details on skinfold measurements and their interpretation has been published elsewhere [19, 24].

Modern technologies can provide information on body composition. Bioelectric impedance analysis is easily undertaken in a clinical setting using foot to foot or hand to foot techniques. However, while studies have reported validity of this method of determining body composition in healthy populations of young children, validity in sick children and infants has yet to be fully established [25, 26]. More invasive technologies for assessing body composition include dual-energy x-ray absorptiometry and air displacement plethysmography. These tend to be restricted to research assessments of body composition and further information can be found elsewhere [19].

Interpreting anthropometric measurements

Anthropometric measurements alone confer limited information on growth, nutritional status and health and require the use of growth reference data and conversion to indices for interpretation.

Growth charts

Measurements should be regularly plotted on a relevant growth chart. In the UK the growth standards are the UK-WHO Growth Charts 0–4 years and the UK Growth Charts 2–18 years [27]. The charts for preschool children incorporate data from the WHO multicentre growth study, a longitudinal study of optimal growth in breast fed singleton births from six countries across the world [28]. Every child in the UK is issued with a growth centile chart as part of the personal child health record that is held by parents and completed by healthcare professionals whenever the child is weighed or measured.

Accuracy is crucial when plotting growth charts, and therefore training is essential as a number of different professionals may be plotting on a single chart and errors could result in the misdiagnosis or non-identification of nutritional and growth problems. When assessing a child in relation to the growth charts a number of factors need to be accounted for including gestational age at birth and parental height. The growth charts give clear guidance on correction for prematurity and the estimation of the child's adult height.

It can be difficult to assess progress or decide upon targets where a measurement falls outside the nine centile lines (<0.4th centile or >99.6th centile). The Neonatal and Infant Close Monitoring growth charts [27] show −3, −4 and −5 standard deviation lines to allow assessment of very small infants up to the age of 2 years. 'Thrive lines' have also been developed to aid interpretation of infants with either slow or rapid weight gain. The 5% thrive lines define the slowest rate of normal weight velocity in healthy infants. If an infant is growing at a rate parallel to or slower than a 5% thrive line, weight gain is abnormally slow. The 95% thrive lines define the most rapid rate of normal weight gain in healthy infants and weight gain that parallels or is faster than the 95% thrive line is abnormally rapid [28]. There are a range of resources available to support training on the plotting and interpretation of growth charts on the Royal College of Paediatrics and Child Health website.

Some medical conditions have a significant effect on growth and where sufficient data exist separate growth charts have been developed, e.g. Down's syndrome, Turner syndrome, sickle cell disease, achondroplasia.

Body mass index

A BMI measurement can be calculated from weight and height measurements: BMI = weight (kg)/height (m^2). This provides an indication of relative fatness or thinness. In children the amount and distribution of body fat is dependent on age and sex. BMI is now routinely used to identify and monitor overweight and obesity in children, on an individual and population basis, in the clinical and research environments [29]. There are limitations, however, to the use of BMI in children:

- It is not recommended in children <2 years of age as during this period BMI changes rapidly and weight gain rather than BMI has been shown to be more indicative of future overweight and obesity [30].
- In chronic undernutrition there is stunting as well as low weight for age and thus undernutrition may be masked by using BMI.
- Although BMI is a relative index of weight to height it does not provide information about body composition; it cannot be used to distinguish between fat mass and lean mass.

Paediatric BMI charts have been developed and can be used to indicate how heavy a child is relevant to its height and age [31]. The UK growth charts have a quick reference guide to estimate BMI centile on the basis of the child's weight and height centiles.

Anthropometric indices and the classification of nutrition status

The World Health Organization (WHO) and research publications frequently report standard deviation (SD) score or *z*-score for length/height, weight and BMI. This involves converting the measurement or index into a finite proportion of a reference or standard measurement, the calculation giving a numerical score indicating how far away from the 50th centile for age the child's measurements/index falls. For the UK growth charts each centile space equates to 0.67SD; therefore a child on the 2nd centile will have a *z*-score of −2SD and a child on the 98th centile will have a *z*-score of +2SD; a measurement that falls exactly on the 50th centile will have a *z*-score of 0SD. Calculation of *z*-scores by hand is extremely laborious, but a computer software program is available (www.childgrowthfoundation.org) that will enable calculation of *z*-scores from height, weight, BMI, gender and age data. The *z*-score can also used when comparing groups of children when a comparison of the measurements themselves would not be useful.

The WHO defines moderate malnutrition and obesity in children in terms of *z*-score for weight as −2SD and +2SD respectively [28].

The calculation of height for age, height age and weight for height are useful when assessing nutritional status initially or when monitoring progress in children who are short for their chronological age. Table 1.3 shows examples of calculations for these indices. The Waterlow classification [32] may be of use when assessing children in the UK with severe failure to thrive. An adaptation of the classification is shown in Table 1.4. Calculation of height age is necessary when determining nutrient requirements for children who are much smaller (or larger) than their chronological age.

Clinical assessment

Clinical assessment of the child involves a medical history and a physical examination. The medical history will identify medical, social or environmental factors that may be risk factors for the development of nutritional problems. Such factors may include parental knowledge and finance available for food purchase, underlying disease, treatments, investigations and medications. Clinical signs of poor nutrition, revealed in the physical examination, only appear at a late stage in the development of a deficiency disease and absence of clinical signs should not be taken as indicating that a deficiency is not present.

Table 1.3 Height for age, height age and weight for height.

Worked example: 6-year-old girl with cerebral palsy referred with severe feeding problems

Visit 1	Decimal age = 6.2 years
	Height = 93 cm (<0.4th centile)
	Weight = 10 kg (<0.4th centile)
	50th centile for height for a girl aged 6.2 years = 117 cm
	Height for age = $\frac{93}{117}$ = 79.5% height for age
	Height age is the age at which 93 cm (measured height) falls on 50th centile = 2.7 years
	50th centile for weight for 2.7 years = 14 kg
	Weight for height = $\frac{10}{14}$ = 71% weight for height
Visit 2	Decimal age = 6.8 years
(after intervention)	Height = 95.5 cm (<0.4th centile)
	Weight = 12 kg (<0.4th centile)
	50th centile for height for a girl aged 6.8 years = 121 cm
	Height for age = $\frac{95.5}{121}$ = 79% height for age
	Height age = 3.1 years
	50th centile for weight for age 3.1 years = 14.5 kg
	Weight for height = $\frac{12}{14.5}$ = 82.7% weight for height

Conclusions: the girl has shown catch-up weight gain. Weight for height has increased from 71% to 83%. She has continued to grow in height, but has not had any catch-up height. Her height continues to be about 79% of that expected for her chronological age

Table 1.4 Classification of malnutrition.

Acute malnutrition (wasting)	Chronic malnutrition (stunting ± wasting)
Weight for height	Height for age
80%–90% standard – grade 1	90%–95% standard – grade 1
70%–80% standard – grade 2	85%–90% standard – grade 2
<70% standard – grade 3	<80% standard – grade 3

Source: Adapted from Waterlow [32].

Table 1.5 Physical signs of nutritional problems.

Assessment	Clinical sign	Possible nutrient(s)
Hair	Thin, sparse Colour change – 'flag sign' Easily plucked	Protein and energy, zinc, copper
Skin	Dry, flaky	Essential fatty acids B vitamins
	Rough, 'sandpaper' texture	Vitamin A
	Petechiae, bruising	Vitamin C
Eyes	Pale conjunctiva	Iron
	Xerosis Keratomalacia	Vitamin A
Lips	Angular stomatitis Cheilosis	B vitamins
Tongue	Colour changes	B vitamins
Teeth	Mottling of enamel	Fluorosis (excess fluoride)
Gums	Spongy, bleed easily	Vitamin C
Face	Thyroid enlargement	Iodine
Nails	Spoon shape, koilonychia	Iron, zinc, copper
Subcutaneous tissue	Oedema Over-hydration	Protein, sodium
	Depleted subcutaneous fat	Energy
Muscles	Wasting	Protein, energy, zinc
Bones	Craniotabes Parietal and frontal bossing Epiphyseal enlargement Beading of ribs	Vitamin D

Typical physical signs associated with poor nutrition which have been described in children in western countries are summarised in Table 1.5. Physical signs represent very general changes and may not be due to nutrient deficiencies alone. Other indications such as poor weight gain and/or low dietary intake are needed in order to reinforce suspicions, and biochemical and haematological tests should be carried out to confirm the diagnosis. These include the analysis of levels of nutrients or nutrient dependent metabolites in body fluids or tissues, or measuring functional impairment of a nutrient dependent metabolic process. The most commonly used tissue for investigation is the blood. Whole blood, plasma, serum or blood cells can be used, depending on the test. Tests may be static, e.g. levels of zinc in plasma, or may be functional, e.g. the measurement of the activity of glutathione peroxidase, a selenium dependent enzyme, as a measure of selenium status.

Although an objective measurement is obtained from a blood test there are a number of factors that can affect the validity of such biochemical or haematological investigations:

- Age specific normal ranges need to be established for the individual centre unless the laboratory participates in a regional or national quality control scheme.
- Recent food intake and time of sampling can affect levels and it may be necessary to take a fasting blood sample for some nutrients.
- Physiological processes such as infection, disease or drugs may alter normal levels.
- Contamination from exogenous materials such as equipment or endogenous sources such as sweat or interstitial fluid is important for nutrients such as trace elements, and care must be taken to choose the correct sampling procedure.

A summary of some biochemical and haematological measurements is given in Table 1.6.

Urine is often used for adult investigations, but many tests require the collection of a 24 hour urine sample and this is difficult in babies and children. The usefulness of a single urine sample for nutritional tests is limited and needs to be compared with a standard metabolite, usually creatinine. However, creatinine excretion itself is age dependent and this needs to be taken into consideration. Stool samples can be useful in determining reasons for malabsorption if suspected. Hair and nails have been used to assess trace element and heavy metal status in populations, but a number of environmental and physiological factors affect levels and these tissues are not routinely used in the UK. Tissues that store certain nutrients, such as the liver and bone, also provide useful materials for investigation, but sampling is too invasive for routine clinical use.

A more detailed overview of clinical assessment can be found elsewhere [19].

Dietary intake

For children over the age of 2 years food intake is assessed in the same way as for adults: using a recall diet history; a quantitative food diary or food record chart at home or on the ward, recorded over a number of days; a weighed food intake over a number of days; or a food frequency questionnaire. These methods are not mutually exclusive and combinations are often used to provide the greatest depth of information. There are benefits and limitations to each of these methods and these are summarised in Table 1.7 [19, 33].

For most clinical purposes an oral history from the usual carers (or from the child if appropriate) will provide sufficient information on which to base recommendations. As well as assessing the range and quantity of foods eaten it is also useful to assess whether the texture and presentation of food is appropriate for the age and developmental level of the child. Estimation of food intake is particularly difficult in infants, as it is not possible to assess accurately the amount of food wasted through, for example, spitting or drooling. Similar difficulties occur in children with physical feeding difficulties and dysphagia. Observation of feeding can be particularly useful in these situations. Recorded intake can often be utilised at annual assessments of children with chronic conditions, in the identification of food related symptoms (allergies and intolerances), or in the assessment of diet related doses of medications such as pancreatic enzymes or insulin. A range of tools are available to assist with the assessment of dietary intake including pictorial portion size guides, computerised dietary analysis programmes and texture descriptors [34]. The adequacy of dietary intake is assessed in relation to the dietary reference values (DRV).

The assessment of milk intake for breast fed infants is difficult and only very general estimations can be made. Historically infants have been test weighed before and after a breast feed to allow the amount of milk consumed to be estimated. This required the use of very accurate scales ($\pm 1-2$ g) and included all feeds over a 24 hour period as the volume consumed varied throughout the day. Test weighing should be avoided if at all possible as it is disturbing for the infant, engenders anxiety in the mother and is likely to compromise breast feeding. Studies have shown that the volume of breast milk

Table 1.6 Biochemical and haematological tests.

Nutrient	Test	Normal values in children	Comments
Biochemical tests			
Protein	Total plasma protein Albumin	55–80 g/L 30–45 g/L	Low levels reflect long term not acute depletion
	Caeruloplasmin Retinol binding protein	0.18–0.46 g/L 2.6–7.6 g/L	Low levels indicate acute protein depletion, but are acute phase proteins which increase during infection
Thiamin	Erythrocyte transketolase activity coefficient	1–1.15	High activity coefficient (>1.15) indicates thiamin deficiency
Vitamin B_{12}	Plasma B_{12} value	263–1336 pmol/L	Low levels indicate deficiency
Riboflavin	Erythrocyte glutathione reductase activity coefficient	1.0–1.3	High activity coefficient (>1.3) indicates riboflavin deficiency
Vitamin C	Plasma ascorbate level	8.8–124 μmol/L	Low levels indicate deficiency
Vitamin A	Plasma retinol level	0.54–1.56 μmol/L	Low level indicates deficiency
Vitamin D	Plasma 25-hydroxy-colecalciferol level	30–110 nmol/L	Low level indicates deficiency
Vitamin E	Plasma tocopherol level	α-tocopherol 10.9–28.1 μmol/L	Low levels indicate deficiency
Copper	Plasma level	70–140 μmol/L	Low levels indicate deficiency
Selenium	Plasma level Glutathione peroxidase activity	0.76–1.07 μmol/L >1.77 μmol/L	Low levels indicate deficiency Low levels indicate deficiency
Zinc	Plasma level	10–18 μmol/L	Low levels indicate deficiency
Haematology tests			
Folic acid	Plasma folate Red cell folate	7–48 nmol/L 429–1749 nmol/L	Low levels indicate deficiency Low levels indicate deficiency
Haemoglobin	Whole blood	104–140 g/L	Levels <110 g/L indicate iron deficiency
Red cell distribution width	Whole blood	<16%	High values indicate iron deficiency
Mean corpuscular volume	Whole blood	70–86 fL	Small volume (microcytosis) indicates iron deficiency Large volume (macrocytosis) indicates folate or B_{12} deficiency
Mean cell haemoglobin	Whole blood	22.7–29.6 pg	Low values indicate iron deficiency
Percentage hypochromic cells	Whole blood	<2.5%	High values (>2.5%) indicate iron deficiency
Zinc protoporphyrin	Red cell	32–102 μmol/mol haem	High levels indicate iron deficiency
Ferritin	Plasma level	5–70 μg/L	Low levels indicate depletion of iron stores. Ferritin is an acute phase protein and increases during infection

Table 1.7 Strengths and limitations of dietary assessment methodologies for individuals.

Method	Strength	Limitation
24 hour recall	Quick and easy Low respondent burden	Relies on memory May not be representative of usual intake
Estimated food diary	Assesses actual usual intake	Respondents must be literate Ability to estimate portion size Longer time-frames increase respondent burden
Weighed food diary	Accurate assessment of actual intake	High respondent burden Respondents must be literate and motivated Setting may not be conducive to weighing (e.g. eating out)
Food frequency questionnaire	Quick Low respondent burden Can identify food consumption patterns: high/ medium/low	Ability to quantify intakes poor

Source: Gibson [19].

consumed is approximately 770 mL at 5 weeks and 870 mL at 11 weeks [35]. In general an intake of 850 mL is assumed for infants who are fully breast fed and over the age of 6 weeks. Estimation of nutritional intake in a breast fed infant is further complicated by the varying composition of breast milk [36].

Expected growth in childhood

The 50th centile birth weight for infants in the UK is 3.5 kg for boys and 3.3 kg for girls [37]. Most babies lose weight after birth whilst feeding on full volumes of milk is gradually established. They begin to gain weight between 3 and 5 days of age, with the majority regaining their birth weight by the 10th–14th day of life. The National Institute for Health and Care Excellence (NICE) recommends that babies are weighed at birth and in the first week of life as part of the overall assessment of their feeding. Thereafter babies should be weighed at 8, 12 and 16 weeks and again at 1 year of age [38].

Table 1.8 Average weight gain throughout the first year of life.

	Boys (g/week)	**Girls** (g/week)
First 3 months	240	210
Second 3 months	130	120
Third 3 months	80	75
Fourth 3 months	65	60

The average weight gain during the first year of life, using the 50th centile for age of the UK-WHO growth charts [27], is shown in Table 1.8. The increase in length during the first year of life is 24–25 cm. During the second year, the toddler following the 50th centile gains 2.5–2.6 kg in weight and a further 11–12 cm in length. Average weight gain continues at a rate of approximately 2–3 kg per year. Height gain in the second year is 10 cm, steadily declining to 7 cm down to 5 cm per year until the growth spurt at puberty. Puberty in boys usually starts between the ages of 9 and 14 years. Onset of puberty before 9 years of age is considered precocious whilst puberty is delayed if there are no signs by 14 years. For girls, puberty usually begins between 8 and 13 years, with the onset of puberty before 8 years considered to be precocious and puberty not present by 13 years considered to be delayed.

Dietary reference values

The 1991 Department of Health Report on Dietary Reference Values [39] provides information and figures for requirements for a comprehensive range of nutrients and energy. The requirements are termed dietary reference values (DRV) and are for normal healthy populations of infants fed artificial formulas, and for older infants, children and adults consuming food. DRV were not set for breast fed babies as it was considered that human milk provides the necessary amounts of nutrients when fed on demand. In some cases the DRV for infants aged up to 3 months who are formula fed are in excess of those which would be expected to derive from breast milk; this is because of the different bioavailability of some nutrients from breast and artificial formulas.

Table 1.9 Selected dietary reference values, 1991.

	Weight*	Energy (EAR) per day				RNI per day: Protein		Sodium		Potassium		Vitamin C	Calcium	Iron
Age	kg	MJ	kJ/kg	kcal	kcal/kg	g	g/kg	mmol	mmol/kg	mmol	mmol/kg	mg	mmol	mg
Males														
0–3 months	5.9	2.28	480–420	545	115–100	12.5	2.1	9	1.5	20	3.4	25	13.1	1.7
4–6	7.7	2.89	400	690	95	12.7	1.6	12	1.6	22	2.8	25	13.1	4.3
7–9	8.9	3.44	400	825	95	13.7	1.5	14	1.6	18	2.0	25	13.1	7.8
10–12	9.8	3.85	400	920	95	14.9	1.5	15	1.5	18	1.8	25	13.1	7.8
1–3 years	12.6	5.15	400	1230	95	14.5	1.1	22	1.7	20	1.6	30	8.8	6.9
4–6	17.8	7.16	380	1715	90	19.7	1.1	30	1.7	28	1.6	30	11.3	6.1
7–10	28.3	8.24	–	1970	–	28.3	–	50	–	50	–	30	13.8	8.7
11–14	43.1	9.27	–	2220	–	42.1	–	70	–	80	–	35	25.0	11.3
15–18	64.5	11.51	–	2755	–	55.2	–	70	–	90	–	40	25.0	11.3
Females														
0–3 months	5.9	2.16	480–420	515	115–100	12.5	2.1	9	1.5	20	3.4	25	13.1	1.7
4–6	7.7	2.69	400	645	95	12.7	1.6	12	1.6	22	2.8	25	13.1	4.3
7–9	8.9	3.20	400	765	95	13.7	1.5	14	1.6	18	2.0	25	13.1	7.8
10–12	9.8	3.61	400	865	95	14.9	1.5	15	1.5	18	1.8	25	13.1	7.8
1–3 years	12.6	4.86	400	1165	95	14.5	1.1	22	1.7	20	1.6	30	8.8	6.9
4–6	17.8	6.46	380	1545	90	19.7	1.1	30	1.7	28	1.6	30	11.3	6.1
7–10	28.3	7.28	–	1740	–	28.3	–	50	–	50	–	30	13.8	8.7
11–14	43.8	7.92	–	1845	–	42.1	–	70	–	80	–	35	20.0	14.8
15–18	55.5	8.83	–	2110	–	45.4	–	70	–	90	–	40	20.0	14.8

EAR, estimated average requirement; RNI, reference nutrient intake.
*Standard weights for age ranges [39].
Source: Department of Health [39]. Reprinted with permission of The Stationery Office.

It is important to remember that these are recommendations for groups, not for individuals; however, they can be used as a basis for estimating suitable intakes for the individual, using the reference nutrient intake (RNI). This level of intake should satisfy the requirements of 97.5% of healthy individuals in a population group. A summary of the 1991 DRV for energy, protein, sodium, potassium, vitamin C, calcium and iron is given in Table 1.9. The DRV for other nutrients may be found in the full report.

The Scientific Advisory Committee on Nutrition (SACN) revised the DRV for energy in 2011 [40] in the light of advancements in the methodology to measure total energy expenditure. This report gives a detailed account of the evidence that SACN used when updating the estimated average requirements (EAR) for energy for infants, children, adolescents and adults in the UK. This has coincided with other revisions of energy requirements by the Food and Agriculture Organization of the United Nations, World Health Organization and United Nations University (FAO/WHO/UNU) and the Institute of Medicine (IoM) in the USA.

The new EAR for energy have decreased for infants and children under 10 years of age and slightly increased for older children and adults. The new EAR for energy for infants and children are shown in Tables 1.10 and 1.11.

It must be emphasised that these values are for assessing the energy requirements of large groups of people and are not requirements for healthy or sick individuals. Also, when estimating requirements for the individual sick child it is important to calculate energy and nutrient intakes based on actual body weight and not expected body weight. The latter will lead to a proposed intake that is inappropriately high for the child who has an abnormally low body weight. In some instances it may be more appropriate to consider the child's height age rather than chronological age when comparing intakes with the DRV as this is a more

Table 1.10 Estimated average requirements for energy for infants, 2011.

	Breast fed		Breast milk substitute fed		Mixed feeding or unknown	
Age (months)	kcal (MJ) per kg/day	kcal (MJ) per day	kcal (MJ) per kg/day	kcal (MJ) per day	kcal (MJ) per kg/day	kcal (MJ) per day
Boys						
1-2	96 (0.4)	526 (2.2)	120(0.5)	598 (2.5)	120 (0.5)	574 (2.4)
3-4	96 (0.4)	574 (2.4)	96 (0.4)	622 (2.6)	96 (0.4)	598 (2.5)
5-6	72 (0.3)	598 (2.5)	96 (0.4)	646 (2.7)	72 (0.3)	622 (2.6)
7-12	72 (0.3)	694 (2.9)	72 (0.3)	742 (3.1)	72 (0.3)	718 (3.0)
Girls						
1-2	96 (0.4)	478	120 (0.5)	550 (2.3)	120 (0.5)	502 (2.1)
3-4	96 (0.4)	526	96 (0.4)	598 (2.5)	96 (0.40)	550 (2.3)
5-6	72 (0.3)	550	96 (0.4)	622 (2.6)	72 (0.3)	574 (2.4)
7-12	72 (0.3)	646	72 (0.3)	670 (2.8)	72 (0.3)	646 (2.7)

Source: Scientific Advisory Committee on Nutrition [40].

Table 1.11 Estimated average requirement (EAR) for energy for children.

	EAR (kcal (MJ) per day)*	
Age (years)	Boy	Girls
1	765 (3.2)	717 (3.0)
2	1004 (4.2)	932 (3.9)
3	1171 (4.9)	1076 (4.5)
4	1386 (5.8)	1291 (5.4)
5	1482 (6.2)	1362 (5.7)
6	1577 (6.6)	1482 (6.2)
7	1649 (6.9)	1530 (6.4)
8	1745 (7.3)	1625 (6.8)
9	1840 (7.7)	1721 (7.2)
10	2032 (8.5)	1936 (8.1)
11	2127 (8.9)	2023 (8.5)
12	2247 (9.4)	2103 (8.8)
13	2414 (10.1)	2223 (9.3)
14	2629 (11.0)	2342 (9.8)
15	2820 (11.8)	2390 (10.0)
16	2964 (12.4)	2414 (10.1)
17	3083 (12.9)	2462 (10.3)
18	3155 (13.2)	2462 (10.3)

*Calculated with the median physical activity ratio.
Source: Scientific Advisory Committee on Nutrition [40].

realistic measure of the child's body size and hence nutrient requirement.

In order to make the new EAR for energy more usable in clinical practice, it is suggested that the data given in Tables 1.10 and 1.11 are condensed and summarised (Table 1.12).

The estimated requirements for children with specific disorders are given in the relevant chapters. It is important to remember that requirements are not necessarily increased during illness. Factors to consider when estimating requirements for the individual are: nutritional status prior to onset of the disease; whether the disorder is acute or chronic; is mobility affected; are there any impacts on normal feeding such as dysphagia or reduced appetite; are there increased gastrointestinal losses such as vomiting, diarrhoea; consider any urinary losses; is there an inability to metabolise dietary constituents.

A guide to increased oral and enteral (feeding by tube into the gut) requirements is given in Table 1.13.

Fluid requirements

Preterm and low birthweight infants

Chapter 6 gives a full account of the special requirements of these babies.

The newborn infant over 2.5 kg birthweight

Breast feeding is the most appropriate method of feeding the normal infant and may be suitable for sick infants with a variety of clinical conditions. Demand breast feeding will automatically ensure that the healthy infant gets the right volume of milk and, hence, nutrients. The suck–swallow–breathe sequence that allows the newborn infant to feed orally is usually well developed by 35–37 weeks of gestation. If the infant is too ill or too immature to suckle the mother may express her breast milk;

Table 1.12 Guide to energy requirements in clinical practice.

	Boys			Girls		
Age	Energy (EAR) (kcal/day)	Weight†	Energy (EAR)* (kcal/kg/day)	Energy (EAR) (kcal/day)	Weight†	Energy (EAR)* (kcal/kg/day)
1–2 months		5.0	96–120		4.7	96–120
3–4		6.7	96		6.1	96
5–6		7.7	72–96		7.0	72–96
7–12		9.0	72		8.3	72
1 years	770	9.6	80	720	9.0	80
2	1000	12.2	82	930	11.5	81
3	1170	14.4	82	1080	13.9	78
4	1390	16.3	85	1290	16.0	81
5	1480	18.6	80	1360	18.2	75
6	1560	21.0	74	1480	21.0	70
7	1650	23.0	71	1530	23.0	67
8	1750	26.0	67	1630	26.0	63
9	1840	29.0	63	1720	29.0	59
10	2030	31.5	64	1940	32.0	61
11	2130	34.5	62	2020	35.9	56
12	2250	38.0	59	2100	40.0	53
13	2410	43.0	56	2220	46.0	48
14	2630	49.0	54	2340	51.0	46
15	2820	55.5	51	2390	53.0	45
16	2970	60.2	49	2410	55.3	44
17	3080	64.0	48	2460	57.0	43
18	3160	66.2	48	2460	57.2	43

1 kcal = 4.18 kJ.
*Depending on method of feeding for infants (see Table 1.10).
†Median weight from the UK-WHO growth charts ages 1–4 years [27] and the UK 1990 reference for children aged >4 years [37].

Table 1.13 Guide to increased oral and enteral requirements.

	Infants 0–1 year*	Children
Energy	High: 130–150 kcal (545–630 kJ)/kg/day Very high: 150–180 kcal (630–750 kJ)/kg/day	High: 120% EAR† Very high: 150% EAR
Protein	High: 3–4.5 g/kg/day Very high: 6 g/kg/day Very high: 6 g/kg/day	High: 2 g/kg/day* It should be recognised that children may easily eat more than this amount
Sodium	High: 3.0 mmol/kg/day Very high: 4.5 mmol/kg/day A concentration >7.7 mmol Na^+/100 mL of infant formula will have an emetic effect	
Potassium	High: 3.0 mmol/kg/day Very high: 4.5 mmol/kg/day	

*Based on actual weight, not expected weight.
†May be better to base on height age rather than chronological age in very small children.

Table 1.14 Infant milk formulas and follow-on milks.

Whey based infant formula	Casein based infant formula	Follow-on milks*
Aptamil First Infant Milk	Aptamil Hungry Milk	Aptamil Follow On Milk (Milupa)
Babynat 1	–	Babynat 2 (Vitagermine)
Cow & Gate First Infant Infant Milk	Cow & Gate Infant Milk for Hungrier Babies	Cow & Gate 3 (Cow & Gate)
Hipp First	Hipp Hungry Infant	Hipp Follow on (Hipp UK)
SMA First Infant Milk	SMA Extra Hungry Infant Milk	SMA Follow-on Milk (SMA Nutrition)

*Suitable from 6 months.

expressed breast milk (EBM) may be modified to suit the sick infant's requirements. If EBM is unavailable or inappropriate to feed in certain circumstances (see Chapter 3 Infants under 12 months), infant milk formulas must be used (Table 1.14).

A systematic review of the volumes of breast milk and infant formula taken in early infancy [41] has revealed that formula fed infants have a higher intake than breast fed babies (Table 1.15). Whilst there was variation in the amount of breast milk taken in the first few days of life, on average demand breast fed babies took only 21.5 ± 4.2 mL on day 1, whereas formula fed babies took 170 ± 55.8 mL on day 1. By day 14, the bottle fed babies were still taking a greater volume: 761.8 ± 18 mL vs. 673.6 ± 29 mL in the breast fed babies. Not only did the bottle fed babies take a larger volume, they also had a more energy dense milk: 67 kcal/100 mL vs. 53.6 ± 2.5 kcal/100 mL for colostrum (days 1–5) and 57.7 ± 4.2 kcal/100 mL for transitional milk (days 6–14).

Most babies will need 150–180 mL/kg/day of infant formula until they are 6 months old, although this will vary for the individual baby [42]. Bottle fed babies should be allowed to feed on demand and not be encouraged to 'finish the bottle'. A suggested way to feed these babies is to offer on the first day approximately one seventh of requirements, say 20 mL/kg, divided into eight feeds and fed every 2–3 hours. The volume offered should be gradually increased over the following days to

Table 1.15 Volume of milk taken in the first 2 weeks of life.

Day of life	Breast milk (mL)	Infant formula (mL)
1	21.5 ± 4.2	170.5 ± 55.8
2		265.0 ± 67.7
7	495.3 ± 33.4	
14	673.6 ± 29	761.8 ± 18

Source: Hester *et al*. [41].

appetite so that newborn babies gradually increase their intake from about 20 mL/kg on the first day of life to around 150 mL/kg by 7–14 days. Breast fed infants will regulate their own intake of milk.

Fluid requirements after the first few weeks

Healthy formula fed infants should be allowed to feed on demand, although parents often wish to get them into a 'routine'. Many infants will take their feeds four hourly, five to six bottles per day at around 4–6 weeks of age, although many will continue to demand feeds more frequently. The infant may start to sleep longer through the night and drop a feed. A fluid intake of around 150 mL/kg should be maintained to provide adequate fluids, energy and nutrients. Infants should not normally be given more than 1200 mL of feed per 24 hours as this may induce vomiting and, in the long term, will lead to an inappropriately high energy intake. Sick infants may need smaller, more frequent feeds than the normal baby and, according to their clinical condition, may have increased or decreased fluid requirements. Breast fed infants will continue to regulate their own intake of milk and feeding pattern.

After the age of 6 months a follow-on milk may be used (Table 1.14). These milks are higher in protein, iron and some other minerals and vitamins than formulas designed to be given from birth and may be useful for infants with a poor intake of solids or who are fluid restricted.

Fluid requirements in older infants and children

Once solids are introduced around the age of 6 months of age the infant's appetite for milk will lessen. Breast milk and infant formulas fed at 150 mL/kg provide 130 mL water/kg. The fluid requirements for older infants aged 7–12 months

Table 1.16 Water content of foods.

Food	Percentage water content
Fruits and vegetables	80–85
Yoghurt and milk puddings	70–80
Rice and pasta	65–80
Fish	70–80
Eggs	65–80
Meat	45–65
Cheese	40–50
Bread	30–45

Source: Grandjean and Campbell [43].

Table 1.17 Daily water requirements for infants and children.

Age	EFSA 2010* [44] Dietary reference values	IoM 2005† [45] Dietary reference intakes
0–6 months	100–190 mL/kg	700 mL
6–12	800–1000 mL	800 mL
12–24	1100–1200 mL	
1–3 years		1300 mL (900 mL from drinks)
2–3	1300 mL	
4–8	1600 mL	1700 mL (1200 mL from drinks)
9–13 (boys)	2100 mL	2400 mL (1800 mL from drinks)
9–13 (girls)	1900 mL	2100 mL (1600 mL from drinks)
14–18 (boys)	2500 mL (adult)	3300 mL
14–18 (girls)	2000 mL (adult)	2300 mL

*Includes water from beverages and food.
†Includes water from beverages, food and drinking water.

decrease to 120 mL/kg, assuming that some water is obtained from solid foods (Table 1.16). At 1 year, the healthy child's thirst will largely determine how much fluid is taken. There are some published fluid requirements for healthy populations (Table 1.17). These are all based on observations of water intakes and urine osmolality, not hydration status.

If all a child's nutrition comes from feed and there is no significant contribution to fluid intake from foods, then fluid requirements may be estimated using an adaptation of the Holliday–Segar formula [46]. This formula was originally designed to calculate fluid requirements for parenteral nutrition and is based on the child's weight, using an average requirement of 100 mL water for each 100 kcal (420 kJ) of energy metabolised. If less energy is required, then less water will be needed. If nutritional requirements are met from a smaller volume of feed, then any extra fluid needed (e.g. if the child is losing more than usual fluid though breathing, sweating, vomiting, diarrhoea, passing dilute urine) may simply be given as water.

Body weight	***Estimated fluid requirement***
11–20 kg	100 mL/kg for the first 10 kg + 50 mL/kg for the next 10 kg
>20 kg	100 mL/kg for the first 10 kg + 50 mL/kg for the next 10 kg + 25 mL/kg thereafter

Worked example for a child weighing 22 kg

100 mL/kg for the first 10 kg	= 1000 mL
+ 50 mL/kg for the next 10 kg	= 500 mL
+ 25 mL/kg for the final 2 kg	= 50 mL
Total	= 1550 mL = 70 mL/kg

Overweight children will need less fluid than the calculated volume as their actual body weight is higher than normal. It would be reasonable to estimate their weight for these calculations as the value on the centile that matches their height centile, e.g.

- 7 year old boy weight with a weight of 35 kg = 99.6th centile: fluid requirements using above formula 1875 mL
- He is 122 cm tall = 50th centile
- Base fluid requirements initially on a body weight of 23 kg = 50th centile, using above formula is 1575 mL
- Monitor fluid status and adjust accordingly. More water may be required, but not necessarily more feed.

For underweight children it is important to calculate their fluid requirement based on their actual weight, not their expected weight for age or height, but as this is lower than normal they will need increased energy and protein density in their feed to achieve catch-up growth.

Supplementing feeds for infants with faltering growth or who are fluid restricted

Supplements may be used to fortify standard infant formulas and special therapeutic formulas to achieve the necessary increase in energy, protein and other nutrients required by some infants. Expressed breast milk can also be fortified using a standard infant formula powder in term babies (Table 1.18) or a breast milk fortifier in preterm infants (p. 92). Care needs to be taken not to present an osmotic load of more than 500 mOsm/kg H_2O to the normal functioning gut; otherwise an osmotic diarrhoea will result. If the infant has malabsorption, an upper limit of 400 mOsm/kg H_2O may be necessary. Infants who are fluid restricted will need to meet their nutritional requirements in a lower volume of feed than usual and the following feed manipulations can be used for these babies.

Concentrating infant formulas

Normally infant formula powders, whether whey and casein based formulas or specialised dietetic products, should be diluted according to the manufacturers' instructions as this provides the correct balance of energy, protein and nutrients when fed at the appropriate volume. However, there are occasions when, to achieve a feed that is denser in energy, protein and other nutrients, it is necessary to concentrate the formula. Most normal baby milks in the UK are made up at a dilution of around 13%. By making the baby milk up at a dilution of 15% (15 g powder per 100 mL water), more nutrition can be given in a given volume of feed, e.g. energy content may be increased from 67 kcal (280 kJ) per 100 mL to 77 kcal (325 kJ) per 100 mL and protein content from 1.3 g/100 mL to 1.5 g/100 mL. Similarly special therapeutic formulas that are usually made up at a dilution of, say, 15% may be concentrated to a 17% dilution. This concentrating of feeds should only be performed as a therapeutic procedure and is not usual practice. The consequence of concentrating feeds is to increase the osmolality. Steele *et al*. have shown a linear relationship between feed concentration and osmolality so that the osmolality of a concentrated feed can be reliably calculated from the manufacturer's data for normal dilution rather than necessitating the feed to be measured by osmometry in the laboratory [47]. Table 1.18 shows an example of a 15% feed and a 17% feed.

The protein:energy (P:E) ratio of the feed should ideally be kept within the range 7.5%–12% for

Table 1.18 Examples of energy and nutrient dense formulas for infants (per 100 mL).

	Energy kcal	kJ	Protein g	CHO g	Fat g	Na mmol	K mmol	Osmolality mOsm/kg H_2O	P : E ratio
12.7% SMA 1	67	280	1.3	7.3	3.6	0.7	1.7	300	7.6
15% SMA 1	79	330	1.5	8.6	4.3	0.8	2.0	354*	7.6
EBM† + 3% SMA 1	85	355	1.6	8.9	4.9	0.8	1.9	–	7.5
17% SMA 1	90	375	1.7	9.8	4.8	0.9	2.3	402*	7.6
SMA High Energy (SMA Nutrition)	91	380	2.0	9.8	4.9	1.0	2.3	387	8.8
Infatrini (Nutricia)	100	420	2.6	10.3	5.4	1.1	2.4	345	10.4
Similac High Energy (Abbott)	100	420	2.6	10.1	5.4	1.1	2.3	333	10.4
17% SMA 1 + Maxijul to 12% CHO + Calogen to 5% fat	100	420	1.7	12.0	5.0	0.9	2.3	–	6.8

P : E, protein : energy. EBM, expressed breast milk.
The Scientific Advisory Committee on Nutrition used an energy density for breast milk of 0.67 kcal/g (2.8 kJ/g) rather than 0.69 kcal/g (2.9 kJ/g) in the revised *Dietary Reference Values for Energy*, 2011 [40].
*Calculated value.
†Holland B, Welch AA, Unwin ID *et al. McCance & Widdowson's The Composition of Foods*, 5th edn. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food, Cambridge 1991.

infants (i.e. 7.5%–12% energy from protein) and 5%–15% in older children. For accelerated weight gain or catch-up growth [48]:

- weight gain of 10 g/kg/day requires 126 kcal (530 kJ)/kg/day, 2.8 g prot/kg/day, 8.9% P:E
- weight gain of 20 g/kg/day requires 167 kcal (700 kJ)/kg/day, 4.8 g prot/kg/day, 11.5% P:E
- optimal P:E for catch-up height is not determined but is likely to be 11%–12%

In some clinical situations it is not possible to preserve this protein:energy ratio as carbohydrate and fat sources alone may be added to a feed to control deranged blood biochemistry, for example. In these situations it is important to ensure that the infant is receiving at least the RNI for protein.

If infants are to be discharged home on a concentrated feed the recipe may be translated into scoop measures for ease of use. This will mean that more scoops of milk powder will be added to a given volume of water than recommended by the manufacturer. As this is contrary to normal practice the reasons for this deviation should be carefully explained to the parents and communicated to primary healthcare staff.

Nutrient dense ready to feed formulas

Nutrient dense ready to feed formulas are available for hospital use and in the community (Table 1.18). They are nutritionally complete formulas containing more energy, protein and nutrients per 100 mL than standard infant formulas. They are suitable for use from birth and are designed for infants who have increased nutritional requirements or who are fluid restricted. They obviate the need for carers to make up normal infant formulas at concentrations other than the usual one scoop of powder to 30 mL water.

Energy and protein modules

There may be therapeutic circumstances when energy and/or protein supplements need to be added to normal infant formulas or special formulas without necessarily the need to increase the concentration of the base feed. Sometimes a ready to feed formula does not meet the needs of the individual child. Energy and protein modules and their use are described.

Carbohydrate

Carbohydrate provides 4 kcal/g (16 kJ/g). It is preferable to add carbohydrate to a feed in the form of glucose polymer, rather than using monosaccharides or disaccharides, because it exerts a lesser osmotic effect on the gut. Hence, a larger amount can be used per given volume of feed (Table 1.19). Glucose polymers should be added in 1% increments each 24 hours, i.e. 1 g per 100 mL feed per 24 hours. This will allow the concentration at which the infant becomes intolerant (i.e. has loose stools) of the extra carbohydrate to be identified. Tolerance depends on the age of the infant and the maturity and absorptive capacity of the gut. The addition of 2% (2 g per 100 mL) glucose polymer (Super Soluble Maxijul) to infant formulas has been shown to increase the feed osmolality by 31.2 mOsm/kg H_2O [47].

As a guideline the following percentage concentrations of carbohydrate (g total carbohydrate per 100 mL feed) may be tolerated if glucose polymer is introduced slowly:

- 10%–12% carbohydrate concentration in infants under 6 months (i.e. 7 g from formula, 3–5 g added)
- 12%–15% in infants aged 6 months to 1 year
- 15%–20% in toddlers aged 1–2 years
- 20%–30% in older children

If glucose or fructose needs to be added to a feed where there is an intolerance of glucose polymer, an upper limit of tolerance may be reached at a total carbohydrate concentration of 7%–8% in infants and young children.

Fat

Fat provides 9 kcal/g (37 kJ/g). Long chain fat emulsions are favoured over medium chain fat emulsions because they have a lower osmotic effect on the gut and provide a source of essential fatty acids. Medium chain fats are used where there is malabsorption of long chain fat (Table 1.19).

Table 1.19 Energy modules.

Per 100 g	Ingredients*	Energy kcal*	kJ	Na mmol	K mmol	PO_4 mmol
Glucose polymers						
Caloreen (Nestle)	Maltodextrin	385	1610	<1.8	<0.3	0
Super Soluble Maxijul (SHS)	Dried glucose syrup	380	1590	0.4	0.04	0.05
Polycal (Nutricia)	Maltodextrin	384	1605	0.1	Trace	0
Vitajoule (Vitaflo)	Dried glucose syrup	380	1590	<0.7	<0.1	0
Fat emulsions						
Calogen[†] (Nutricia)	Canola oil, sunflower oil	450	1880	0.5	0	
Liquigen (Nutricia)	Coconut oil	450	1880	0.65	0	
Combined fat and carbohydrate supplements						
Super Soluble Duocal (Nutricia)	Glucose syrup, canola oil, coconut oil, safflower oil	492	2055	<0.9	<0.1	
MCT Duocal (Nutricia)	Cornstarch, coconut oil, walnut oil, canola oil, palm oil	497	2075	<1.3	<0.5	

*As quoted by manufacturers.
†Unflavoured.

Fat emulsions should be added to feeds in 1% increments each 24 hours, so providing an increase of 0.5 g fat per 100 mL per 24 hours. Infants will tolerate a total fat concentration of 5%–6% (i.e. 5–6 g fat per 100 mL feed) if the gut is functioning normally. The addition of 2% long chain fat emulsion (Calogen) to infant formulas has been shown to increase the feed osmolality by only 0.7 mOsm/kg H_2O [47]. Children over 1 year of age will tolerate more fat, although concentrations above 7% may induce a feeling of nausea and cause vomiting. Medium chain fat will not be tolerated at such high concentrations and may be the cause of abdominal cramps and osmotic diarrhoea if they are not introduced slowly to the feed.

There are combined carbohydrate and fat supplements using both long and medium chain fats (Table 1.19). Again these must be introduced to feeds in 1% increments to determine the child's tolerance of the product. The addition of 2% of a long chain fat and glucose polymer powder (Super Soluble Duocal) to infant formulas has been shown to increase the feed osmolality by 23.0 mOsm/kg H_2O [47].

A schedule for the addition of energy supplements to infant formulas is given in Table 1.20.

Table 1.20 Schedule for the addition of energy supplements to infant formulas.

Day	Energy source added	Additional CHO/fat per 100 mL feed	Energy added per 100 mL (kcal)	(kJ)
1	1% glucose polymer	1 g CHO	4	17
2	2% glucose polymer	2 g CHO	8	33
3	3% glucose polymer	3 g CHO	12	50
4	3% glucose polymer + 1% fat emulsion	3 g CHO 0.5 g fat	17	69
5	3% glucose polymer + 2% fat emulsion	3 g CHO 1 g fat	21	88
6	4% glucose polymer + 2% fat emulsion	4 g CHO 1 g fat	25	105
7	5% glucose polymer + 2% fat emulsion	5 g CHO 1 g fat	29	121
8	5% glucose polymer + 3% fat emulsion	5 g CHO 1.5 g fat	34	140

Table 1.21 Protein modules.

Per 100 g	Type of protein	Energy kcal	kJ	Protein g	CHO g	Fat g	Na mmol	K mmol	Ca mmol	PO_4 mmol
Vitapro (Vitaflo)	Whole whey protein	390	1630	75	9.0	6.0	9.6	17.1	9.0	9.2
ProMod (Abbott)	Whole whey protein	426	1780	76	10.2	9.1	16.5	17.5	28.5	18.1
Protifar (Nutricia)	Whole milk protein	380	1590	89	<1.5	2.0	4.3	3.1	33.8	22.6
Pepdite Module 0767 peptides from hydrolysed meat and soya (SHS)		346	1469	86.4	–	–	–	–		
Complete Amino Acid Mix Code 0124 L-amino acids (SHS)		328	1394	82	–	–	–	–		

Table 1.22 Vitamin supplements.

		Healthy Start Children's Vitamin Drops (NHS)	Abidec (Chefaro UK)	Dalivit (LPC)	Ketovite (Paines & Byrne)
		5 drops for all infants from 6 months of age†	0.3 mL < 1 year 0.6 mL > 1 year*	0.3 mL < 1 year 0.6 mL > 1 year*	5 mL liquid+ 3 tablets
Thiamin (B_1)	mg	–	0.4	1	3.0
Riboflavin (B_2)	mg	–	0.8	0.4	3.0
Pyridoxine (B_6)	mg	–	–	0.5	1.0
Nicotinamide	mg	–	8	5	9.9
Pantothenate	mg	–	–	–	3.5
Ascorbic acid (C)	mg	20	40	50	50
Alpha-tocopherol (E)	mg	–	–	–	15
Inositol	mg	–	–	–	150
Biotin	μg	–	–	–	510
Folic acid	μg	–	–	–	750
Acetomenaphthone (K)	mg	–	–	–	1.5
Vitamin A	μg	200	400	1500	750
Vitamin D	μg	7.5	10	10	10
Choline chloride	mg	–	–	–	150
Cyanocobalamin (B_{12})	μg	–	–	–	12.5

*Values relate to 0.6 mL dose.
†Unless taking >500 mL infant formula or follow-on milk (see Chapter 27 Vitamin supplements).

Protein

Protein may be added to feeds in the form of whole protein, peptides or amino acids (Table 1.21). Protein supplementation is rarely required without an accompanying increase in energy consumption.

Protein supplements are added to feeds to provide a specific amount of protein per kilogram actual body weight of the child. It is rarely necessary to give intakes >6 g protein/kg; if intakes do approach this value, blood urea levels should be monitored twice weekly to avoid the danger of uraemia developing. Supplements should be added in small increments as they can very quickly and inappropriately increase the child's intake of protein. The osmotic effect of whole protein products will be less than that of peptides, and peptides less than the effect of amino acids.

Vitamin and mineral requirements

Vitamin and mineral requirements for populations of normal children are provided by the DRV [39]. Where no RNI is set, safe levels are given. Some are shown in Table 1.9. In disease states, requirements

Table 1.23 Vitamin and mineral supplements, daily dose.

		Paediatric Seravit Unflavoured powder (SHS)	Forceval Junior Capsule (Alliance)	Forceval Tablet (Alliance)	Fruitivits Soluble Orange flavoured powder (Vitaflo)	Phlexy-Vits Powder and tablet (SHS)
		17 g 6–12 months 17–25 g* 1–7 years	1 capsule >12 years	1 tablet >6 years	6 g 3–10 year	7 g/5 tablets >11 year
Energy	kcal (kJ)	75 (315)	0	9 (38)	2 (8)	0.2† (1.4‡)
CHO	g	18.8	0	0.86	0.5	0.04† (0.01‡)
Protein	g	0	0	0	0.02**	0
Fat	g	0	0	0	0	0.14‡
Sodium	mg	<5	0	250	0	8.8†
Potassium	mg	<0.8	4	98	0	<1.4†
Calcium	mg	640	100	0	800	1000
Phosphorus	mg	430	77	0	500	775
Magnesium	mg	90	30	1	200	300
Iron	mg	17.3	12	5	10	15.1
Zinc	mg	11.5	15	5	10	11.1
Copper	mg	1.2	2	1	1	1.5
Iodine	μg	83	140	75	169	150
Manganese	mg	1.2	3	1.3	1.5	1.5
Molybdenum	μg	88	250	50	68	70
Selenium	μg	34	50	25	41	75
Chromium	μg	34	200	50	41	30
Vitamin A	μg	1050	750	375	500	800
Vitamin D	μg	14	10	5	10	10
Vitamin E	mg	3.7	10	5	9.3	9
Vitamin K	μg	41.5	0	25	60	70
Vitamin C	mg	5.4	60	25	40	50
Thiamin	mg	0.8	1.2	1.5	1.2	1.2
Riboflavin	mg	1.1	1.6	1	1.4	1.4
Niacin	mg	8.8	18	7.5	15	20
Pyridoxine	mg	0.9	2	1	1.7	1.6
Pantothenic acid	mg	4.3	4	2	4.7	5
Vitamin B_{12}	μg	2.2	3	2	2.8	5
Folate	μg	76	400	100	240	700
Biotin	μg	54	100	50	112	150
Inositol	mg	175	0	0	0	0
Choline	mg	87.5	0	0	250	0

*25 g dose.
†7 g sachet dose only.
‡5 tablet dose only.

for certain vitamins and minerals will be different and are fully described in the dietary management of each clinical condition. The prescribable vitamin and mineral supplements that are most often used in paediatric practice are given in Tables 1.22 and 1.23.

Prescribing products for paediatric use

The majority of specialised formulas, supplements and special dietary foods can be prescribed for specific conditions. The Advisory Committee on Borderline Substances recommends suitable products that can be prescribed for use in the community and defines their indications. Prescriptions from the general practitioner (FP10; GP10 in Scotland) should be marked 'ACBS' to indicate that the prescription complies with recommendations. A list of prescribable items for paediatric use appears in the *BNF (British National Formulary) for Children* under the Borderline Substances Appendix and is also available on line at www.bnf.org. Children under the age of 16 years in the UK are exempt from prescription charges.

Useful links and further reading

Infant and Toddler Forum, Open Book on Growth https://www.infantandtoddlerforum.org/open-book-on-growth

Royal College of Paediatrics and Child Health, UK-WHO Growth Charts http://www.rcpch.ac.uk/child-health/research-projects/uk-who-growth-charts/uk-who-growth-charts

Health for all children, Growth charts http://www.healthforallchildren.com/index.php/shop/category-list/Growth+Charts/0

Gibson RS *Principles of Nutritional Assessment*. Oxford: Oxford University Press, 2005.

Hall DMB, *Elliman D* Health for All Children, 4th edn. Oxford: Oxford University Press, 2003.