Part 6

Life stages

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Pre-pregnancy, pregnancy, and lactation

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32.1 Pre-pregnancy

The lifelong nutritional status of a mother, from her own conception and throughout her life to the birth of her baby, will impact on the health and wellbeing of that baby. In addition, the particular importance of the mother's nutrition in the months before conception is now recognized. Here the emphasis is on the achievement of appropriate body weight and optimal nutritional status (and stores) for the months ahead. In addition, pre-pregnancy nutrition takes account of the needs of the very early stages of pregnancy (embryogenesis) when the woman may not be sure she is pregnant.

Maternal nutrition has a profound effect on all aspects of reproduction, including fertility. When energy stores are low, menarche may be delayed, and if energy stores are diminished after menarche, menses are likely to become irregular, infrequent, and possibly stop. Amenorrhoea has been well described in excessive weight loss and in anorexia nervosa. It is estimated that where body fat is less than 22% of body weight, ovulation is unlikely. Healthy, fertile young women have an average body fat proportion of 28%. Menarche can be delayed by athletic training or eating disorders and accelerated by excessive nutrient consumption. It is thought this is due to a requirement for a certain energy store to be present to permit reproduction to occur. In natural settings where energy has been acutely restricted (e.g. due to famine) prior to pregnancy, ovulation is likely to fail.

Obese women are commonly infertile but simple weight reduction of at least 5–10% body weight is thought to bring about return of ovulation, menstruation, and fertility. It is estimated that approximately 30% of sub-fertile couples are overweight or obese. Women with a high body mass index (BMI) also have a lower live birth rate after assisted conception, as well as an increased miscarriage rate.

While there has been considerable speculation about the role of pre-conceptual nutrition and malformation, the only strong evidence relates to the benefit of folic acid supplements in minimizing neural tube defects (NTDs) (spina bifida, anencephaly, and encephalocele). NTDs are the most common congenital malformations of the central nervous system. The highest rates in the Western world are found in Ireland and Scotland (9.9 per 10 000 pregnancies). The neural tube, which will develop into the brain and spinal cord, starts as the neural fold, under the ectoderm along the back of the embryo. Between days 21 and 28 after conception, it closes into a tube, the neural tube. If folate is inadequate, the tube may not close fully and spina bifida may result or the brain may not develop at all. It is thought that NTDs arise from a combination of genetic and environmental components, both of which must be triggered for the

defects to occur. An MRC trial demonstrated that a daily 4-mg folic acid supplement given around the time of conception to women at high risk (those who had already had one affected NTD pregnancy) was shown to prevent the disease in most women (MRC Vitamin Study Research Group, 1991). From the MRC trial it was concluded that folic acid should be given to all women with a previous affected pregnancy and that public health measures (e.g. supplement and/or food fortification) should be available to all women of childbearing age. In the UK, folic acid supplements (400 μg/day) are recommended to all women prior to conception so that folate status is adequate during the early embryonic stages. Surveys suggest that about 55% of women do take this action, but as around a half of all pregnancies are unplanned, universal supplementation is unlikely to be achieved. Low pre-conception folic acid use is associated with low levels of formal education, young maternal age, lack of a partner, immigrant status, and unplanned pregnancy. A higher-dose supplement (5 mg) is recommended for women if they (or their partner) have a neural tube defect, have had a previous baby with a NTD, or have a family history of NTDs or have diabetes.

Mean (± SD) daily intakes of folate in non-pregnant women from dietary sources in the UK is 290 ± 500 μg, which is lower than that provided by supplement use (400 μg) and likely to be insufficient to meet the requirements of women at risk of having an NTD-affected pregnancy. It should be noted that the bioavailability of natural folates found in food is approximately half that of pure folic acid. Some countries (USA and Canada) now have mandatory fortification of key staple foods with folic acid e.g. bread and cereals, and recent data from the USA associates this action with the decreasing spina bifida rates of 14% per year between 1991 and 2002. In other countries, there has been voluntary fortification of some processed foods with folic acid.

32.2 Pregnancy

Pregnancy is a period of rapid growth and development of the fetus, with high physiological, metabolic, and emotional demands on the mother. Adequate nutrition during pregnancy is important to enable the fetus to grow and develop physically and mentally to full potential. It is widely believed that fetal nutrition plays a key role in the wellbeing of the newborn infant and further influences health during childhood and adulthood, with possible effects into the next generation. In addition to fetal nutrient needs, food intake during pregnancy needs to be free from food safety hazards and contribute to the health and wellbeing of the mother. Nutrition during pregnancy is especially important in adolescent mothers who have not yet completed their own growth.

Fetal growth is divided into three stages: the 2-week blastogenesis stage, where the fertilized ovum rapidly develops and implants itself into the endometrial lining of the uterus; the critical embryonic stage where the rudiments of all the principal organs and membranes develop (lasts for 6 weeks); and the fetal stage, which extends to term (40 weeks). During the embryonic stage, all the tissues and organs are defined. The fetus is particularly vulnerable to retarded development or abnormality at this stage if necessary nutrients are absent.

32.2.1 Regulation of nutrient supply to the fetus

The relationship between fetal nutrition and maternal food intake is indirect. In addition to the quantity, quality, and balance of maternal dietary intake, nutrient supply to the fetus will be influenced by a number of adaptive physiological processes that occur during pregnancy. These include increased maternal absorption of some nutrients (e.g. iron), increased bone turnover (facilitating calcium needs), an increase in circulating blood volume resulting in haemodilution of red cells (as plasma volume increases), and an accompanying fall in

haemoglobin concentration. In general, maternal plasma levels of water-soluble vitamins fall with a relative rise in fat-soluble vitamins. The placenta is responsible for the exchange of nutrients between the mother and fetus, and nutrient supply will be influenced by an expanding uteroplacental blood flow (up to 800 mL/min at term), placental transfer mechanisms (by diffusion, facilitated diffusion, and active transport), and fetal uptake. Thus, mothers have many protective mechanisms that will help to moderate the effect of poor diet and lifestyle (alcohol, activity, smoking), but these do not provide universal protection or guarantee life-long health.

32.2.2 The energy cost of pregnancy

Researchers who have investigated energy economics in pregnancy have found big differences between women in developing countries, who tend to be smaller and have to do more physical work, and well-nourished women in developed countries. In both settings individual women vary considerably in their pre-pregnant size, in how much fat they put on during the pregnancy, in changes of basal metabolic rate, and in reduction of their physical activity.

Recommendations for average energy intake are based on energy expenditure for women within the healthy weight category. In pregnancy, this is estimated from (i) the energy value of the fetus and placenta and the extra maternal tissues: uterus, breasts, and adipose tissue; plus (ii) any extra energy expenditure (basal metabolic rate plus physical activity for the heavier body) at the different stages of pregnancy. The total energy cost of pregnancy is then distributed into the trimesters and it is agreed that there is little or no extra energy need in the first trimester. It is estimated that the *average* energy cost of pregnancy for a woman who gains 12 kg weight works out to 325 MJ. From this, the expert committees in North America and Australasia both recommend an extra 1.5 MJ/day in the second trimester and 1.9 MJ/day in the third trimester (Table 32.1).

However, many measurements of energy intake throughout pregnancy in women in 10 different countries (nearly 1000 women in all) found that most of them ate less than one extra MJ/day and the average was +0.3 MJ/day. This finding forms the basis of the 1991 UK recommendation of 0.8 MJ extra/day (only) in the third trimester (Table 32.1), but women who are underweight at the beginning of pregnancy and women who do not reduce activity may need more, the report stated.

Table 32.1 Extra energy recommendations in pregnancy for the average woman (MJ/day)

	North American 2002 and Australasian 2006	WHO 2004	UK 1991
First trimester	0	+0.375	0
Second trimester	+1.4	+1.2	0
Third trimester	+1.9	+1.95	+0.8

Weight gain throughout pregnancy is thought to average 11, 47, and 42% of the total in the first, second, and third trimesters. Table 32.2 shows the

Table 32.2 The distribution of maternal weight gain at 40 weeks' gestation

	Weight gain distribution (g)
Fetus	3300–3500
Placenta	650
Increase in blood volume	1300
Increase in uterus and breasts	1300
Amniotic fluid	800
Fat stores and additional fluid retention	4200–6000
Total	11 550–13 550

distribution of maternal weight gain at birth. Increase in maternal tissue (i.e. uterine and breast tissue), blood and other body fluids, and adipose tissue occurs mainly in the second trimester, while growth of the fetus, placenta, and amniotic fluid occurs mainly in the third.

Adequate maternal weight gain during pregnancy is the principal means of ensuring adequate fetal growth and, hence, infant birth weight. Excessive gain is associated with large infants (>4200 g), increased likelihood of caesarean delivery, and postpartum obesity. Because of the wide variation in weight gain among women who give birth to optimally grown infants, a range of weight gains is regarded as acceptable for each BMI. A normal weight gain for most healthy women is between 11–15 kg, averaging about 12.5 kg. The US Institute of Medicine guidelines, which are based on observational data, indicate that healthy American women who are a normal weight for their height (BMI 18.5–24.9 kg/m^2) should gain 11.5–16 kg (25–35 pounds) during pregnancy. Overweight women (BMI 25–29.9 kg/m^2) should gain 7–11.5 kg (15–25 pounds) and obese women (BMI > 30 kg/m^2) should only put on 5–9 kg (11–20 pounds). However, these figures are not recommended by NICE (UK), who note that there are no evidence-based guidelines from the UK government or professional bodies on what constitutes appropriate weight gain during pregnancy.

Maternal anthropometry differs between ethnic groups and separate guidelines should be used for other ethnic groups, such as Chinese and Polynesians.

32.2.3 Birth weight: the effect of maternal age, maternal weight, and energy intake

Birth weight is regarded as one of the best indicators of overall nutritional status of the infant and its wellbeing. The normal birth weight range is considered to be between 2500 and 4200 g. Low-birth-weight (LBW), i.e. babies weighing less than 2500 g, is a major cause of infant mortality and has been linked with long-term morbidity, including deficits in growth and cognitive development in childhood and diabetes and heart disease in adult life.

UNICEF estimates that around 19 million newborns each year in the developing world weigh less than 2500 g at birth, and more than half of them are born in South Asia. India has the highest number of LBW babies each year: 7.4 million.

In Australia, babies born to indigenous (aboriginal) women in 2007 were twice as likely to be LBW (12.5%) as those born to non-indigenous women (5.9%). LBW is caused by preterm birth, intrauterine growth retardation, or both.

Adolescents who are still growing are one population subgroup at greater risk of having LBW babies. Even when their own weight gain is sufficient to ensure adequate fat stores, they do not appear to mobilize these stores to enhance fetal growth late in pregnancy. Consequently, their nutritional requirements are greater, and this is reflected in higher recommended energy intakes for younger pregnant women in the UK. Low maternal body weight is also associated with LBW. However, in the developed world, current evidence suggests that chronic low maternal energy intakes does not significantly contribute to LBW, and attempts to increase birth weight through energy supplements have had negligible effects. One (positive) potential nutritional influence on birth weight is a diet rich in long-chain ω-3 polyunsaturated fatty acids (LCP), and randomized control trials have shown an increase in gestation (6 days) with LCP supplements, although overall the effects are rather modest. A wide range of nutrients has been examined in an attempt to influence birth outcomes (including iron, folate, zinc, vitamin D) but these have had little effect. Supplementation with magnesium from the 25th week of gestation has been shown to result in fewer preterm and LBW deliveries, but these results did not differ significantly from placebo groups. It should be noted that protein supplements have a negative effect on birth weight.

32.2.4 Obesity in pregnancy

Recent data (2007) from England show that maternal obesity has doubled from 7.5% to 15.6% over 19 years. In addition, around a quarter of all women in the first trimester are in overweight category. Women who are obese when they become pregnant have higher health risks, including impaired glucose tolerance and gestational diabetes, miscarriage, pre-eclampsia, thromboembolism, and maternal death. Additionally, it has been observed that even a relatively small gain of 1–2 BMI units (kg/m^2) between pregnancies may increase the risk of gestational hypertension and gestational diabetes. Obese women are more likely to have an induced or longer labour, instrumental delivery, caesarean section, or postpartum haemorrhage. Reduced mobility during labour can result in the need for more pain relief and possibly general anaesthesia with its associated risks. Babies born to obese women also face health risks, including a higher risk of fetal death, stillbirth, congenital abnormality, shoulder dystocia, macrosomia (large baby), and subsequent obesity. However, in the absence of trial data on the impact of weight modification during pregnancy, obstetricians remain cautious and recommend that dieting for weight loss during gestation should be discouraged, as this may result in LBW infant if there is serious caloric restriction in the third trimester.

In the UK, the National Institute for Health and Clinical Excellence (NICE) (2010) advises that during pregnancy the key message is to ensure that the myth to 'eat for two' is dispelled. Professionals should be clear that extra calories (above nonpregnant intake) are required, but only during the last trimester, and it is also important to communicate that slimming is not appropriate during pregnancy. For women with a BMI > 30 kg/m^2, weight loss during pregnancy is not recommended. Personalized guidance on healthy eating (with appropriate assessment) and ways to become more physically active are advised. In terms of starting to increase activity, women should begin with no more than 15 min of continuous exercise, 3 times a week, increasing gradually to daily 30 min sessions. Encouragement should be given to lose weight after pregnancy.

32.2.5 Fetal nutrition, birth outcome, and health in later life

An increasing body of evidence suggests that early nutritional status (as indicated by birth weight and other parameters) modifies the risk of disease (notably cardiovascular) in later life. Birth weight has been used as a proxy measure of fetal nutrient exposure, although it may not be a sensitive enough measure to describe inadequate or unbalanced maternal nutrition. The hypothesis for the relationship between nutrition and early origins of disease is based on the concept that in fetal life the tissues and organs of the body go through periods of rapid development, termed critical periods. Critical periods may coincide with periods of rapid cell division. Thus, if the fetus is deprived of nutrients or oxygen at such times, it may adapt by slowing the rate of cell division, especially in tissues undergoing critical periods. Even brief periods of undernutrition may permanently reduce the numbers of cells in particular organs. It is postulated that fetal undernutrition may change or programme the body with respect to distribution of cell types, hormonal feedback, metabolic activity, and organ structure.

Extensive research by David Barker and colleagues (Barker, 1994) has related causes of adult mortality and morbidity to fetal and infant life. These observational studies have related LBW to adverse health outcomes in adulthood, including hypertension, type 2 diabetes, and coronary heart disease. Variations in newborn ponderal index (kg/m^3) and placenta weight/birth weight ratios have also been related to subsequent hypertension. These observations have led to the fetal origins hypothesis, which states that fetal undernutrition in middle-to-late gestation leads to disproportionate fetal growth and programmes the later development of several diseases which are common in affluent societies and other groups undergoing rapid acculturation.

This hypothesis has been challenged by a number of researchers. Other studies only show a direct association between small size in early life and later adult health outcomes if body size at some intermediate period has been adjusted for. Researchers have suggested that this finding implies that it is probably the change in size across the whole time interval (postnatal centile crossing), rather than fetal biology, that is implicated. Thus, it remains to be resolved whether people who are small in early life and then grow rapidly are more at risk than those who remain small.

32.2.6 Nutrient requirements during pregnancy

Energy Women do not eat or need to eat for two (see Section 32.2.2), but they do need to eat a high-quality nutritious diet to ensure that they obtain their extra requirements for several essential nutrients.

Protein A summary of recommended intakes for protein and other nutrients for a number of countries is presented in Table 32.3. Additional protein is

Table 32.3 Recommended daily nutrient intakes during pregnancy

	USA[a]			Australia/ NZ[b]	UK
	Women NOT pregnant 2005	Change for pregnancy	Pregnant 2005	Pregnant 2006	Pregnant 1991
Protein (g)	46	+54%	71	60	51
Vitamin A (μg)	700	+10%	770	800	700
Vitamin D (μg)	5	0	5	5	10
Vitamin E (mg)	15	0	15	7	–
Vitamin C (mg)	75	+13%	85	60	50
Thiamin (mg)	1.1	+27%	1.4	1.4	0.9
Riboflavin (mg)	1.1	+27%	1.4	1.4	1.4
Niacin (NE) (mg)	14	+29%	18	18	13
Folate (μg)	400	+50%	600	600	300[c]
Vitamin B_{12} (μg)	2.4	+8%	2.6	2.6	1.5
Calcium (mg)	1000	0	1000	1000	700
Magnesium (mg)	310	+13%	350	350	300
Iron (mg)	18	+50%	27	27	15
Zinc (mg)	8	+38%	11	11	7
Iodine (μg)	150	+47%	220	220	140

[a]Numbers for USA are recommended daily allowances (RDAs) from dietary reference intake (DRI) recommendations for females 19–50 years.

[b]These recommendations are RDIs 2004, except for vitamin D and vitamin E, which are adequate intakes.

[c]A supplement of 400 μg/day folic acid is now advised.

NE, niacin equivalents.

required during pregnancy to provide for the synthesis of fetal, placental, and maternal tissue. Maternal and fetal growth accelerates in the second month of pregnancy and continues to increase until just before term. The need for protein follows this growth. However, the extra amount is relatively small (6–10 g/day) and is usually readily provided in a normal pre-pregnant Western diet.

Folate Pregnancy is a period characterized by extra cell division and growth. This increases folate requirements more than for any other nutrient. Folate requirement is increased in the first 12 weeks (see Section 32.2.6) and supplements are recommended preconceptually and in early pregnancy. Increases in dietary intakes of folates are also recommended throughout pregnancy to avoid megaloblastic anaemia in late pregnancy or the puerperium. Differences in recommended dietary intakes by country (Table 32.3) have arisen due to differences in primary indicators of status.

Calcium Around two-thirds of the calcium in the fetus is deposited during the last 10 weeks of gestation, mostly in the fetal skeleton. Alterations in maternal calcium metabolism, including a substantial increase in the absorption of dietary calcium, occur early in pregnancy to facilitate this increase in fetal demand. There has been concern that inadequate dietary intake of calcium during pregnancy was compensated by mobilization of skeletal calcium, leading to an increased risk of osteoporosis in later life. However, recent evidence suggests that the adaptation in calcium metabolism that occurs in pregnancy is sufficient to maintain fetal growth, even if dietary calcium is not increased. Current guidance promotes an adequate calcium intake throughout life, rather than increasing dietary intake during the gestation period. A Cochrane review on calcium supplementation during pregnancy for preventing hypertensive disorders and related problems (Hofmeyr *et al.*, 2006) has reported that calcium supplementation appears to be beneficial for women at high risk of gestational hypertension and in communities with low dietary calcium intake, although optimum dosage requires further investigation.

Iron The demand for iron is not evenly distributed throughout gestation. During the first trimester, requirements are minimal, as iron is no longer lost during menstruation. Iron absorption increases as pregnancy progresses, from an absorption rate of around 7% at 12 weeks' gestation to 66% at 36 weeks. Many women enter pregnancy with low iron stores or even frank iron-deficiency anaemia (IDA). Maternal IDA may increase the risk of preterm delivery, resultant LBW, and perinatal mortality. As well, evidence is accumulating that maternal IDA reduces infant iron stores postpartum, leading to the possibility of impaired development in the infant. There remains considerable debate on the use of iron supplements during pregnancy with respect to whether this is an attempt to alter a natural physiological process that in some way enhances nutrient supply. Dietary guidance in the UK suggests that no dietary changes to iron intake are required due to physiological changes, although women with poor iron status at the time of obstetric booking may need iron supplements. The WHO recommend a cut-off of 110 g/L for anaemia throughout pregnancy and in the UK NICE recommends that iron supplementation should be considered for women with haemoglobin concentrations below 110 g/L in the first trimester and 105 g/L at 28 weeks.

Zinc Zinc is necessary for DNA and RNA synthesis. Maternal zinc deficiency may be responsible for growth retardation, preterm delivery, and abnormality in the fetus, and birth complications in the mother. Factors that limit the absorption of zinc such as high intakes of dietary phytate, calcium, and iron supplements may cause secondary zinc deficiency. Recently published dietary recommendations include an increase of zinc intake in pregnancy. The extra zinc should come from foods (see Section 11.1.5). It is possible that iron supplements could reduce zinc intake.

Iodine Iodine deficiency during pregnancy remains a major public health problem in many areas of the world. Cretinism, caused by severe lack of iodine during fetal development, is characterized by both mental and physical retardation. Millions of

babies are born each year at risk of mental impairment due to iodine-deficient diets. Iodization of salt is commonly used to prevent deficiency. In areas where there is cretinism and extensive goitres, expectant mothers should be given an injection of iodized oil, preferably before conception (see Section 11.3.5). However, overt iodine deficiency is not seen in developed countries among pregnant women.

Vitamin A Vitamin A deficiency, seen mostly in some developing countries, may be associated with blindness, depressed immune function, and increased morbidity and death from measles and other infectious diseases, as well as increased mother-to-child transmission of AIDS. Encouraging foods rich in this vitamin (see Chapter 12) is the most appropriate approach to ensuring adequacy. But in pregnancy, intakes above the RDI (> 3000 μg retinol daily) resulting from the use of supplements, excessive intakes of fortified foods, and, occasionally, high intakes of liver can be teratogenic, causing central nervous and heart defects. High levels of vitamin A have been detected in the liver of farmed animals in the UK (due to the composition of animal feedstuffs); thus, all pregnant women are advised to avoid liver, liver products, vitamin supplements, and fish oil supplements that are high in retinol. In developing countries where appropriate foods are not readily available, supplementation may be considered (700 μg/day).

Vitamin D Populations at risk for vitamin D deficiency are those whose skin exposure to sunlight is low, particularly dark-skinned women living in northern climates such as ethnic minority groups in the UK. The infants born in such populations have low vitamin D stores. Vitamin D insufficiency during pregnancy is associated with lower maternal weight gain, neonatal tetany, and biochemical evidence of disturbed skeletal homeostasis in the infant. In extreme situations, reduced bone mineralization, radiologically evident rickets, and fractures may occur. In the UK, it is recommended that all pregnant women take a vitamin D supplement (10 μg/day), and this has been reinforced recently following cases of rickets.

Vitamin C It appears that the fetus concentrates vitamin C at the expense of maternal stores and circulating vitamin levels. Accordingly, it is recommended that dietary intake of foods rich in vitamin C are increased during pregnancy.

In summary, while mineral requirements increase during pregnancy, most of the extra nutrients can be attained through physiological adaptation rather than dietary change (in the well-nourished). With respect to vitamins, extra dietary intakes of vitamin C and vitamin A are required, which may mean increasing intakes by rich dietary sources (but not by supplements). Increasing intakes of folate and vitamin D should be met by increasing dietary sources, as well as by supplements.

32.2.7 Lifestyle factors that impact on pregnancy outcome

Alcohol Heavy drinkers have a greatly increased risk of inducing the fetal alcohol syndrome, with characteristic underdevelopment of the mid-face, small body size, and mental retardation. Any effect of alcohol is likely to be greatest in the first few weeks after conception, the embryogenesis stage. Women who intend to become pregnant should not have multiple alcoholic drinks whatever the occasion; they could already be 2 or 3 weeks pregnant. Once pregnancy is established, the rule should be no more than one standard drink a day to be sure of avoiding minor effects, chiefly growth retardation.

Smoking Smoking causes retardation of fetal growth, thereby increasing the risk of producing a LBW baby. The older the mother and the more cigarettes smoked, the greater the effect. A decrease in birth weight of approximately 200–250 g is usually found in infants of mothers who smoke more than 20 cigarettes a day. Smoking also increases the risk of spontaneous abortion, preterm delivery, and sudden infant death.

Exercise Most recent studies show that moderate exercise during pregnancy does not harm the fetus

and benefits the mother. Benefits can include reduced fat gain, lower risk of gestational diabetes, maintenance of aerobic fitness, shorter labour, quicker delivery, and fewer surgical interventions. However, high-impact exercise or hard physical work can affect fetal development and often results in LBW babies and a higher frequency of obstetric complications.

32.2.8 Other diet and health concerns

Coffee Caffeine freely crosses the placenta. The risk of spontaneous abortion and LBW appears to increase with high maternal caffeine intake during pregnancy. It is sensible to limit caffeine consumption in pregnancy and current guidelines suggest pregnant women have no more than 200 mg of caffeine a day (approximately 2 mugs of instant coffee or 4 cups of tea). Some women develop aversion to coffee when they are pregnant.

Oil-rich fish Due to contaminants such as mercury, which may be stored in high concentrations in fatty fish, pregnant women are recommended to restrict intake of oily fish. These recommendations will vary by region. In the UK, pregnant women are advised not to eat marlin, shark, or swordfish, to limit tuna to four cans per week, and not to exceed oily fish consumption above two portions per week. However, it is considered beneficial to consume at least one portion of oil-rich fish, e.g. herring, salmon, and sardines, weekly during pregnancy.

Food safety Pregnant women are unusually susceptible to infection with *Listeria monocytogenes*, which can contaminate uncooked foods. After an incubation period of 2–6 weeks, infection can result in a mild chill or more severe illness, premature birth, or stillbirth. There can also be effects in the newborn, including meningitis. Listeriosis responds to antibiotics when it is diagnosed. In the UK, the incidence is estimated at 1 in 30 000 live and stillbirths. The department of health recommends that pregnant women avoid certain ripened soft cheeses, such as Brie, Camembert, and blue-veined cheese, and any type of paté.

Salmonella, toxoplasma and food poisoning more generally also needs to be avoided with greater care during pregnancy than at other times.

32.2.9 Physiological effects of pregnancy that impact on dietary intake

Nausea and vomiting It is hypothesized that nausea and vomiting are part of the maternal system to protect against toxins. In support of this hypothesis, a comprehensive review reported that: (i) symptoms peak when embryonic organogenesis is most susceptible to chemical disruption (weeks 6–18); (ii) women who experience morning sickness are less likely to miscarry than women who do not; (iii) women who vomit suffer fewer miscarriages than those who experience nausea alone; and (iv) many pregnant women have aversions to alcoholic and non-alcoholic (mostly caffeinated) beverages and strong-tasting vegetables, especially during the first trimester.

There is no generally effective remedy for morning sickness and, given the vulnerability of the fetus in the early stages of development, it is important to find alternatives to drug therapy.

Changes in eating habits such as small, frequent meals and avoidance of strong food odours appear to help some women. A recent Cochrane review using data from six double-blind randomized controlled trials with a total of 675 participants and a prospective observational cohort study indicated that ginger was effective in relieving the severity of nausea and vomiting episodes with no significant side effects or adverse effects on pregnancy outcomes. The authors concluded that more observational studies are needed to confirm this encouraging preliminary data on ginger.

Hyperemesis gravidarum (HG) is a condition that causes severe nausea and vomiting in early

pregnancy, often resulting in hospital admission. The incidence of HG varies from 0.1 to 1% and appears higher in multiple pregnancies, hydatidiform mole, and other conditions associated with increased pregnancy hormone levels. Both the aetiology and pathogenesis of HG remain unknown, although a range of pregnancy hormones (progesterone, oestrogen, and human chorionic gonadotrophin) and other hormones have been implicated. Infants from HG pregnancies have significantly lower birth weight, younger gestational age, and a greater length of hospital stay. The persistent vomiting can lead to Wernicke's encephalopathy (also see 13.1.4) so it is important that thiamin is given with replacement intravenous fluids.

Cravings and aversions Some change in liked and disliked foods is common in pregnancy. There can be cravings or aversions. Food cravings are popularly believed to be related to the nutritional needs of the mother, to have symbolic value, or to be related to sensory or physiological causes. Food aversions have been defined as 'a definite revulsion against food and drink not previously disliked'. Typical examples are tea, coffee, and alcohol. The explanation for these cravings and aversions is incomplete. They may relate to changes in olfactory and taste sensitivity during pregnancy.

Constipation Around 40% of women report having been constipated some time during pregnancy. Its aetiology is complex and includes depressed gut mobility in pregnancy, increased fluid absorption from the large intestine, decreased physical activity, and dietary changes. However, an increase in fibre, from an average intake of about 18 g/day to 27 g/day, has shown to be effective in treating constipation.

32.3 Lactation

The decision to breastfeed is influenced by psychobiological and psychosocial factors, which vary between and within cultures. The proportion of babies who were ever breastfed varies widely, as does the duration of exclusive feeding. Across Europe, less than 70% of babies in France and Ireland to around 100% in Denmark, Norway, and Sweden initiate breastfeeding. In Australia in 2005, around 88% of mothers started breastfeeding but only 17% were exclusively breastfeeding at 6 months. In the UK around 78% of mothers initiate breastfeeding but less than 3% are still exclusively breastfeeding at 6 months.

This compares with Rwanda and North Korea, where 88% and 65% are still exclusively breastfeeding at 6 months. In most countries, initiation and duration of breastfeeding are positively associated with maternal education status, maternal income, and marital status.

The physiology of lactation is complex, but may be briefly summarized as follows: the suckling infant stimulates the mother's pituitary gland to release prolactin, a hormone required for the synthesis of breast milk. Milk-producing cells synthesize most of the protein and some of the fats and sugars, which combine with other nutrients derived from the mother's circulation. A second pituitary hormone, oxytocin, is responsible for releasing the milk from the cells into the ducts that carry the milk to the nipples.

32.3.1 Composition of breast milk and implications for maternal nutrition

Human milk feeding is adequate as the sole source of nutrition for up to age 6 months providing that the maternal diet and stores are adequate and the milk is successfully transferred to the infant. The composition and volume of breast milk progressively changes with the stage of lactation and can be influenced by maternal nutritional factors. Current evidence indicates that infant demand is the major

determinant of the quantity of milk produced. The nutritional demands of lactation on the mother are directly proportional to volume and duration of milk production.

The daily milk volume varies over the duration of lactation but is fairly consistent except in extreme maternal malnutrition or severe dehydration. Breast milk intake among healthy infants averages 750–800 g/day and ranges from 450 to 1200 g/day. The composition of milk will be influenced by time of day, gestational age (prematurity versus term), stage of lactation, parity, month (i.e. seasonal food intake), nutritional status of mother, and maternal dietary intake. Lipids are the most variable constituent in human milk. In the first week after birth, colostrum is produced, which has a fat content of 2.6 g/100 mL. This is followed by transitional milk between days 7 and 14, and then finally mature milk, which has a fat content of 4.2 g/100 mL.

32.3.2 Maternal nutrient requirements to support lactation

During pregnancy, the mother's body prepares for lactation by storing some nutrients and energy. It is difficult to determine precise nutrient requirements for lactation since there is variation in nutritional status before and during pregnancy, and limited knowledge about utilization of maternal nutrient stores and adaptations of maternal metabolism during lactation.

The total energy cost of lactation is derived from the energy content of the milk plus the energy required to produce it. The energy value of breast milk is between 2.7 MJ/L and 3.1 MJ/L. The ratio between the energy content of milk and the total energy cost of lactation is the efficiency of milk production. Current estimates for exclusive breastfeeding suggest that the energy cost of lactation is around 2.625 MJ/day (625 kcal) based on a mean milk production of 750 g/day with an energy density of milk of 2.8 kJ/g and energetic efficiency of 0.80. In well-nourished women, this will be partially met by energy mobilization from fat tissues of about 0.65 MJ/day (for weight reduction of 0.5 kg fat/month), resulting in a net increment of around 2.0 MJ/day (480 kcal)) over non-pregnant, non-lactating energy requirements. This assumes the ideal situation where the new mother gradually uses up the extra 2–5 kg fat put on during pregnancy over 6 months of breastfeeding. The value will vary when complementary feeding is introduced or the baby becomes only partially breastfed. Women who exclusively breastfeed for 6 months may require as much as 2.4 MJ extra/day.

32.3.3 Other nutrients

Table 32.4 shows recommended nutrient intakes for five countries. The North American recommended nutrient intakes were published between 1998 and

Table 32.4 Recommended daily nutrient intakes during lactation

Nutrient	USA	USA and Canada, Australia/NZ[a]	USA and Canada	UK 1991
	NPNL women	Lactating	% Increase	Lactating
Protein (g)	46	67	+46	56
Vitamin A (μg)	700	1300 (1100)	+86	950
Vitamin D (μg)	5	5	0	10
Vitamin E (mg)	15	19 (11)	+27	–

(*Continued*)

Table 32.4 Recommended daily nutrient intakes during lactation (*Continued*)

Nutrient	USA	USA and Canada, Australia/NZ[a]	USA and Canada	UK 1991
	NPNL women	Lactating	% Increase	Lactating
Vitamin C (mg)	75	120 (80)	+60	70
Thiamin (mg)	1.1	1.4	+ 27	1.0
Riboflavin (mg)	1.1	1.6	+45	1.6
Niacin (NE) (mg)	14	17	+21	15
Folate (µg)[b]	400	500	+25	260
Vitamin B_{12} (µg)	2.4	2.8	+17	2.0
Calcium (mg)	1000	1000	0	1250
Iron (mg)	18	9[c]	–50	15
Zinc (mg)	8	12	+50	13
Iodine (µg)	150	290 (270)	+93	140

[a]Where the Australasian RDI is different, it is shown in brackets.

[b]These are RDIs for dietary folate equivalents in USA, Australia, and NZ.

[c]For first 6 months of lactation; assumes menstruation not restarted.

NPNL = not pregnant, not lactating.

2002 and the Australasian in 2005–2006. The British recommendations date from 1991. In developed countries, there is sufficient protein and most other nutrients in usual diets so that the average extra 2.0 MJ of food per day will cover the extra nutrient needs with two exceptions. In the northern winter, a vitamin D supplement is advisable, and vegans must take a vitamin B_{12} supplement (these are available from microbiological, i.e. non-animal, sources). Although some 260 mg of calcium are secreted per day in mother's milk, epidemiological studies have found no increase in osteoporosis or fracture in women who have breastfed compared with those who did not.

The US Institute of Medicine sums it up:

> 'The loss of calcium from the maternal skeleton that occurs during lactation is not prevented by increased dietary calcium, and the calcium lost appears to be regained following weaning. There is no evidence that calcium intake in lactating women should be increased above that of non-lactating women.'

Some nutrients in the breast milk are increased if there is more of them in the mother's diet: water-soluble vitamins, vitamin A, and polyunsaturated fatty acids. Most other constituents in the milk—protein, lactose, total fat, and calcium—do not appear to be influenced by maternal intake.

It is now no longer considered necessary to advise mothers with a family history of allergy to avoid peanuts or peanut butter during pregnancy and lactation. After a cup of coffee or glass of wine, the concentration of caffeine or alcohol in the milk is about the same as in the mother's plasma; the infant gets a lower dose per kg than the mother but has less metabolizing capacity.

Adequate fluid intake (especially water) should be advised for breastfeeding mothers. The exact amount required is unknown but 6–8 glasses is generally sufficient. The nutrient reference values for Australia and NZ (2005) recommend 2.6 litres per day during lactation (2.3 L during pregnancy).

32.3.4 Lactation and maternal obesity

Pregnancy is a risk factor for obesity. Some women put on more than the standard 2–5 kg of fat. The question arises whether milk production and the baby will suffer if the lactating mother restricts her food intake. Lovelady *et al.* (2000) tested this out in a randomized controlled trial in overweight (not obese) women. They lost approximately 0.5 kg per week between 4 and 14 weeks postpartum from moderate food restriction and exercise: their infants gained the same weight and length as the controls, but some of the control mothers put on weight. Overall, current evidence (reviewed by NICE, 2010) suggests that weight management interventions (addressing diet and physical activity) during lactation have little or no adverse effects on breastfeeding outcomes, including milk volume, infant intake, and time and frequency of feeding.

Further Reading

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Useful Websites



To see topical and scientifically robust updates on nutrition associated with this textbook and web links to many of the journals in the Further Reading sections, please see the dedicated Online Resource Centre at **http://www.oxfordtextbooks.co.uk/orc/mann4e/**



Infant and toddler feeding

Vishal Avinashi, Donna Secker, and Stanley Zlotkin

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Interest in infant and toddler feeding centres around two principal objectives: the promotion of normal growth and brain development, and the prevention of illness during the first years of life. Infants and toddlers grow and develop rapidly in the first 2 years, making them particularly vulnerable to nutritional inadequacies. Breastfeeding, followed by the introduction of a wide variety of solid foods, provides the best opportunity for optimal growth and health during infancy. After 1 year of age, the infant should be consuming a variety of foods from the adult diet to ensure a nutritionally balanced intake.

Decades of animal experiments as well as studies evaluating the growth of human infants under varying environmental conditions suggest that early infant nutrition and postnatal growth are important factors for long-term health. Researchers have hypothesized that nutritional deficits occurring during fetal life predispose or programme an individual towards a tendency to develop chronic diseases in later life. The original fetal origins hypothesis by Barker, also known as the thrifty phenotype, proposed an association between low birth weight, accelerated postnatal growth, and adult heart disease. This hypothesis has since been expanded to include chronic diseases such as hypertension, insulin resistance, and obesity. More recently, researchers have proposed a postnatal programming hypothesis (the Lucas hypothesis), implying that it is early postnatal nutrition and growth that influences later health, rather than prenatal life. It has been suggested that limiting caloric intake and subsequently the rate of weight gain in infancy could reduce the risk of developing these chronic conditions. However, providing evidence to support this claim is nearly impossible given the multiple confounders and differing genetic backgrounds and exposures, as well as the great difficulty and cost following up such a cohort. Restriction of nutrition during infancy is not recommended, especially as undernutrition adversely affects brain growth.

33.1 Milk diet

33.1.1 Breastfeeding

Human milk is specifically composed to meet the nutritional requirements of the human infant and is considered the optimal nutrition source for healthy newborns (Box 33.1). Breastfeeding provides immunological protection, which is greatest

BOX 33.1 Benefits of breastfeeding

Short-term benefits	Possible long-term benefits
Low cost	Decreased obesity
Increased bonding	Decreased type 1 diabetes
Immunological benefit	Increased cognitive benefits
Decreased infections—diarrhoeal and respiratory	
Decreased SIDS	

during the early months, but increases with the duration and exclusiveness of breastfeeding. The psychological benefit of early and prolonged physical contact contributes to the development of a strong mother–infant bond. Other benefits include convenience, safety, and low cost, in addition to the benefits gained by the mother, such as delayed resumption of ovulation, increased postpartum weight loss, and decreased risk of breast cancer. With the exception of vitamins D and K, breast milk produced by adequately nourished mothers provides all the nutrients needed by a normal, healthy, full-term infant for the first 6 months of life. Water or other fluid supplementation is unnecessary in the otherwise-healthy infant in the first 6 months of life. The water requirements of infants in a hot, humid climate can be provided entirely by the water content in human milk. When it is hot, infants may just nurse more often.

Recent studies have provided good evidence that, even in developed countries, breastfeeding protects against gastrointestinal and respiratory infections, reduces the risk of otitis media, and reduces the incidence of sudden infant death syndrome. Breastfeeding also decreases the incidence of atopy (clinical forms of inherited hypersensitivity) in infants, with some evidence to suggest that the protection is extended into childhood.

On the longer-term basis, there is some evidence suggesting that breastfeeding may play a role in preventing type 1 diabetes (insulin-dependent diabetes mellitus). Breastfed children have been shown to have a lower prevalence of obesity later in life than formula-fed infants, even after adjusting for key factors such as energy intake, screen time, physical activity, and mothers' body mass index. In addition, there is documentation that the mean values for cognitive development in populations of children who were breastfed are slightly higher compared with bottle-fed infants from similar environments.

Breastfeeding is rarely contraindicated. Exceptions include infants with galactosaemia and mothers who have untreated active tuberculosis, active herpetic breast lesions, or human T-lymphotropic virus type I infection, or are receiving ongoing radiation therapy or certain chemotherapeutic agents. Neither smoking nor environmental contaminants are necessarily contraindications to breastfeeding. Moderate, infrequent alcohol ingestion, the use of most prescription and over-the-counter drugs, and many maternal infections do not preclude breastfeeding.

Although maternal-to-child transmission of HIV through breast milk is a known route of transmission, avoidance of breastfeeding is not practical in settings where formula feeding is not available, affordable, sustainable, or safe. Lessons learned have shown that in the context of an HIV-positive mother, if one cannot provide appropriate infant formula feeds consistently, there will be less viral transmission if the infant is breastfed exclusively until 6 months compared to infants who are receiving a mix of formula and breast milk.

33.1.2 Formula feeding

When a mother chooses not to breastfeed, the only acceptable alternative is a commercial infant formula. Manufacturers continue to modify their products in an effort to emulate human milk and, although they provide less than the optimal benefits of human milk, they are nutritionally adequate for the first year of life. The standard formula choice is a formula based on cow's milk, containing skimmed milk powder, lactose, and a variable blend of oils. These formulas are available in two versions: low iron (similar amounts to human milk, but with much lower bioavailability) or iron-

fortified (10–12 mg/L elemental iron). Use of low-iron formulas is one of several risk factors implicated in the incidence of iron-deficiency anaemia, the most common nutritional deficiency among infants and toddlers. To provide the best guarantee of normal iron status, the use of iron-fortified formulas is recommended.

Soy-based formulas made from soy protein, vegetable oils, and glucose polymers (with or without sucrose) are available for infants of vegetarian families, infants with galactosaemia, confirmed lactose intolerance, or infants with confirmed IgE-mediated allergy to cow's milk protein. Soy formulas are not indicated for low-birth-weight infants, prevention or management of colic, prevention of allergy or food intolerance, routine treatment of gastroenteritis, or treatment of infants with non-IgE-mediated allergy to cow's milk protein (i.e. enteropathy or enterocolitis). Since the distinction between IgE- and non-IgE-mediated allergy to cow's milk protein is not easily made or practical, it is safer not to use soy formula for the treatment of cow's milk protein allergy.

Recent concerns with respect to the safety of soy formulas are related to their content of phyto-oestrogens. Since phyto-oestrogens have oestrogen-like activity, it has been suggested that adverse effects on the developing endocrine system may occur in infants fed soy protein-based formulas. The presence of phyto-oestrogens in human infants does not necessarily mean that they are biologically or clinically active. Soy-based formulas have been used for almost 40 years without evidence of hormone-related adverse effects and term infants fed soy-based formula have grown and developed normally. The only caution should be in infants with congenital hypothyroidism, as abnormal thyroid function has been described in those infants consuming soy-based formula.

Studies provide conflicting evidence about the importance of providing preterm and full-term infant formula supplemented with long-chain polyunsaturated fatty acids. Long-chain polyunsaturated fatty acids (docosahexanoic acid in particular) accumulate in the brain and eye of the fetus, especially during the last trimester of pregnancy, and some studies suggest that infants, in particular preterm infants, may benefit from direct consumption. Infants receiving breast milk or infant formula supplemented with docosahexanoic acid and arachidonic acid have higher levels of these fatty acids in the blood, brain, and retina than infants fed regular formula. These higher levels are thought to have benefits related to visual acuity, growth, and psychomotor and mental development. Despite the widespread availability of infant formulas supplemented with long-chain polyunsaturated fatty acids and their use in research settings for nearly a decade, there is limited evidence of long-term benefit to term and preterm populations.

Lactose-free cow's milk-based formulas are also available for infants; however, routine use is not recommended. 'Follow-on' or transition formulas are designed for the second 6 months of life and although nutritionally superior to cow's milk, they provide no nutritional advantages over regular iron-fortified infant formulas. Home-made formulas from evaporated milk are nutritionally incomplete and are not recommended. Formulas containing pre- and probiotics have gained popularity in recent years. While prebiotics have been shown to increase the number of bifidobacteria and lactobacilli in infant stools and probiotics have been shown to likely help prevent infectious diarrhoea in the short term, long-term clinical benefits have not been shown. Until research can promote their standardization (strain and dose) and long-term effects, caution should be taken in promoting such formula.

Specialized infant formulas are available for the small number of infants who are allergic to, or unable to digest, intact proteins. These products, which come as extensively hydrolysed formulas and free amino-acid formulas, have been heat-treated and enzymatically hydrolysed to produce peptides of various lengths and/or free amino acids. The more the proteins are broken down, the more unpalatable and expensive the products become. Partially hydrolysed formulas should not be considered 'hypoallergenic,' nor should they be used for the purposes of allergy treatment. Some formulas contain medium-chain triglycerides; these formulas are designed for infants with fat malabsorption.

33.1.3 Vitamin and mineral supplementation

With the exception of vitamins D and K, human milk from well-nourished mothers provides all the nutrients required for approximately the first 6 months of life. Routine administration of intramuscular vitamin K at birth has eliminated vitamin K deficiency. Commercial infant formulas are fortified with vitamins and minerals; therefore, supplements are unnecessary.

Vitamin D The amount of vitamin D in human milk is insufficient to prevent rickets. Although vitamin D can be produced from exposure of the skin to sunlight (ultraviolet B rays), with increasing use of sunscreen and avoidance of sun exposure due to the risks of sunburn and skin cancer, both mothers and infants are at risk of vitamin D deficiency and indeed, the incidence of vitamin D deficiency is rising in many countries. Hence, in Canada and the USA, a daily vitamin D supplement is recommended for breastfed infants, beginning at birth and continuing until vitamin D intake from other dietary sources meets their recommended intake. Few foods contain significant amounts of naturally occurring vitamin D (e.g. liver and oily fish), whereas only milk and margarine are fortified with vitamin D in some countries. Infants at the highest risk for vitamin D deficiency and the development of nutritional rickets are those who are born to vitamin D-deficient mothers, dark-skinned, exclusively breastfed, living at high northern or southern latitudes, or weaned to vegan diets. There is an increasing amount of research being done on vitamin D status throughout the lifespan which extends far beyond bone health to include multiple sclerosis, autoimmune conditions, cardiovascular diseases, and cancer. The conservative recommended dose of vitamin D for infants who are breastfeeding is between 200 and 400 IU/day. Recently, the American Academy of Paediatrics has suggested that all infants, children, and adolescents have a minimum daily intake of 400 IU (10 μg) per day.

33.2 Transition to solids

33.2.1 Introduction of solids

At some point in time, exclusive breastfeeding no longer meets a growing infant's energy and nutrient needs and complementary foods must be added. These additional foods are not intended to replace or interfere with breastfeeding. The timing and type of complementary foods is variable, reflecting the numerous cultural practices of society, as well as the child's developmental maturation. Recommendations that breast milk should be given exclusively for the first 6 months and that complementary food should be introduced after this time are based on issues related to nutritional need, physiological maturation, behavioural and developmental aspects of feeding, immunological safety, and environmental influences. Most evidence suggests that introduction before 4 months or later than 6 months has more risks than benefits. Individual infants may have unique needs or feeding behaviours that may require introduction of complementary foods as early as 4 months of age.

Scientific evidence in support of traditional recommendations for the order and progression of introducing solids is limited. Infants should be introduced to nutrient-rich solid foods, and because they require a good source of iron around 6 months of age, the most commonly used first food has been iron-fortified infant cereal. Iron-rich meat is also a good choice. Gluten, one of the more common allergens, is found in wheat, rye, oats, and barley, but not rice or maize. Therefore, for theoretical reasons, rice cereal has been considered the most appropriate first food. Because each

new food constitutes a potential allergic challenge, the introduction of one new food every 2–3 days has been advised, using single rather than mixed foods initially. This is primarily important for infants at high risk for allergies, who are generally introduced to new foods more cautiously. Puréed or finely mashed vegetables and fruits, meats, poultry, tofu, legumes, and lentils are generally introduced after infant cereals. Although not evidence-based, highly allergenic foods such as fish, seafood, and eggs are commonly introduced later. While it can be common practice in developed countries to offer bland foods, there is no evidence to suggest that infants are unable to tolerate spices or strong flavours. When an infant begins to make lateral motions of the jaw, chewing should be encouraged by increasing the texture of foods to include mashed table foods. An infant who is not encouraged to chew at this time may have trouble later accepting anything but fluids and purees. Between 9 and 12 months of age, finger foods should be introduced to encourage self-feeding. The size, shape, and texture of the food should be considered because they influence the infant's ability to chew and swallow safely without choking (Table 33.1).

Feeding a toddler The second year of life involves infants becoming more involved with their own feeding, which gives them a sense of control and independence. With more teeth and the advancement in fine motor skills and oral coordination, infants can successfully use feeding utensils and move towards different foods with firmer textures. A transition from bottle feeding should be encouraged to promote drinking from a cup. As infants gain mobility and are more active, food intake does not always increase correspondingly. With increasing age, toddlers' likes and dislikes can be intensified, which certainly involves having strong and sometimes limited food preferences. Efforts must be made to continue to offer a wide variety of foods, allow toddlers to play with their food, and make eating an enjoyable experience for the parents and the child.

33.2.2 Safety issues around feeding

Infants are less immune to bacteria in the digestive tract than older children and adults. The risk of choking on foods with the potential for aspiration and asphyxia is highest for infants and toddlers. Therefore, foods provided to infants must be free of pathogens, appropriate in size and texture, nutritionally wholesome, and fed safely (Box 33.2).

The greatest risk of choking and aspiration on food occurs in children under the age of 4 years, with a significant peak in the 12–24-month age group. Small, round, smooth foods such as sausages, hotdogs, grapes, nuts, peanuts, candies, raisins, seeds, peas, kernel corn, and popcorn are the most dangerous, as they can slip prematurely into the pharynx and with a quick gasp for breath be drawn downward and become lodged in the airway. These foods are not recommended before 3–4 years of age unless they are cut into pieces. Highly viscous foods, such as peanut butter, can plug the airway and should not be served by themselves. In addition to the shape and texture of foods, environmental factors such as distractions or inadequate supervision during eating increase the risk of food asphyxiation.

33.2.3 Iron deficiency

Iron deficiency is most common among infants between the ages of 6 and 24 months. The major risk factors for iron-deficiency anaemia in infants relate to socioeconomic status and include the early consumption of cow's milk, use of non-iron-fortified infant formula, inadequate funds for appropriate foods, and poor knowledge of nutrition. Other high-risk groups include low-birth-weight and premature infants and older infants who drink large amounts of milk (>1 L/day) or juice and eat little solid food. The importance of preventing rather than treating anaemia has been accentuated by findings that iron-deficiency anaemia is a risk factor for developmental delays in cognitive function and that this delay is irreversible with iron therapy and persists into early childhood (Box 33.3).

Table 33.1 Development of feeding skills and introduction of appropriate foods

Age	Oral–motor skills	Self-feeding	Foods to introduce
Birth–6 months	Well-developed sucking and rooting reflexes facilitate intake of human milk or formula Extrusion reflex causes tongue to protrude when solid food or spoon is put in mouth	Sees breast or bottle and becomes excited	Human milk or iron-fortified infant formula is all the infant needs
6 months	Sits up alone or with support Holds head up on own Indicates desire for food by watching spoon, opening mouth and closing lips over spoon, and swallowing Indicates disinterest in food or satiety, by leaning back, keeping mouth closed, and turning head away Extrusion reflex decreases Able to depress the tongue and transfer semi-solids from spoon to back of mouth for swallowing Smacks lips	Pats or puts hands on breast or bottle	Iron-fortified infant cereal or puréed meat to introduce a supplementary source of iron
6–9 months	Teething starts Lips begin to move while chewing Begins chewing up and down Jaw and tongue move up and down Lip closure achieved	Plays with spoon May help spoon find mouth Holds bottle Feeds self crackers, toast, cookies, etc. Feeds from cup with help	Cooked, puréed, or mashed vegetables to add new flavours and textures Soft, puréed, or mashed fruits Puréed, minced, or finely chopped meat, poultry, cooked egg yolk, cooked mashed legumes, lentils, tofu to provide additional iron, protein and B vitamins Grains, toast, crackers, and dry unsweetened cereals to provide opportunity for self-feeding Limited amounts of unsweetened fruit juices offered in a child-sized cup

Table 33.1 (*Continued*)

Age	Oral–motor skills	Self-feeding	Foods to introduce
			Yoghurt, cheese, and cottage cheese
9–12 months	Rotary chewing movement develops Rhythmic biting movements begin Licks food from lower lip Fine motor skills improve	Can hold own bottle well Can hold cup but may spill contents Picks up foods in fingers or palms Puts food in mouth	Soft, bite-sized pieces of vegetables, mashed potatoes, fruits, meats, and alternatives; soft breads, rolls, plain muffins, rice and noodles to enhance chewing skills Finger foods: soft-cooked vegetables, cut into bite-sized pieces; soft, ripe, peeled fresh fruit, or canned fruits; strips of tender meat; soft, whole legumes or lentils; diced tofu to enhance motor skills and encourage self-feeding

BOX 33.2 Guidelines for feeding infants safely

- Unpasteurized milk, or unpasteurized food should not be fed to infants as they can introduce pathogens such as *Escherichia coli* 0157:H7, *Salmonella*, or *Cryptosporidium*, which cause diarrhoea or other more serious infections.
- To prevent botulism, infants under 1 year of age should not be fed honey.
- To prevent *Salmonella* poisoning, raw eggs and foods containing raw eggs should not be fed to infants.
- Infant cereal or other solids should not be added to human milk or formula in a bottle as it may put the infant at risk for choking and aspiration.
- To avoid burns to an infant's palate or face, formula or food warmed in a microwave should be shaken or stirred thoroughly, and the temperature tested, before serving.
- Avoid hard, small and round, smooth, and sticky solid foods, which may cause choking and aspiration.
- Avoid feeding an infant using a 'propped' bottle.
- Ensure that infants are always supervised during feeding.

BOX 33.3 Strategies for the prevention of iron-deficiency anaemia

- Exclusive breastfeeding during the first 4–6 months
- Introduction of iron-fortified infant cereal and/or other iron-rich foods (e.g. puréed meats) and enhancers of iron absorption (vitamin C, e.g. fruit) from approximately 6 months
- Use of iron-fortified formula for infants weaned early from the breast or formula-fed from birth
- Delaying introduction of unmodified cow's milk until at least 9–12 months of age and limiting the amount to a maximum of 720 mL per day

33.2.4 Fruit juice

Infants may drink excessive amounts of fruit juice for a variety of reasons, including taste; however, juice overall plays a minimal role in providing nutrients to the infant or toddler. If juice consumption decreases the infant's appetite for solid foods, energy and nutrient intakes (e.g. fat, protein, calcium, vitamin D, iron, zinc) can be inadequate, leading to poor weight gain, nutrient deficiencies, and failure to thrive. While 100% pure juice can be a good source of vitamin C, it can also cause problems by displacing the intake of milk and whole foods, including fruits. It can also cause diarrhoea due to the osmotic effect of carbohydrates such as fructose and sorbitol. If juice is given, it should always be offered in a cup (not a bottle) and the amounts should not exceed 120 mL. Fruit drinks should be avoided.

33.2.5 Cow's milk

The use of unmodified cow's milk before 9–12 months of age is not recommended. In comparison with human milk and iron-fortified formula, cow's milk is higher in nutrients such as protein, calcium, phosphorus, sodium, and potassium and significantly lower in iron, zinc, ascorbic acid, and linoleic acid (Table 33.2). Nutrients in solid foods emphasize these excesses and deficiencies, so that infants fed cow's milk receive a higher renal solute load and are at greater risk of eating an unbalanced diet. In particular, the risk for iron depletion and iron-deficiency anaemia is higher because the iron content of cow's milk is low and not readily bioavailable, and its absorption may be impaired by the high concentrations of calcium and phosphorus and low concentration of ascorbic acid. In addition, intestinal loss of (blood) iron in the stool is associated with cow's milk-feeding in the first 6 months of life. Whole cow's milk (3.3% butterfat) continues to be recommended for the second year of life. Two per cent milk may be an acceptable alternative provided that the child is eating a variety of foods and growing at an acceptable rate; there is, however, a theoretical risk of growth faltering and essential fatty deficiency when partially skimmed milk provides a significant component of the infant's daily intake.

Cow's milk and diabetes The aetiology of type 1 diabetes appears to require both genetic predisposition to an autoimmune destructive process and exposure to environmental triggers. Several infant-feeding practices have been investigated as possible environmental factors for genetically predisposed individuals, including early exposure to cow's milk protein (or early termination of breastfeeding) and the timing of solids with a focus on gluten ingestion. The evidence supporting these specific foods as triggering antigens remains inconclusive. Modification of current infant-feeding practices to avoid the disease is not warranted.

33.2.6 Goat's milk

Pasteurized goat's milk is not an appropriate milk choice for infants before 9–12 months of age. Like cow's milk, it contains a high renal solute load with large amounts of sodium and protein. When goat's milk is used after this age, a product with added vitamin C, vitamin D, and folic acid should be chosen.

Table 33.2 Nutrient content of human milk, formula, and cow's milk (per litre)

Nutrient	Human milk mature	Formula			Cow's milk 3.3% fat
		Cow's milk[a]-based	Soy-based[b]	Follow-on[b]	
Energy (kcal)	680	670	670	670	640
Protein (g)	10	15	19	17	32
Fat (g)	39	36	37	33	36
Carbohydrate (g)	72	72	69	79	48
Sodium (mmol)	8	8	11	10	22
Potassium (mmol)	14	18	19	23	40
Chloride (mmol)	12	13	13	15	27
Vitamin D (µg)	<0.5	10	10	10	9[d]
Iron (mg)[c]	0.4	2.3/12	12	12	0.4

[a]Average value of seven brands.

[b]Average value of four brands.

[c]Non-fortified/iron-fortified.

[d]If fortified.

Infants who are allergic to cow's milk protein should not try goat's milk as they are also likely to have an allergic reaction to goat's milk. Unmodified (raw) goat's milk is never an appropriate feeding choice.

33.2.7 Other beverages and herbal teas

Soy, rice, and other vegetarian beverages, whether or not they are 'fortified', are inappropriate alternatives to breast milk or infant formula or to pasteurized whole cow's milk in the first 2 years. There are no minimum requirements for total fat or protein content of these products, and if used as a whole or major source of nutrition, they may result in malnourishment and failure to thrive. Herbal teas are of no known benefit to an infant and may be harmful; toxic effects of herbal teas have been reported in infants fed herbal tea, as well as breastfed infants whose mothers were drinking large amounts of herbal tea.

33.3 Common feeding-related problems

33.3.1 Food allergies

Adverse food reactions are divided into two general categories: food intolerance and food allergy. A true allergic reaction to a food involves the body's immune system. In the paediatric population, estimates of food allergy range from 1–8%, with the highest frequency in the first year of life. There is

general agreement that the prevalence is increasing with time. The risk of developing food allergies is largely related to genetic predisposition and the age at which the food is introduced, with the chance of sensitization greatest in the first year of life. Young infants are especially prone because their immature intestinal system is more permeable to absorption of food allergens and lacks local immunity defences. Most allergens are proteins of large molecular size. Therefore, food allergy commonly presents in infancy with the intake of milk, egg, or peanuts. Along with soy, fish, nuts, and wheat, these foods are responsible for about 95% of food allergies in infants and toddlers.

The issue of preventing allergy is controversial. There is good evidence that when there is a family history of atopic disease, exclusive breastfeeding for at least 6 months decreases the risk of food allergy. It is no longer believed that maternal elimination diets during pregnancy and lactation play a role in decreasing the incidence of food allergies. Prebiotics and probiotics have also not proven to be effective in allergy prevention. There is no scientific evidence that anyone without a close family history of allergic disease should make changes to the normal introduction of solid foods. In at-risk infants, there is not agreement about the benefits of delaying introduction of, or the age at which to introduce, commonly allergenic foods. Avoidance of allergenic foods can postpone the development of allergic disease in individuals at risk, but not prevent it. Traditionally, parents have been advised to delay the introduction of allergenic foods such as peanuts and nuts until 1 year of age (Box 33.4). Management of food allergies involves strict avoidance of the allergenic food and requires careful reading of food labels to detect hidden sources. Sensitivity to many foods disappears within a few years; therefore, retesting and rechallenging with the offending food should occur at regular intervals in a controlled and supervised manner. Allergies to peanuts, nuts, fish, and seafood are the most severe and tend to be lifelong. Follow-up should take place particularly in the context of multiple allergies to ensure that infants ingest adequate macro- and micronutrients and achieve appropriate growth while on their elimination diet.

33.3.2 Allergy to cow's milk protein

Cow's milk protein is the most important trigger of food allergy in infancy, with estimations of prevalence ranging from 1 to 5%. If the child is formula fed, the decision of which formula to use should include consideration of the type of allergic reaction to cow's milk protein. Studies have revealed that 8–60% of milk-sensitive infants also react to soy. Although soy formulas are not hypoallergenic, they may be tolerated by infants with IgE-associated symptoms of cow's milk protein allergy (e.g. urticaria, wheezing, rhinitis, vomiting, eczema, anaphylaxis). In infants at high risk for allergy, identified by a strong family history of allergies, who are unable to be breastfed completely, there is no evidence that feeding with a soy formula compared with a cow's milk formula reduces allergies, whereas there is evidence that prolonged feeding with a hydrolysed formula compared with cow's milk formula reduces infant and childhood allergy including cow's milk protein allergy. Goat's milk has some similar antigens to cow's milk and is not recommended. Newer formulas with partially hydrolysed protein are less expensive and more palatable than the hypoallergenic hydrolysed formulas;

BOX 33.4 Strategies for reducing the incidence and severity of allergy in high-risk infants

- Exclusive breastfeeding until 6 months
- Use of protein hydrolysate formulas in at-risk non-breast-fed infants
- Delayed introduction of solids until at least 4 months, and preferably 6 months, especially for foods that are hyperallergenic

however, they contain a significant percentage (approximately 20%) of peptides in the allergenic range and therefore should not be used as treatment. The partially hydrolysed formulas have also not been shown to prevent milk allergy as much as extensively hydrolysed formulas. Rare reactions to extensively hydrolysed formulas have been reported in highly allergic infants who are then fed formulas based on free amino acids.

33.3.3 Lactose intolerance

The majority of adverse reactions to foods do not involve the immune system and are known as food intolerance. The most common food intolerance in humans is lactose intolerance, from lack of the lactase enzyme that normally splits lactose in the intestine. Congenital lactase deficiency is extremely rare, while primary lactase deficiency is very common in the general population due to a normal developmental decrease in lactase activity with increasing age. It is uncommon for infants under the age of 2 to have primary lactase deficiency, and, as a result, other conditions should be excluded prior to treatment. Certain ethnicities are more affected, including Blacks, Ashkenazi Jews, Chinese, and North American Aboriginal people. Lactose intolerance that develops in infants as a result of intestinal mucosal damage caused by infectious gastroenteritis, malnutrition, cow's milk protein enteropathy, coeliac disease, giardiasis, bacterial overgrowth, inflammatory bowel disease, or drugs is called secondary lactase deficiency. Common symptoms include gas, cramps, and diarrhoea. Diagnosis can be obtained by performing a non-invasive breath-hydrogen test in older children or through intestinal biopsies with enzyme activities; however, on a more practical level, diagnosis is confirmed clinically by a trial of a lactose-free diet. Infants under the age of 12 months with lactose intolerance should be changed from a cow's milk formula to either a lactose-free cow's milk formula or a soy formula. Infants beyond 9–12 months of age can be given cow's milk treated with β-galactosidase (LactAid) or a soy formula. Soy milks, even those fortified with calcium and vitamin D, are inadequate in the first 1–2 years of life due to their low fat and energy content. Infants and children with primary lactase deficiency may be able to tolerate small amounts of lactose-containing foods such as yoghurt and cheese, particularly if taken in small amounts and spaced out. Special attention should be paid to ensure affected infants have an adequate calcium intake. Following secondary lactase deficiency, reintroduction of small amounts of lactose should be tried at regular intervals to return to a balanced diet as soon as possible.

33.3.4 Dietary management of acute diarrhoea

In developed countries, the typical infant with acute diarrhoea is well nourished, presents with mild to moderate dehydration, and has a viral-induced diarrhoea with low stool electrolyte losses. In developing countries, children with acute diarrhoea are more likely to be malnourished and severely dehydrated with a viral or bacterial-induced diarrhoea with high stool electrolyte losses. Oral rehydration therapy, which combines the use of oral electrolyte solutions with early refeeding, has proven to be safe and efficacious for restoring and maintaining hydration and electrolyte balance in infants with mild and moderate dehydration, including those with vomiting. Oral rehydration therapy has been shown to decrease childhood mortality from diarrhoeal diseases. Infants with severe dehydration should receive intravenous rehydration. Oral electrolyte solutions containing specific concentrations of carbohydrate, sodium, potassium, and chloride promote fluid and electrolyte absorption, whereas fluids such as juices, soft drinks, tea, jelly, or broth do not. Human milk is well tolerated during diarrhoea and may reduce its severity and duration; therefore, breastfeeding should continue throughout the diarrhoeal illness with additional fluids given as oral electrolyte solutions.

Early and rapid refeeding should occur as soon as rehydration is achieved and vomiting stops (ideally

within 6–12 h of beginning treatment) as infants treated with oral rehydration therapy and early refeeding have reduced stool output, shorter duration of diarrhoea, and improved weight gain. Routine change to lactose-free or diluted feedings is unnecessary in well-nourished infants with mild to moderate gastroenteritis. Factors that appear to increase the risk of developing lactose intolerance include younger age, malnutrition, bacterial diarrhoea, prolonged diarrhoea before treatment, and a greater degree of dehydration on assessment. Infants and toddlers who were fed solid food before the onset of the diarrhoea should continue to receive their usual diet once rehydration occurs. The use of age-appropriate, nutrient-dense mixtures of common foods is recommended. These foods should be nutritious, easily digested and absorbed, and culturally acceptable, and should not have a deleterious effect on the illness. Although not based on strong science, starchy foods are generally well tolerated as the initial foods for refeeding. Use of a low-residue diet (commonly called the BRAT diet: bananas, rice, apple sauce or apple juice, and tea or toast) can theoretically worsen the clinical state as it supplies less than one-half of an infant's daily energy and protein needs.

Newer interventions for the control of diarrhoea Administration of certain strains of probiotic bacterium (e.g. *Lactobacillus* GG) can be given to patients with acute diarrhoea (regardless of the cause) with the intent of modifying intestinal flora. When given at the beginning of the illness, probiotics have been shown to be safe and to shorten recovery of acute diarrhoea managed by oral rehydration therapy and early refeeding. The probiotic may even decrease viral shedding.

In the context of malnourished children, it has been demonstrated that zinc supplements given during an episode of acute diarrhoea reduce the severity and duration of the episode and reduce the incidence of diarrhoea during the following 2–3 months. The WHO currently recommends 10–20 mg zinc/day for 10–14 days (10 mg for infants under 6 months of age) at the start of an episode of diarrhoea.

33.3.5 Constipation

There is wide variation in the stooling patterns of infants, ranging from a bowel movement after each feed to one every few days. Stool frequency and consistency are influenced by the infant's volume and type of feeding (e.g. human milk or formula, introduction of solid foods, and transition from puréed foods to table foods). Bowel frequency decreases with age as a result of the maturing gut's ability to conserve water. After 3–4 years of age, the frequency of bowel movements does not change. Breastfed and non-breastfed infants receiving an adequate diet are rarely constipated. Although an infant may appear to be straining, it is normal for an infant to grimace or have a red face when having a bowel movement. Educating parents about the wide variation in stooling patterns is important for avoiding overtreatment of normal stooling habits. Hard and painful bowel movements, abdominal distension, or blood in the stool may be signs of true constipation.

Approximately 90–97% of infants and children with constipation have idiopathic non-organic constipation, most often due to a conscious or unconscious decision to delay defecation after experiencing a painful or frightening evacuation (e.g. due to an anal fissure). This is known as *functional* constipation, or withholding constipation. Functional constipation is uncomfortable but not dangerous, and therefore is considered benign. An infant of less than 6 months who is believed to be truly constipated should be referred to a physician for investigation of organic causes. The earlier constipation occurs, the greater the chance of an underlying problem (e.g. Hirschsprung's disease). Common recommendations regarding therapy for constipation in infants are based on theory, not scientific evidence. Practices such as adding sugar or corn syrup to formula to cause osmotic diarrhoea, or increasing free fluid intake by giving additional water, are generally safe but without scientific support in the literature. Fruit juices such as prune, apple, and pear are also commonly suggested because of their high sorbitol content. However, there is no evidence to support the use of dietary factors to alleviate chronic constipation once stool withholding and stool retention have

become a problem. In a small, select population of infants, chronic constipation can be a manifestation of intolerance or allergy to cow's milk. For children with constipation who do not respond to laxatives and dietary modifications, a trial of cow's milk elimination may be considered.

33.3.6 Infant obesity

With an increasing prevalence of preschool children who are overweight and obese, increased attention is being paid towards modifiable risk factors such as infant growth and feeding practices. The first protective risk factor is breastfeeding, which has a true effect even after correcting for relevant factors such as parental obesity, maternal smoking, and social class. Other infant risk factors that have been linked with obesity include being a large infant (weight for height) and prolonged bottle use. One study showed delayed introduction of solid foods was protective against obesity; a decade later, however, the timing of food introduction was earlier than present-day recommendations. In recent years much attention is being drawn to early rapid weight gain in the first few months and first year of life as a predictor of obesity in adolescence. While the issue of childhood obesity should not be oversimplified to focus solely on infant feeding, it does increase the awareness that obesity is a lifelong condition. Infants should never be overfed and attention should be paid to follow their cues of being full.

Fat intake Dietary fat modifications recommended for adults are not applicable to infants. In contrast, a high-fat diet (approximately 50% of energy from fat) helps to meet the infant's requirements for energy and fatty acids. Restricting dietary fat may lead to inadequate energy intake and jeopardize growth and development. There is no consistent evidence that use of a fat-reduced, cholesterol-lowering diet in infancy decreases the risk of atherosclerosis in adulthood.

33.3.7 Early childhood caries

The cause of extensive tooth decay in infants is multifactorial and should be considered a preventable infectious condition. Acids produced by bacteria (*Streptococcus mutans*) ferment dietary carbohydrate and attack the teeth, eventually causing demineralization and cavitation, particularly during sleep, when salivary secretions are decreased. Infection or severe tooth decay may warrant tooth extraction. One modifiable aspect of early childhood caries involves decreasing the amount (and frequency) of carbohydrate exposure, particularly sucrose. Feeding practices such as not putting an infant to bed with a bottle of milk or formula, avoiding the use of pacifiers dipped in sugar, syrup, or honey, avoiding bottle-feeding past 12 months of age, and limiting juice intake and other sugary items can all help in decreasing early caries. Bedtime bottles are unnecessary, but if used should contain only plain water.

Fluoride Fluoridation of the water supply has proven to be the most effective, cost-efficient means of preventing dental caries. In areas with low fluoride levels in the water source, fluoride supplements are recommended. The increased availability of fluoride (fluoridated water, foods, or drinks made with fluoridated water, toothpaste, mouthwashes, vitamin and fluoride supplements) has resulted in an increasing incidence of mild forms of dental fluorosis in both fluoridated and non-fluoridated communities. This is relevant to infants as the first year of life has been shown to be the most important period in the development of fluorosis. This sign of excess fluoride intake has led to modifications in fluoride recommendations, including later introduction and lower doses of fluoride supplements, and caution to parents of children to use small amounts and to discourage the swallowing of toothpaste. Mild dental fluorosis has not been shown to pose any health risks and, while there may be mild cosmetic effects, the teeth remain resistant to caries.

33.3.8 Vegetarianism

The past decade has seen an increased interest and acceptance of vegetarian diets. The focus has switched from questions about nutritional adequacy

to studies demonstrating benefits for disease prevention. Whether the beneficial effects observed in adults take root in infants and toddlers raised on vegetarian diets has not been investigated.

Although the low saturated fat and high-fibre content of vegetarian diets offers advantages to the health of adults, their bulky nature and low energy density can restrict the amount of food energy that infants (with their limited stomach capacity and higher needs for accelerated growth) can consume. Vegetarian infants fed adequate amounts of breast milk or commercial infant formula and a balanced, varied diet grow similarly to non-vegetarian infants. However, the risk of nutritional deficiencies increases if the variety of foods making up the diet is very restrictive (e.g. macrobiotic, Rastafarian, fruitarian, raw diets) and/or if supplementation and medical supervision is avoided. Key nutrients include energy, protein, fibre, vitamin B_{12}, iron, vitamin D, calcium, zinc, and n-3 fatty acids. Because dietary practices among vegetarians are variable, assessment of dietary intake is important to determine whether fortified foods or supplements are needed to meet recommendations for individual nutrients.

Most vegetarians will continue breastfeeding well into the second year of life. Problems of nutritional inadequacy in the infant (e.g. vitamin B_{12}) are likely to occur if the mother's diet is very restricted, if prolonged breastfeeding is not supplemented around 6 months of age, or if infants are weaned prematurely on to an unsuitable breastmilk substitute. While some still advocate that infants should not be fed vegan diets, vegan infants who are weaned from the breast before 1 year of age should receive a commercial soy formula until 1–2 years of age.

In infants consuming a macrobiotic diet, a clear relationship has been demonstrated between diet, nutrient intake, and physical and biochemical evidence of deficiency for several nutrients, including iron, vitamin B_{12}, vitamin D, and riboflavin. Slower growth rates (peaking between 6 and 18 months), slower psychomotor development, and higher incidence of nutritional diseases such as rickets, kwashiorkor, and anaemia have been reported. Macrobiotic diets consist of unpolished rice, pulses, and vegetables with small additions of fermented foods, nuts, seeds, and fruits; animal products are generally not consumed but some types of fish may be accepted for occasional use. Even less restricted vegetarian diets typically have a high content of phytates and other modifiers of mineral (e.g. iron, zinc, calcium) absorption, which are associated with a higher prevalence of rickets and iron-deficiency anaemia.

33.4 Assessing nutritional adequacy

In general, it is assumed that an infant or toddler's nutritional status is normal, and nutritional needs are being met, if he or she has a normal rate of growth, drinks adequate amounts of breast milk (or suitable formula or milk for age), and eats a variety of age-appropriate foods from each of the food groups. When nutritional status or growth is questionable, the infant or toddler's intake should be evaluated in comparison with established standards such as growth charts and recommended nutrient intakes or allowances.

33.4.1 Energy and nutrient requirements

Due to their rapid rate of growth and higher metabolic rate, energy requirements for infants and toddlers are higher than at any other time of life. Recent studies have facilitated measurements of total energy expenditure of infants and toddlers. Evidence from these studies resulted in lower energy requirements than previously predicted,

starting from 110 kcal/kg/day in the first month of life down to 80 kcal/kg/day at one year of age. During the second year of life, energy requirements stay stable on a per-kilogram basis but the overall amount of calories required does increase.

When an infant or toddler's energy requirements are met from a well-balanced diet the risk of other nutrient deficiencies is minimized. Intakes of individual nutrients that fall between 70% and 100% of recommended levels do not necessarily indicate a deficiency, as recommendations (with the exception of energy) are set at the mean requirement, plus two standard deviations, to ensure that the needs of almost all infants and toddlers are met.

33.4.2 Monitoring growth

Postnatal growth and development of the central nervous system are most rapid during the first year of life. The typical infant doubles his or her birth weight during the first 4–5 months, triples it in the first year, and quadruples it by 2 years of age, by which time a child has grown to half of their adult height. Plotting serial measurements of length-by-age and weight-by-length can be used to compare growth with normative values for healthy infants.

International in scope, the new WHO growth charts reflect the growth of children from six developed and developing countries around the world who were raised under favourable conditions for supporting optimal growth. Based on the growth pattern of breastfed infants, the charts now reflect current international guidelines for optimal feeding of infants and toddlers and, as such, are considered growth *standards,* rather than growth *references*.

In most children, height and weight measurements follow consistently along a channel (i.e. on or between the same centile(s)). Normal growth is indicated by weight-for-length and length-for-age tracking along similar percentiles or growth channels; however, it is common for infants to shift percentiles for both length and weight in the first 2–3 years of life, with the majority settling into a channel towards the 50th percentile (i.e. regression towards the mean), rather than away. When length-for-age and weight-for-length percentiles are disproportional or weight and/or height measurements are on a downward or upward trend, investigation of potential nutritional imbalances is indicated.

Summary

- Nutrition during infancy is an important determinant of overall health.
- Breastmilk is the only nutrition a healthy infant needs for the first six months and it carries many benefits over formula.
- The evidence for the importance of vitamin D in all infants and toddlers is growing.
- At six months, texture-appropriate foods should be introduced one at a time. Efforts should be made to choose iron-rich sources of food in order to prevent iron deficiency anaemia.
- By 9–12 months the infant can begin drinking whole cow's milk and should be eating a wide variety of foods.
- Adequate nutritional intake can be monitored by infant and toddler growth charts.

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34 Childhood and adolescent nutrition

Anne-Louise Heath and Rachael Taylor

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Introduction

Childhood and adolescence are periods of rapid growth, learning, and development. Nutritional needs are high and differ in many respects from those of adults. Ensuring adequate food intake remains the challenge for many of the world's children. In contrast, for most children in the developed world, making more appropriate food choices and maintaining healthy eating habits is paramount. Most of this chapter refers to both childhood (age 2–12 years), and adolescence (age 13–18 years). The final section (34.8) covers issues that predominantly relate to adolescents.

34.1 Dietary recommendations

Dietary recommendations for children and adolescents are expressed in two very different but complementary formats: dietary guidelines (providing advice on food intake and related behaviours in a way that is accessible to members of the general public), and nutrient intake values (levels of nutrient intake calculated to minimize the risk of deficiency or disease).

Ideally, each country should develop its own dietary guidelines to ensure that the food- and nutrient-related health concerns of the country are addressed in the context of customary dietary patterns. However, the dietary guidelines for children shown in Table 34.1 are fairly typical.

Nutrient intake values such as dietary reference intakes (in Canada and the USA), dietary reference

Table 34.1 Dietary guidelines for children and adolescents in Australia

Encourage and support breastfeeding
Children and adolescents need sufficient nutritious foods to grow and develop normally
• Growth should be checked regularly for young children
• Physical activity is important for all children and adolescents
Enjoy a wide variety of nutritious foods
Children and adolescents should be encouraged to:
• Eat plenty of vegetables, legumes, and fruits
• Eat plenty of cereals (including breads, rice, pasta, and noodles), preferably wholegrain
• Include lean meat, fish, poultry, and/or alternatives
• Include milks, yoghurts, cheese, and/or alternatives
– Reduced-fat milks are not suitable for young children under 2 years, because of their high energy needs, but reduced-fat varieties should be encouraged for older children and adolescents
• Choose water as a drink
– Alcohol is not recommended for children
and care should be taken to:
• Limit saturated fat and moderate total fat intake
– Low-fat diets are not suitable for infants
• Choose foods low in salt
• Consume only moderate amounts of sugars and foods containing added sugars
Care for your child's food: prepare and store it safely

values (in the UK), and nutrient reference values (in Australia and New Zealand) provide specific information on nutrient requirements and safe upper limits of intake. Nutrient requirements alter so rapidly during childhood and adolescence that three age bands are usually reported for children (1–3 years, 4–8 years, 9–13 years), and one for adolescents (14–18 years). A typical set of nutrient intake values is shown in Table 34.2.

34.2 Growth

34.2.1 Growth and body composition

The rapid growth period of infancy sees a tripling of birth weight during the first year, growth then slows during childhood, and is relatively consistent and predictable, with annual increments typically ranging from 6–7 cm in height and 2–3 kg in weight. Body proportions also change over this time, from that in infancy, where the head and trunk predominate, to a more adult profile resulting from considerable

Table 34.2 Dietary reference intakes for children and adolescents

Nutrient	Age group (years) and gender					
	Children		Boys		Girls	
	1–3	4–8	9–13	14–18	9–13	14–18
Protein (g/day)						
EAR	10	15	27	45	28	38
RDA	13	19	34	52	34	46
Calcium (mg/day)						
EAR	500	800	1100	1100	1100	1100
RDA	700	1000	1300	1300	1300	1300
Iron (mg/day)						
EAR	3.0	4.1	5.9	7.7	5.7	7.9
RDA	7	10	8	11	8	15
Vitamin C (mg/day)						
EAR	13	22	39	63	39	56
RDA	15	25	45	75	45	65
Vitamin A (μg/day)						
EAR	210	275	445	630	420	485
RDA	300	400	600	900	600	700

EAR, estimated average requirement; RDA, recommended dietary allowance.

Source: Dietary reference intake documents prepared for the USA and Canada by the Food and Nutrition Board and Institute of Medicine (2000, 2001, 2002) available at http://www.nap.edu. Calcium values are from the revised 2010 report.

lengthening of the limbs and a reduction in the size of the head relative to the rest of the body. The onset of puberty signals a second accelerated phase in growth, typically lasting 2 or so years, with a younger onset in females. Although the age of onset can vary considerably (Fig. 34.1), males typically gain around 20 kg of weight and 20 cm in height and females 16 kg and 16 cm.

Marked age and sex differences in body composition are apparent between birth and the end of adolescence. Children are relatively lean at birth (approximately 15% body fat), but increase steadily in adiposity during the first year of life. Adiposity tends to decline during the preschool years and reach a nadir at approximately 5–6 years of age, before increasing again through later childhood. This phenomenon is known as the adiposity rebound (AR) and has received considerable attention over recent years as a potential 'critical period' in the development of childhood obesity. Children who undergo AR at an early age are more likely to be overweight in later adolescence and early adulthood. During adolescence, males gain approximately twice as much lean tissue as females, with a rapid acceleration during the peak growth spurt and much smaller increments in body fat. By contrast, gains in lean tissue mass appear more consistent during growth in females and body fat continues to be laid down until late adolescence/early adulthood.

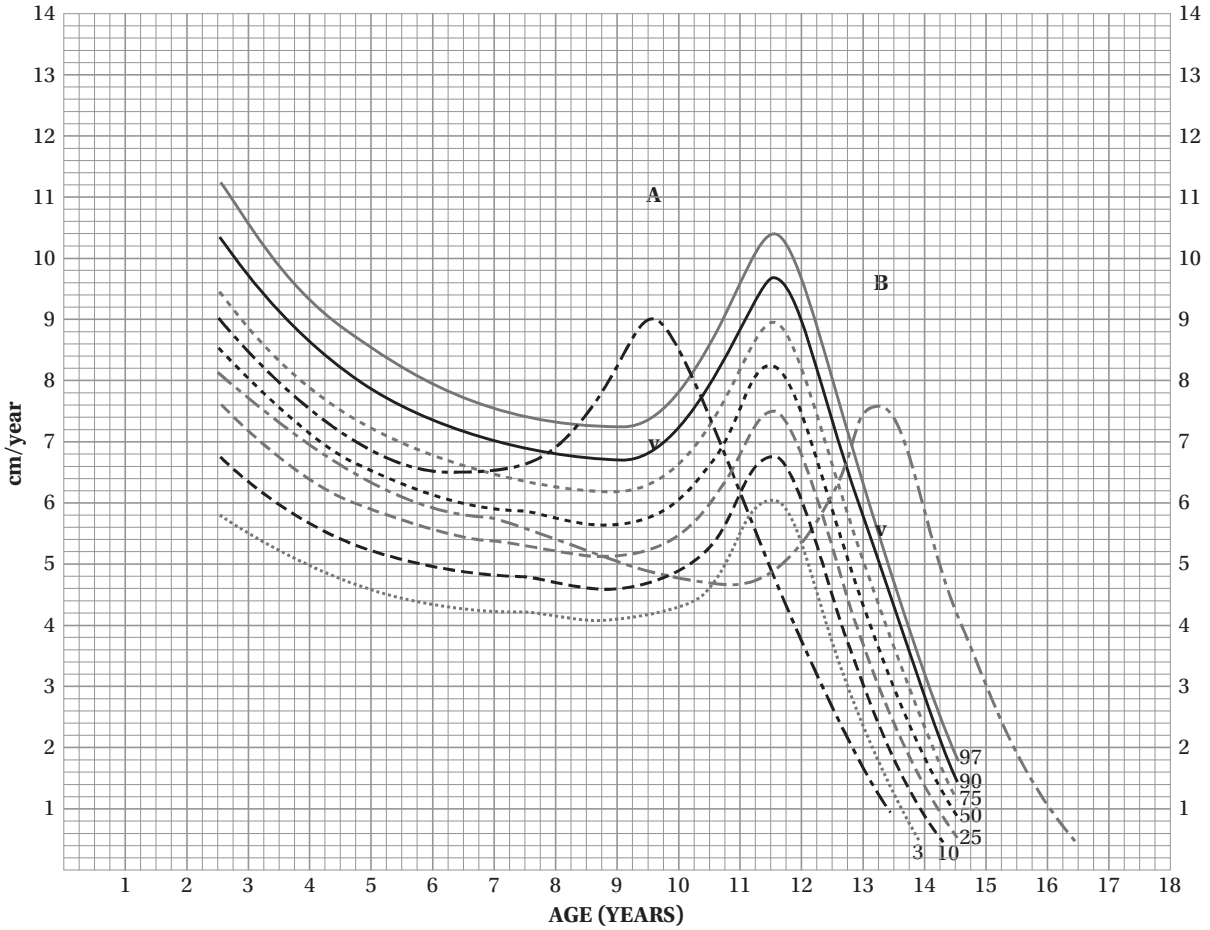


Fig. 34.1 Height velocity for girls. The outlying peaks are an early (A) and a late (B) maturer.

Source: Tanner, J., and Davis, P.S.W. (1985) Clinical longitudinal standards for height and weight velocity for North American children. *J Pediatr*, **107**, 317–29.

34.2.2 Assessment of growth and body composition

An accurate record of growth remains one of the most useful tools for the assessment of both under- and overnutrition. Serial measurements at multiple time points reveal more information about a child's health than single measurements because of individual variation in growth and development. Anthropometric indices such as height and weight can most usefully be interpreted by plotting them on reference growth charts. These provide a reference for an individual child's growth, rather than the absolute standard that each child should achieve. The most commonly used are the Centers for Disease Control and Prevention (CDC) 2000 growth charts (http://www.cdc.gov/growthcharts) which are based on breast-fed and formula-fed American children (Fig. 34.2).

Given known differences in growth between breast-fed and formula-fed infants, the World Health Organization (WHO) published the WHO Child Growth Standards (http://www.who.int/childgrowth/en/) in 2006, created from the Multicentre Growth Reference Study which followed approximately 8500 breast-fed infants from widely different ethnic backgrounds and cultural settings from birth to 5 years. These are expressed (separately) both as centiles and as Z scores (see Chapter 31).

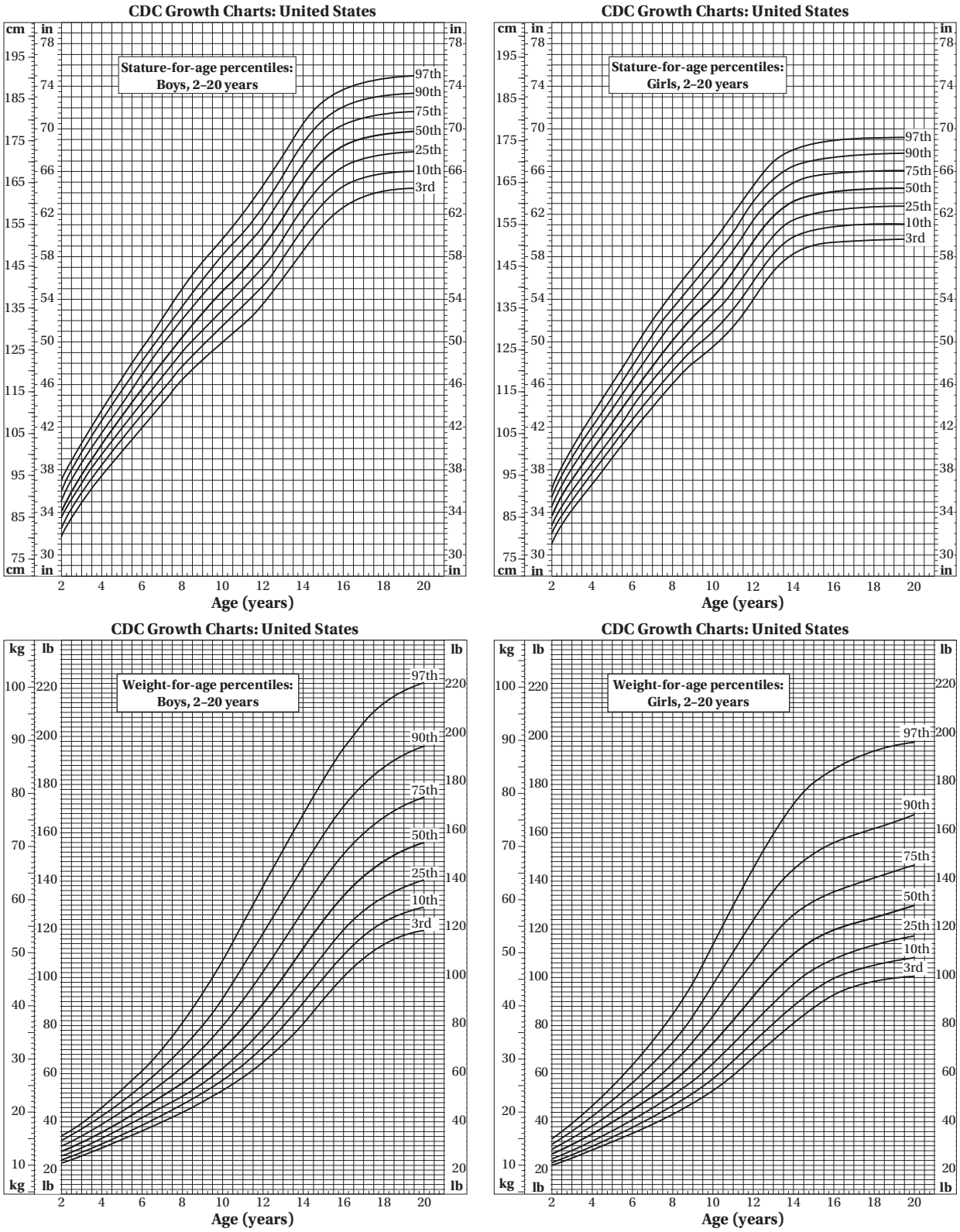


Fig. 34.2 CDC growth charts for boys and girls aged 2–20 years: stature (height) for age and weight for age, with percentile lines.

Source: National Centre for Health Statistics (NCHS)/National Center for Chronic Disease Prevention and Health Promotion (CDC), USA (2000).

BOX 34.1 Measuring the child's growth

1 Regular measurement of weight is the best way of assessing undernutrition or obesity.

2 Growth reference charts for use should be based on current CDC or WHO charts.

3 Growth trends give more information than one measurement.

4 A child who is approximately the same percentile for height and weight and whose height and weight track over time is unlikely to have a serious nutrition or chronic health problem.

5 A child crossing the 90th or 10th percentiles should be assessed.

6 Referral for growth hormone treatment should only be made if the child is consistently below the 3rd percentile and there is no other cause to be found.

7 Dietary guidelines provide advice on consuming a healthy, varied diet that will enable the nutrient reference values to be met.

Although the accurate assessment of body composition (fat and fat-free masses) (see Chapter 31) provides considerable additional information about the health and wellbeing of a child, in most instances the use of anthropometry (height, weight, body circumferences, and skinfold thicknesses) remains the most commonly used way to monitor growth (Box 34.1).

34.3 Undernutrition/failure to thrive

Failure to thrive occurs when a child of normal height and head circumference has a weight-for-age below the 3rd percentile (or a Z-score of minus 2). As well as this absolute definition, a child who was previously growing well who stops growing and drops through several percentile lines should also be included in this group. In developing countries, the same children are usually called 'undernourished'.

In the developed world about half of the cases are due to non-organic causes, including psychosocial problems in carers (e.g. depression) or simply an inadequate diet due to lack of knowledge, neglect, or a very restrictive dietary regime. Organic causes of failure to thrive are numerous and include chronic renal, cardiorespiratory, and endocrine diseases. Gastrointestinal causes include coeliac disease, cystic fibrosis, and Hirschsprung's disease.

More than half of the children diagnosed as 'failure to thrive' in primary care have a relatively simple nutrition problem—not enough food to meet their needs. For example, a child may be thought to have an 'allergy' and may have been placed on a very restrictive diet, or because the adults in the families are placed on a low-fat diet, the child may also be eating the same diet. Many chronic diseases cause growth retardation. In the absence of other symptoms or signs, it is usually appropriate to undertake a trial of improved nutrition rather than going immediately to further investigation. Referral for investigation of growth hormone deficiency is not necessary unless the child is consistently below the lowest percentile line and no other disease is present.

Children may develop food fads and be described by their parents as 'difficult eaters'. Prevention depends on the whole family eating a healthy diet and the children naturally falling into a pattern of good nutrition. The use of food, snacks, and sweets in reward and punishment systems for inappropriate behaviour may lead to poor eating habits.

34.4 Childhood overweight and obesity

34.4.1 Prevalence and health effects

Overweight or obesity in childhood is generally defined as having a body mass index (BMI) value greater than certain age- and sex-specific reference standards, typically the 85th and 95th percentiles, respectively. The CDC and WHO growth standards (see Section 34.2.2) are widely used. In 2000, Cole *et al.* published BMI criteria for defining overweight and obesity in children and adolescents created from a dataset of children from six countries (Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the USA); the criteria are often referred to as the International Obesity Taskforce (IOTF) cutoffs. These BMI values were created from determining the percentiles corresponding to a BMI of 25 kg/m^2 (overweight) and 30 kg/m^2 (obesity) at 18 years of age. Use of the IOTF cutoffs (Table 34.3) is advantageous for international comparisons of the prevalence of overweight and obesity. However, the CDC or WHO growth charts are more useful for tracking weight status in individual children over time, as exact percentiles or Z-scores can be calculated.

In most developed countries, childhood overweight and obesity represents a major health issue, with national estimates indicating that 25–40% of children are heavier than is desired for their health. Much of the recent focus has been on the rapid increase in prevalence that has been observed in many countries. Recent data, however, offer promise that these increases in prevalence appear to be abating, at least in some countries. Regardless of the trends over time, the fact remains that too many of our children are carrying excess body weight, with resultant implications for health. In young children, this translates to deleterious effects on psychosocial health in terms of bullying and impaired self-esteem, and the increased risk of transition to an overweight state as an adult, with all the accompanying health effects. In older children and adolescents, other physical health risks become more apparent including, but not limited to, an increased risk of type 2 diabetes, high blood pressure, high cholesterol, and bone and joint problems, especially fractures of the forearm.

34.4.2 Causes

Obesity is a result of excessive food intake in relation to energy requirements, and may arise due to

Table 34.3 Body mass index levels (kg/m^2) to diagnose overweight and obesity in children

Age (years)	Overweight		Obesity	
	Boys	Girls	Boys	Girls
2	18.41	18.02	20.09	19.81
3	17.89	17.56	19.57	19.36
4	17.55	17.28	19.29	19.15
5	17.42	17.15	19.30	19.17
6	17.55	17.34	19.78	19.65
7	17.92	17.75	20.63	20.51
8	18.44	18.35	21.60	21.57
9	19.10	19.07	22.77	22.81
10	19.84	19.86	24.00	24.11
11	20.55	20.74	25.10	25.42
12	21.22	21.68	26.02	26.67
13	21.91	22.58	26.84	27.76
14	22.62	23.34	27.63	28.57
15	23.29	23.94	28.30	29.11
16	23.90	24.37	28.88	29.43
17	24.46	24.70	29.41	29.69
18	25	25	30	30

Source: Adapted from Cole, T.J., Bellizzi, M.C., Flegal, K.M., *et al.* (2000) Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ*, **320**, 1240–3.

imbalance from either (or both) sides of the energy balance equation. Genetics also plays a major role in determining weight, and susceptibility to weight gain, although very few cases of obesity are a result of an endocrine disorder, chromosomal abnormality, or genetic disorder. Children in affluent countries live in an 'obesogenic' environment, which discourages physical activity and promotes the consumption of nutrient-poor energy-dense foods.

Dietary factors While there is general acceptance that a high consumption of energy-dense foods is an important cause of obesity, there is little certainty regarding the role of individual foods, drinks, or nutrients. High intakes of sugar-sweetened beverages has been fairly consistently shown to be associated with increased weight or weight gain in children. However, the few randomized controlled trials in which advice to reduce intake of such drinks has been the key intervention have not provided convincing evidence of benefit, perhaps because of poor compliance. 'Fast foods' and 'snack foods' have also been implicated but the fact that most such foods are high in sugars and fats and therefore energy-dense, is the most likely explanation for their contribution to an energy intake which exceeds output.

Activity factors The extent to which physical activity has reduced in recent years and thus contributed to the 'epidemic' of childhood obesity is uncertain. However, a number of studies have shown a fairly strong association between television viewing and excess body weight accumulation in young children. This might result, as much if not more, from consumption of energy-dense snack or fast foods while watching television as from lost opportunities for physical activity during prolonged periods of inactivity. The use of computers, computer games, and labour-saving devices and reduction of the use of active transport and school-based physical education are other examples of the obesity-promoting environment which characterize Western and some other affluent societies.

Other behaviour factors Poor sleeping habits have been related to excessive weight gain, especially in young children. This might simply be due to having more opportunities to eat or less time for exercise but changes in several hormones (including cortisol, ghrelin, leptin, and growth hormones) involved in body weight regulation have been observed, suggesting the possibility of more complex mechanisms. Family environment, role modelling, and parental support are also considered as potential determinants of excessive weight gain. Some of the behavioural and societal factors which have been implicated in the development of childhood obesity are listed in Table 34.4.

34.4.3 Prevention and treatment of overweight and obesity

Changes in the obesogenic environment are essential if the prevalence of overweight and

Table 34. 4 Behavioural and societal factors implicated in the development of childhood obesity

Larger portion sizes	Television viewing
Sweetened beverages	Computer use
Fast foods	Video games
Inappropriate snack choices	Labour-saving devices
Food advertising	Built environment
Skipping breakfast	Community access to resources
Reduced sleep	Declines in active transport (cycling or walking to school)
Family environment	Reduced physical education in schools
Parenting styles	Less school recess time
Poverty	Parental work commitments

obesity in children and adolescents is to be reduced (see Chapter 17). This will not be achieved without commitment from relevant opinion leaders and policy makers including governments, local and education authorities, media, food industries, and health professionals. Voluntary as well as legislative measures are required. Abolition or limiting of television advertisements promoting inappropriate foods to children, provision of opportunities for physical activity, and increasing availability of affordable healthy food choices are but three of the many measures which require implementation.

Treating overweight children should in theory be relatively straightforward, since only small changes to eating and/or activity behaviour should be required for most overweight children to successfully reduce their weight over time, given that the energy imbalance is relatively small on a daily basis. Such children need to 'grow into' their weight by restoring the rate of excessive weight gain to a more appropriate level while maintaining linear growth. The fact that so many children are now overweight or obese and that the health consequences are generally not immediately apparent have led to parents often failing to recognize overweight in their children. Furthermore, health professionals finding it difficult to initiate appropriate management, which principally involves the promotion of physical activity and appropriate food choices. For children who are obese, the level of intervention will depend upon severity and duration of obesity. Some form of behavioural theory, including expert dietary advice, given within the context of the family environment is usually regarded as an essential component (see Chapter 38). Management of the overweight and obese child is made all the more difficult by the existence of the obesity-promoting environment.

34.5 Some critical micronutrients

34.5.1 Iron

In adults, iron status reflects the balance between iron losses and iron intake.

In children, iron intakes also need to be sufficient to support growth. In addition to their increased requirements for growth, adolescent girls need to absorb 0.45 mg of iron a day to cover menstrual losses once they reach menarche. This is equivalent to approximately 2.5 mg a day of additional dietary iron. Some girls will require considerably more than this as losses can be three times higher than the median. The age at which this increased requirement starts varies from child to child.

Although the iron status of school-age children is usually adequate, 4% of preschool children in the 2003–06 US National Health and Nutrition Examination Survey (NHANES) were iron-deficient. In the UK and the USA, there are higher rates of iron deficiency amongst the poor, immigrants, and non-Caucasian populations. The rates of iron deficiency are much higher for adolescent girls, with NHANES 2003–06 estimating that 9–16% of girls aged 12 to 19 years are iron-deficient. Approximately 4% of adolescent girls have the severe form of iron deficiency—iron deficiency anaemia.

Iron deficiency anaemia is associated with poorer mental, motor, and behavioural development in young children, and fatigue and poorer cognitive function (especially verbal learning and memory) in adolescents. The effects of non-anaemic iron deficiency are less clear, but probably include subtle negative effects on cognitive function and fatigue. It is important that non-anaemic iron deficiency is treated, because it increases the risk of developing iron deficiency anaemia with rapid growth or onset of menstruation.

Dietary measures may play a role in preventing and treating non-anaemic iron deficiency, although supplementation is required to treat iron deficiency anaemia. Red meat, a rich source of haem iron, is an effective way to boost intake, noting that processed food such as sausages contain much less iron than meat such as lean meat. Beans, peas, lentils, and iron-fortified foods are useful sources of non-haem iron. Absorption of non-haem iron is enhanced by ascorbic acid found in many fresh fruits and vegetables and a yet-to-be identified factor (MFP factor) in meat, fish, and poultry. Phytates and polyphenols (including tannins) are inhibitors of non-haem iron absorption. Wholegrains, nuts, and legumes are sources of phytates but valuable sources of many nutrients. Wholemeal products which are leavened with yeast (e.g. wholemeal bread) and legumes soaked with water discarded before cooking have less phytate. Tea and coffee, rich sources of tannins, should be discouraged. If dietary measures are unable to achieve satisfactory iron status, iron supplements may be necessary.

Iron deficiency and its prevention and treatment are covered more fully in Chapter 10.

34.5.2 Vitamin D

Although severe vitamin D deficiency is now uncommon amongst children in relatively affluent countries such as the UK, Europe, USA, Australia, and New Zealand, clinicians have recently reported a concerning increase in the number of cases of rickets, particularly amongst children with darker skin and from cultures in which the skin is kept covered. Rickets is described in Chapter 15. It has also become apparent that less severe vitamin D insufficiency is common amongst children and adolescents, even in countries such as the USA that have widespread fortification programmes in place. In the US NHANES 2000–04, suboptimal serum 25-hydroxyvitamin D concentrations (defined as serum <50 nmol/L) were present in almost 10% of preschoolers and more than 30% of adolescent girls. Interestingly, supplementation trials in unselected adolescent girls in Lebanon and Finland both reported increased bone mineral density on supplementation with vitamin D even in the absence of rickets. There is some evidence to suggest that low vitamin D status also increases susceptibility to infection and increases the risk of type 1 diabetes; however, these effects have only been investigated in observational studies to date.

Factors that increase the risk of vitamin D deficiency in children and adolescents include darker skin pigmentation (children with dark skin pigmentation may need 5–10 times longer in the sun to generate the same amount of vitamin D), lack of sunlight exposure (including use of sunscreen or concealing clothing), obesity, and clinical conditions resulting in fat malabsorption (e.g. cystic fibrosis) or requiring medication that alters vitamin D metabolism (e.g. anticonvulsants).

A number of foods including milk, margarine, and juice are fortified with vitamin D in the USA, but children and adolescents would need to consume 1 L of milk a day to get the 400 IU currently recommended by the American Academy of Paediatrics. The alternative is daily supplementation with vitamin D, but given the large numbers of people of all ages who have low vitamin D status, a more sustainable solution that is less reliant on individual compliance may be needed should it be determined that the year-round vitamin D status of the population is suboptimal for health.

34.5.3 Iodine

Although severe iodine deficiency is principally seen in the developing world, lesser degrees of iodine deficiency sufficient to influence aspects of cognition have been reported in a number of European countries, Australia, and New Zealand. The problem was believed to have improved with the introduction of iodized salt, but it appears to have recurred at least in some countries to the extent that iodine fortification has been proposed. Iodine is discussed in Chapter 11.

34.6 Other matters related to diet

34.6.1 Dental caries

Dental caries (tooth decay) is the second most common infectious disease after the common cold and is one of the more expensive diet-related health problems. It is also preventable. In the USA, by the age of 5–9 years, more than half of children have had at least one cavity or filling, and by 17 years of age, 78% have had tooth decay. The consequences include pain and infections.

Dental decay is an interaction between three factors: sugars, oral bacteria, and the tooth. Sugars (glucose and fructose, as well as sucrose) are fermented by oral bacteria (particularly *Streptococcus mutans*) that produce acids which demineralize the enamel and may eventually break down the tooth. All three factors are required for dental decay, although in treating and preventing dental caries, multiple strategies are likely to be more successful than attempting to eliminate any one single factor.

It is the frequency of exposure to sugars, rather than the amount of sugar that predicts caries risk. In practice, this means that:

- Sugars can be consumed with meals (especially if children are encouraged to brush their teeth afterwards), but should not be consumed between meals.
- Sticky carbohydrate foods (such as hard sweets, muesli bars, fruit roll-ups, honey, and even dried fruit such as raisins) are particularly bad for teeth because they remain on the tooth surface for longer.
- Children should be encouraged to drink plain water rather than sugar-containing beverages (including fruit juice and sports and energy drinks). The practice of using sugar-containing beverages to settle children to sleep at night is particularly risky because the beverage bathes the teeth for a prolonged period—at a time when production of protective saliva is low.

The sugars contained in the cellular structure of foods (such as the intrinsic sugars of fresh fruits and vegetables) have little cariogenic potential so these are good food choices for snacks.

Bacterial numbers are controlled by twice-daily tooth brushing with a fluoride toothpaste (supervised by an adult until the child is at least 8–9 years of age). Fluoride in the saliva of children who consume fluoridated water or supplements inhibits bacterial growth and the enamel is made more resistant to decay by ingestion of fluoride. In many countries, fluoridation of water supplies and the use of fluoridated toothpaste have resulted in dramatic declines in average levels of dental decay (see Section 11.5).

34.6.2 Food allergies and intolerances

Food allergy in the narrow, technical sense is an abnormal reaction to a food by a mechanism that involves a specific immunoglobulin E in the plasma.

The most common food allergies in young children are to cow's milk, eggs, peanuts, tree nuts, sesame seeds, soy, and wheat. Peanuts, tree nuts, and shellfish are the foods most commonly associated with life-threatening anaphylaxis. Most children who are allergic to cow's milk, soy, wheat, or eggs have grown out of their food allergy by the time they are 5 years of age.

Symptoms of food allergy include hives (urticaria) and/or swelling around the mouth, vomiting, cough, wheeze, a runny or blocked nose, stomach pains, or diarrhoea. Food allergy may also result in gastro-esophageal reflux and eczema.

The three most widely accepted tests used to confirm or exclude potential food triggers are: skin prick allergy tests, blood tests for immunoglobulin E (IgE) specific to the allergen (RAST), and a closely supervised temporary elimination diet followed by food challenges with the suspected food. Currently, it is

considered that food allergies are best managed by identifying and avoiding the food.

A *food intolerance* is a reaction to a food that does not involve immunoglobulins (e.g. urticaria in response to consumption of certain food additives such as tartrazine). Other adverse reactions to food (i.e. reactions other than allergy and food intolerance) include wind and diarrhoea in response to milk in children who have lactase insufficiency; and coeliac disease, an autoimmune enteropathy triggered by sensitivity to wheat gluten.

Diagnosis of food intolerance and other non-immune adverse food reactions is usually based on clinical history and response to removal of the food from the diet, although in some cases a strictly supervised temporary elimination diet followed by food challenges is also used diagnostically.

It is important to avoid unorthodox testing and treatments that can be expensive, and harmful if they delay effective treatment or result in a nutritionally inadequate diet (either because major foods such as milk or wheat have been removed from the diet without appropriate replacement, or because the diet becomes so unpalatable that the child's energy intake is compromised).

34.6.3 Vegetarianism and meat avoidance

There are many different types of vegetarianism, but most vegetarians are either lacto-ovo-vegetarian (avoid meat, poultry, and fish but consume dairy products and eggs) or, less commonly, vegan (no animal products are consumed). Some children are raised as vegetarians within vegetarian families, but many more become vegetarian through personal choice, particularly during adolescence. Reasons for becoming vegetarian include concerns about animal exploitation, the environment, and health. However, adolescents with disordered attitudes to eating may use vegetarianism as a socially acceptable way to restrict their food intake. Many more children and adolescents are meat reducers, consuming small amounts of meat (or poultry or fish only) infrequently, and presumably experiencing health benefits and risks that are intermediate between those of vegetarians and non-vegetarians.

In 2005, 4% of 8–18-year-old US children described themselves as vegetarian or vegan, but this masks what are likely to be higher rates in certain sectors of the population, particularly amongst teenage girls. In the UK, approximately 10% of girls aged 15–18 years describe themselves as vegetarian or vegan.

The nutrient of greatest concern in vegetarian diets is vitamin B_{12}, particularly for vegans who have no natural sources of the vitamin in their diets (foods such as spirulina contain inactive analogues). It is essential, therefore, that vegan children and adolescents either use foods fortified with vitamin B_{12}, or take vitamin B_{12} supplements. Recommended iron intakes are 80% higher for vegetarians; however, studies in adults suggest that while vegetarians have lower iron stores, they do not have a higher risk of iron deficiency anaemia than their non-vegetarian counterparts, perhaps in part because they tend to have higher total iron intakes. Zinc may also be a concern, particularly because of the high phytate content of foods traditionally consumed by vegetarians such as legumes, nuts, and wholegrain cereals. In the past there was some concern that protein intakes might be inadequate in diets that avoided meat, but it is now known that as long as a variety of protein-containing foods are consumed each day, and energy intake is sufficient, protein needs are easily met.

Vegetarian diets are associated with a number of potential benefits. In particular, vegetarians tend to have a healthier body mass index, their saturated fat intake can be lower (as long as meat is not replaced with high-fat dairy products such as cheese), they have a higher fibre intake, and fruit and vegetable intake tends to be greater. They have been noted to have lower cholesterol and blood pressure levels than nonvegetarians and in the long term, vegetarianism is associated with a lower risk of death from ischaemic heart disease. It is uncertain whether these health benefits are due to meat avoidance or the other potentially health-promoting attributes of the diets of most vegetarians.

A vegetarian dietary pattern is certainly consistent with good health in children and adolescents provided it is well planned so that it includes a wide variety of nutritious foods. Some young people remove meat from their diet without ensuring appropriate replacements.

34.7 Developing countries

34.7.1 Introduction

Even in a country that is poor, poverty is not experienced equally across all members of the population. It may not be experienced equally within a family—it is common for children and women to have more limited access to resources, including food, than men. Growing up in a developing country may mean that there is less food and that the nutritional quality of the food is lower. In many cases access to clean water, health care, education, and good sanitation is limited or absent. These factors all have an impact on access to food and on nutritional status.

In 2005–07, 830 million people in developing countries, many of them children, were estimated by WHO to be undernourished and with the recent economic crisis, the rate may exceed 1 billion in 2009. Young children are particularly vulnerable, so that one in four children under the age of 5 is underweight, i.e. 146 million children in developing countries. Childhood undernutrition increases mortality such that it has been estimated that 60% of childhood deaths in developing countries are associated with malnutrition. Malnutrition stunts physical growth, increases the risk of infections (gastroenteritis, pneumonia, tuberculosis) and of serious obstetric complications. Malnourished children are less able to benefit from education, hence there is lower economic productivity, and slowed socioeconomic development.

In developing countries, and poor communities in other countries, childhood malnutrition is due to a complex interaction of factors including insufficient or poor quality food and poor sanitation and health services leading to an increased risk of infection (Fig. 34.3).

Children may not get sufficient food because of: crop failure; conflict which makes it unsafe to plant, tend, or harvest the crops; and, in some cases, poor care and feeding practices. Displacement because of natural disasters such as drought, or conflict and persecution also affects the lives of millions of children (see Chapter 20). The classic protein-energy malnutrition conditions marasmus and kwashiorkor are discussed in Chapter 19.

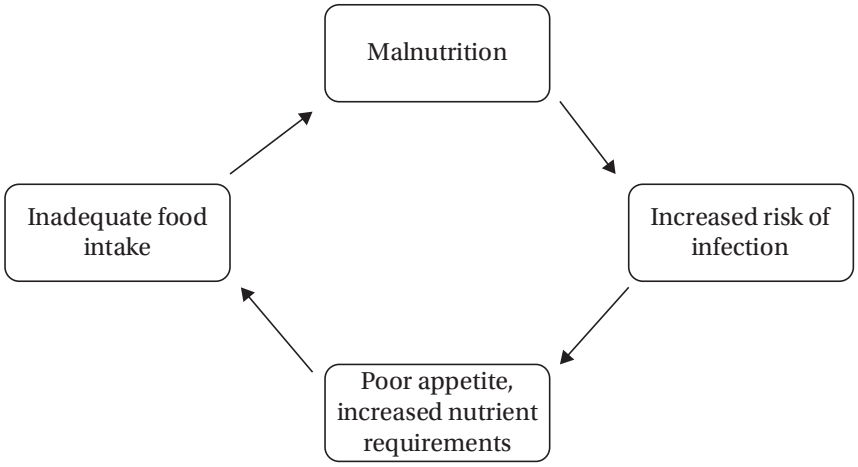


Fig. 34.3 The cycle of malnutrition and infection seen in children living in developing countries.

Consumption of poor-quality food with low nutrient content has been described as the 'hidden hunger' of micronutrient deficiency. In the 2002 World Health Report the World Health Organization identified iodine (Chapter 11), iron (Chapter 10), vitamin A (Chapter 12) and zinc (Chapter 11) deficiencies as being amongst the most serious global health risks.

Key anthropometric indices used as measures of nutritional and health status in children in developing countries are:

- weight-for-age: measures weight relative to that of a healthy reference population of the same age (used to identify 'underweight');
- height-for-age: measures *long-term growth faltering* (used to identify 'stunting');
- weight-for-height: measures *acute growth disturbance* (used to identify 'wasting').

The terms 'underweight', 'stunting', and 'wasting' are used when a child's measurement is two or more standard deviations below the median reference standards for the index.

Table 34.5 The Millennium Development Goals

- Goal 1: Eradicate extreme poverty and hunger
- Goal 2: Achieve universal primary education
- Goal 3: Promote gender equality and empower women
- Goal 4: Reduce child mortality rate
- Goal 5: Improve maternal health
- Goal 6: Combat HIV/AIDS, malaria, and other diseases
- Goal 7: Ensure environmental sustainability
- Goal 8: Develop a global partnership for development

34.7.2 The Millennium Development Goals

The Millennium Development Goals were adopted by United Nations member states in 2001 and are a set of specific measurable goals for the international community to support developing countries to achieve by 2015. They are all relevant to children and adolescents (Table 34.5). Targets and indicators under these goals with specific nutrition implications are in Table 34.6.

There has been mixed progress towards achieving the Millennium Development Goals. Positive gains have been made in terms of poverty reduction, getting more children into school, and immunization, but some of the nutrition targets are proving more resistant to change. The number of people in developing regions who were undernourished increased from 817 million to 830 million between 1990–92 and 2005–07. Disparities within countries have continued, or in some countries worsened. In Southern

Table 34.6 Millennium Development Goals targets and indicators with special relevance to nutrition

- *Target 1C: Halve the proportion of people who suffer from hunger*
  - Prevalence of underweight children under 5 years of age
  - Proportion of population below minimum level of dietary energy consumption
- *Target 4A: Reduce by two-thirds, between 1990 and 2015, the under-5 mortality rate*
- *Target 5B: Achieve, by 2015, universal access to reproductive health*
  - Reduce the adolescent birth rate
- *Target 7C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation*

Asia, for instance, 60% of children in the poorest areas are underweight, compared to 25% in the richest areas.

34.7.3 Interventions for childhood malnutrition

The main dietary approaches to addressing childhood malnutrition in developing countries include supplementation with specific nutrients (e.g. iron supplementation of children identified with anaemia), fortification of a commonly consumed food vehicle (e.g. the iodization of salt), and dietary change (e.g. increasing the intake of animal foods or encouraging processing methods such as fermentation that decrease the phytate content of unrefined cereals and legumes). Deworming can also markedly decrease iron requirements in children who have hookworm or other gastrointestinal parasites. Less direct approaches such as vaccination, improved sanitation, and education on good feeding practices are also important.

Much work has been done in recent years to develop and test home or 'point-of-use' fortification strategies. Two such products being used in programmes for preschool children and school meals are:

- micronutrient sprinkles: these are pre-packaged micronutrients that are sprinkled onto food before it is eaten;
- lipid-based nutrient supplements: these are products that contain vitamins and minerals, protein, and essential fatty acids in a palatable form. One example is 'nutributter', which is based on peanut, milk powder, and flavouring such as cocoa.

The advantage of these home fortification approaches is that the amount of nutrient provided is not dependent on the child's energy intake, and that the nutrients are targeted to the person who needs them.

34.7.4 Emerging issues

HIV continues to place many children in developing countries at extreme nutritional risk. The risk to children lies not only in contracting the condition, but also if one or both their parents are infected (see Chapter 41). It has been estimated that in 2008 alone, 17.5 million children and adolescents lost at least one parent to AIDS. These children are more likely to be malnourished, unwell, or subjected to exploitation and discrimination than children orphaned for other reasons. In addition, the increasing success of programmes to prevent the transmission of HIV from mother to child means that there are now substantial numbers of HIV-exposed uninfected (HIV-EU) children. In some countries in sub-Saharan Africa, up to one in four babies born may be HIV-EU.

Over the past decade there has been increasing concern about the 'double burden of disease' in developing countries, the coexistence of undernutrition and overnutrition in the same country. It is assumed that the substantial changes in traditional diets (to foods that are more energy-dense but micronutrient-poor) and lifestyles (with less physical activity) that have occurred in recent decades are responsible, particularly in urban settings. The problem may be more widespread than is currently thought because the use of weight-for-age to identify malnutrition can incorrectly identify many overweight stunted children as normal or even underweight.

34.8 Special issues in adolescents

Adolescents represent a significant proportion of the total population. It is a time of rapid physical and psychological growth, with numerous pressures and influences resulting from the transition from a dependent childhood state to independent living in some societies. While many of the nutritional problems that

affect children also apply in this age group, adolescents also face additional nutrition-related issues.

34.8.1 Pregnancy

More than 13 million children are born annually to teenage mothers, the vast majority to women in developing countries. For these women, young motherhood may be common, but complications from pregnancy and childbirth also form the leading cause of mortality in girls aged 15–19 years. In developed countries, considerable social stigma can be associated with teenage pregnancy. Teenage mothers are more likely to be unmarried and live in poverty, and most teenage pregnancies are unplanned. Because of this, nutritional support during adolescent pregnancy is important and challenging, and the youngest adolescents are at the greatest risk. In particular, low pre-pregnancy BMI, poor gestational weight gain, impaired iron status, and poor calcium and vitamin D status can adversely affect pregnancy outcomes. Breastfeeding initiation rates and duration are lower in younger and unmarried mothers, although barriers to effective breastfeeding are thought to be more social and cultural than physical.

34.8.2 Dieting and anorexia nervosa

Western culture typically glorifies a thin body ideal and the media influences how adolescents view their body shape. Body dissatisfaction is rife in adolescent girls and it is not uncommon for teenagers to become preoccupied with their physical appearance. However, few adolescents actually go on to develop a diagnosed eating disorder (see Chapter 24), perhaps only 1%. Larger numbers of adolescents engage in unhealthy dieting behaviours which could place them at nutritional risk.

34.8.3 Alcohol

The independence of adolescents from their family is associated with an increased susceptibility to peer pressure, both positive and negative. In many countries, alcohol consumption commences during adolescence and intake is cause for concern. Although alcohol can be consumed safely and in moderation as part of an adolescent's dietary intake, many adolescents are exposed to a more negative side of alcohol and the dangers of alcohol intoxication. If consumed in excess, alcohol can replace more nutrient-dense foods from the diet. Adolescents who drink regularly tend to engage in other risky health behaviours, and careful campaigns are required in order to reach this target audience. It is unlikely that negative messages are well received, so that it may be better to focus on safe and legal drinking limits (rather than drinking and driving) and how to determine the alcohol content of drinks with which adolescents are unfamiliar.

34.8.4 Chronic disease

Chronic disease prevention should start early in life. Although the overt symptoms of most chronic disease may not be apparent until mid-adulthood, post-mortem studies have demonstrated that fatty streaks in the arteries are apparent in adolescents.

Although the majority of children and adolescents with diabetes have type 1 diabetes, up to 45% of new cases in some population groups now have type 2. This has been attributed to the escalating prevalence of obesity. Type 2 diabetes during growth occurs most often during the adolescent years and is more common in females. Thus there is considerable justification for encouraging adolescents to follow widely accepted dietary guidelines. However, it must be acknowledged that adolescence is a time of experimentation when young people inevitably experience the need to assert themselves and respond to peer pressure. This applies as much to food habits as to other aspects of their lifestyle. They generally, with their parents' help, manage to combine enough of the essential nutrients in their own individual way. If appropriate eating habits have been established in childhood, there is the expectation that food habits will improve when they have passed through this transitional stage.

Conclusion

Appropriate nutrition is essential for optimal growth and development in childhood and adolescence. Cognitive development is also influenced by nutritional factors. While one in four of children worldwide suffer from malnutrition, one in three in developed countries are overweight and, in some societies, undernutrition and obesity coexist. In childhood and adolescence overweight and obesity account for the emergence, in some population groups, of type 2 diabetes as a major health issue amongst young people, in addition to the well-recognized psychosocial consequences and risk of fractures. The conditions tend to continue into adult life, when the many comorbidities associated with excess body fat become apparent. Appropriate eating habits established in childhood will encourage healthier food choices in later life, even if in adolescence there is a tendency to adopt less conventional food habits. Thus implementation of dietary guidelines for young people should be regarded as a priority in families as well as in the context of public health.

Further Reading

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7. **Tanner, J. and Davis, P.S.W.** (1985) Clinical longitudinal standards for height and weight velocity for North American children. *J Pediatr*, **107**, 317–29.
8. A series of comprehensive international reports on maternal and child undernutrition appeared in consecutive issues of *The Lancet* starting on p. 243 of the issue of 19 January 2008.

Useful Websites



To see topical and scientifically robust updates on nutrition associated with this textbook and web links to many of the journals in the Further Reading sections, please see the dedicated Online Resource Centre at **http://www.oxfordtextbooks.co.uk/orc/mann4e/**

United States and Canada Dietary Reference Intakes:
http://www.nap.edu/
Growth references of the Centre for Disease Control:
http://www.cdc.gov/growthcharts/

More detailed growth charts for clinical use:
http://www.cdc.gov/growthcharts/clinical_charts.htm
Training module on the use of growth references:
http://www.cdc.gov/growthcharts/educational_materials.htm
Millennium Development Goals:
http://www.endpoverty2015.org/en/goals



Nutrition and ageing

Wija van Staveren, Lisette de Groot, and Caroline Horwath

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Nutrition interacts with the ageing process in numerous ways and the risk of nutrition-related health problems increases in later life. This chapter provides an overview of why nutrition is important in old age, what happens to our bodies as we age, the nutritional needs and status of older adults, and some special issues arising in nutrition–disease relationships.

35.1 Is nutrition one of the secrets to health and long life?

For thousands of years, the search for eternal life and youth has captured people's imagination. In about 1750 George Cheyne, physician to Samuel Johnson, David Hume, and Alexander Pope, wrote 'An Essay of Health and Long Life' in which he is emphatic that:

> *Nothing conduces more to Health and Long Life, than Abstinence and plain Food, with due Labour. Most chronical diseases proceed from Repletion . . . Without due Labour and Exercise, the Juices will thicken, the Joints will stiffen, the Nerves will relax, and on these disorders, Chronical Distempers and a crazy old Age must ensue . . . this [lessening the diet gradually with age] is a powerful means to make their old age Green and Indolent, and to preserve the remains of their Senses to the very last.*

The similarities to recommendations derived from the latest research on ageing are remarkable. Still, it is questionable whether these recommendations have led to the currently continuing increase in life expectancy in many countries (UN 2007). This remarkable gain is not only observed in western Europe, North America, Australia, and New Zealand, with even larger gains in Japan and some southern European countries such as Spain

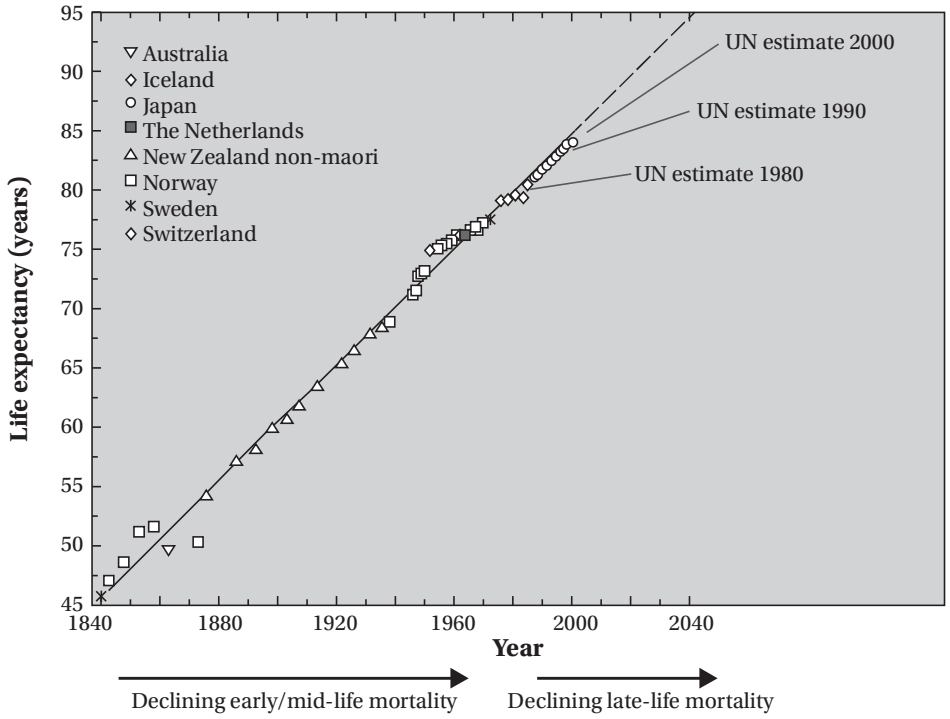


Fig. 35.1 Life expectancy around the world has increased steadily for nearly 200 years. The graph shows the projected life expectancy in the then longest-living country.

Source: Adapted by Kirkwood, T.B. (2008). A systematic look at an old problem. *Nature*, **451**, 644–7, from Oeppen, J., and Vaupel, J.W. (2002) Demography. Broken limits to life expectancy. *Science*, **296**, 1029–31.

and Italy, but also in some developing countries, although with differential speed. The segment of older adults is growing. Fig. 35.1 shows life expectancy from 1840 and projections to 2040 for the then longest-living country. It is generally accepted that these life expectancy improvements were not based on uniform reductions in mortality at all ages. During the nineteenth and early twentieth centuries, improvements in infant and childhood survival contributed most to the increase in record life expectancies. After successful combating of infectious diseases at young ages gains were caused by the decline in late-life mortality. This decline in mortality at age 80 years and over will continue, in some countries even at an accelerating pace.

The changes will lead to a very different population pyramid (Fig. 35.2). Rapidly growing older populations raise concern about whether or not a shrinking labour force will be able to support that part of the population who are commonly believed to be dependent on others, such as disabled and older adults. In order to delay or even prevent disabilities and chronic diseases, healthy ageing policies and programmes focusing on lifestyle are required.

But how can healthy ageing happen? Ageing is a multifactorial process. Genetic factors, for instance, may underlie the ageing process itself and aberrant gene expression is strongly involved in processes leading to the development of diseases that restrict lifespan. Consensus now exists that ageing is caused by the gradual, lifelong accumulation of a wide variation of molecular and cellular damage, eventually resulting in progressive loss of function, frailty, and disease. But if ageing is a matter of things falling apart, can research—and more specifically—can nutrition play a role in a 'healthy ageing' programme?

According to Kirkwood (2008) the answer is yes. How the ageing process plays out is—apart from chances or good luck—not only influenced by factors intrinsic to the individual but also by extrinsic factors such as environmental and lifestyle variables. There is plenty of mechanistic evidence that it is possible to intervene on the interplay

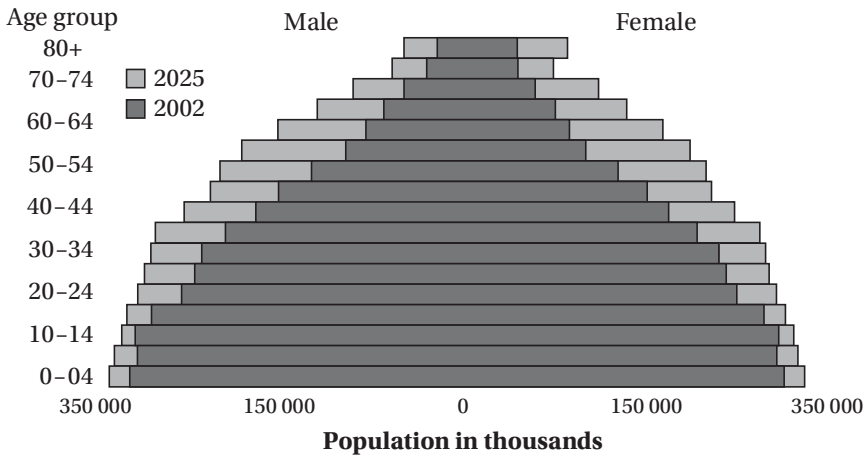


Fig. 35.2 Global population pyramids for 2002 and 2025. Note that as the proportion of children and young people declines and the proportion of people of 60 years and over increases, the triangular population pyramid of 2002 will be replaced with a more rounded structure in 2025.

Source: WHO (2002). *Ageing and life course program. Active ageing: A policy framework*. Geneva: World Health Organization.

between intrinsic factors and nutrition. Of the 20 leading risk factors for disability, chronic disease, and death, a number are nutrition-related and may lead, amongst others, to cardiovascular diseases, type 2 diabetes, Alzheimer's disease, and certain types of cancer. The global epidemiological data have motivated (WHO/FAO 2004, 2008) to update their dietary guidelines. These guidelines are evidence-based for younger adults, but may not have the same impact for elderly people. To get a better understanding of changing nutrient requirements in old age we first have to answer the question: 'What happens to our body as we age?'

35.2 What happens to our bodies as we age?

Changes in body composition, physical performance, and organ system function occur in all of us as we grow older. However, wide variation exists among people in the degree to which functions decline. As people become older, the more dissimilar they become from their contemporaries of the same chronological age. There can also be considerable variability in the rate at which different changes occur within the same person. Some of this variability in functional decline may reflect heterogeneity in true rates of ageing; however, lifestyle and other factors that can accompany ageing seem to be of importance. Changes in body composition and changes in the gastrointestinal tract have an impact on nutritional requirements. These changes will be further discussed here.

35.3 Changes in body composition and energy balance

Changes in body composition during ageing include loss of lean body mass (LBM), bone mass, body water, and a relative increase of fat mass. The latter is also redistributed from mainly subcutaneous to

abdominal fat. The decrease in lean body mass is caused by a reduction in size and strength of skeletal muscle. On average the marked decline in LBM begins around the seventh decade, approaching as much as a 40% loss compared to young adulthood (Fig. 35.3).

A stable body weight in this process can be explained by a concomitant increase in body fat. This loss in lean body mass and change in fat mass is associated with sarcopenia, a term derived from the Greek words *sarx* (flesh) and *penia* (poverty). The term was introduced by Rosenberg (1997), who wanted the medical professionals to recognize this ageing condition in an early stage to diminish the negative impact on morbidity and mortality. Features of sarcopenia are, amongst others, loss of muscle mass and strength (decrease of type 2 fibre number and strength, and less so of type 1 fibres). The pathophysiology is complex. The diagnosis of the medical condition is based on the combined presence of the two following criteria:

1 A low muscle mass, i.e. a percentage of muscle mass > 2 standard deviations below the mean measured in young adults of the same sex and ethnic background. This suggested T-score-based diagnosis is comparable with the diagnosis of osteoporosis; however, for sarcopenia there is a lack of suitable reference values in various populations.

2 Low gait speed, e.g. a walking speed below 0.8 m/s in the 4-minute walking test. This test can

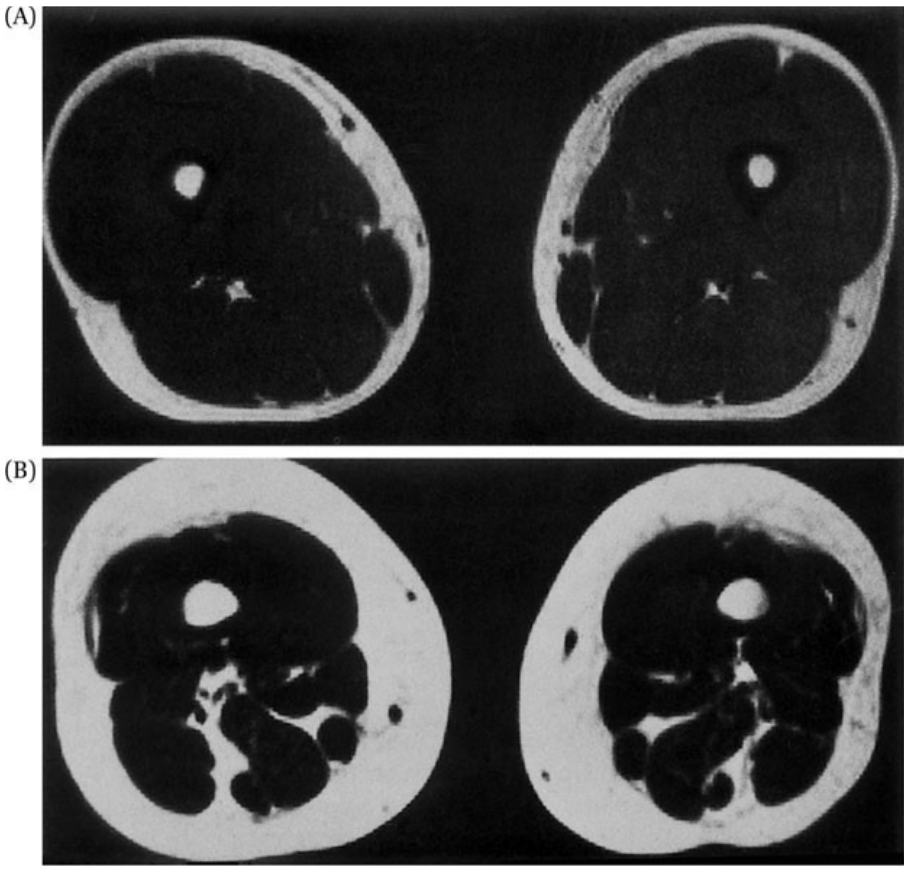


Fig. 35.3 Magnetic resonance images of the thigh showing differences in total muscle, intramuscular fat, subcutaneous fat, and bone between (A) a young woman athlete (age 20 years, body mass index 22.6 kg/m^2) and (B) an elderly sedentary woman (age 64 years, body mass index 30.7 kg/m^2).

Source: Evans, W.J., and Meredith, C.N. (1989) Exercise and nutrition in the elderly. In Munro, H.N., and Danford, D.E. (eds) *Nutrition, aging and the elderly.* New York, Plenum Press.

be replaced by another well-established functional test.

Effective prevention and treatment of sarcopenia is sought in physical activity programmes and the way nutrition and/or nutrition supplements and exercise regimens can be combined for the prevention or treatment of sarcopenia. Due to a lack of trials there is not yet a consensus on the management of sarcopenia.

Together with age-related metabolic diseases, as well as presence of individual handicaps, sarcopenia often coincides with decline of physical activity. Moreover, due to diminished maximum oxygen intake and muscle fibre atrophy, a greater physical effort for the same task is required in older people. As a consequence, older people will reduce physical activity further and have lower energy expenditure. Fig. 35.4 shows how the physical activity level (PAL) calculated as daily total energy expenditure divided by the resting metabolic rate decreases with ageing.

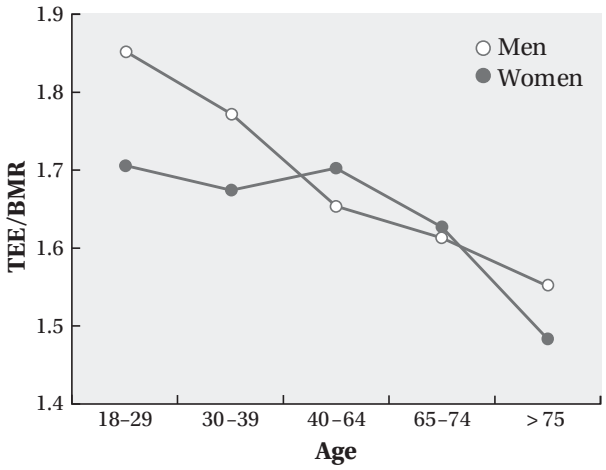


Fig. 35.4 Decrease of physical activity level (PAL) for men and women during ageing. PAL is derived as total energy expenditure (TEE, assessed by doubly labelled water method) and divided by basal metabolic rate (BMR, derived from proxy measures).

Source: Based on Black, A.E. (1996) Physical activity levels from a meta-analysis of doubly labeled water studies for validating energy intake by dietary assessment. *Nutr Rev*, **54**, 170–4; conclusion confirmed by Manini, T.M. (2010) Energy expenditure and aging. *Ageing Res Rev*, **9**, 1–11.

Many nationwide food consumption studies have shown that older people respond to this lower activity with a smaller energy intake and may even overrespond, which results in a negative energy balance. This phenomenon is called anorexia of ageing and is common in people over 70 years of age. In contrast to younger adults, body weight tends to decrease at old age, even in healthy individuals. Weight loss in later life should be prevented, because it increases the risk of progressive malnutrition, micronutrient deficiency, nutrition-related diseases, and is associated with frailty and increased mortality (Fig. 35.5).

Bone mass and bone density may start to decrease already from the age of 35–40 years onwards (see Chapter 9) In women, bone loss accelerates during the menopause. They may lose half of their trabecular and about one-third of their cortical bone mass; in men, this loss is lower, only 50–70% of that of females. The decrease in bone mass density is associated with osteoporotic fractures. Osteoporosis is a multifactorial disease and inadequacies of the nutrients calcium and vitamin D are related to a decline in bone density and to fractures. Vitamin D deficiency is often observed in old age due to

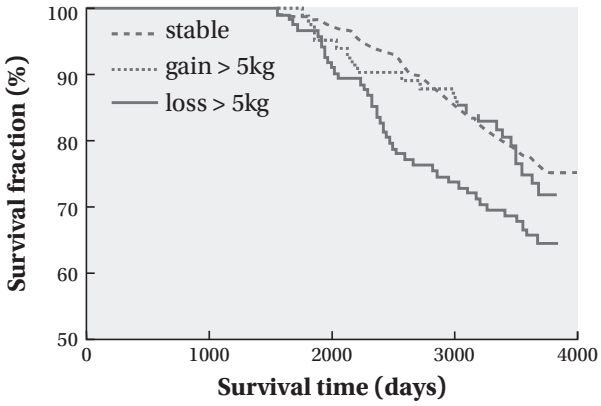


Fig. 35.5 Probability of survival for participants in the SENECA study with and without weight change.

Source: De Groot, C.P.G.M., and Van Staveren, W.A. (2002) Undernutrition in the European SENECA studies. *Clin Geriatr Med*, **18**, 699–708.

diminished synthesis in the skin (Fig. 35.6), as well as lack of sunlight exposure. Recommended intakes for the housebound elderly for vitamin D are 15 μg, which cannot be obtained from ordinary foods.

Dehydration is another problem often observed in elderly people. Due to less LBM, but also less interstitial fluid, the older adult contains less body water (<50% versus 70% of total body mass in younger adults). Further, decreased renal function, loss of thirst sensors, fear of incontinence, and increased arthritic pain resulting from numerous trips to the toilet may interfere with an adequate intake of fluid. Dehydration may result in constipation, faecal impaction, cognitive impairment, and even death. The recommended amount of fluid is about 1500 mL per day, which should be taken during and between meals.

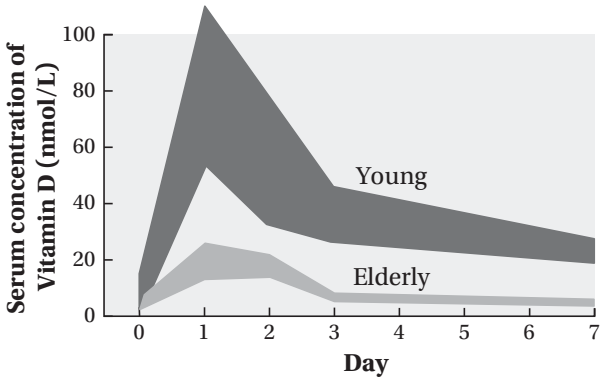


Fig. 35.6 Serum concentrations of vitamin D in healthy young and elderly adults in response to whole-body exposure to a dose of simulated sunlight on day 0.

Source: Holick, M. (1994) Vitamin D—new horizons for the 21st century. *Am J Clin Nutr*, **60**, 619–30.

35.4 Digestive function in old age

For many years it was thought that the efficiency of the digestive and absorptive functions of the gastrointestinal tract declines with age. This is now known to reflect also the effects of medications or disease states. Where malabsorption occurs in an older adult, investigation of possible pancreatic or small intestinal disease is required.

Diminished, altered, or lost taste perception with ageing may be caused by changes in the oral cavity (e.g. reduced taste bud numbers, saliva production, or dental problems) and/or changes in the neuronal fibres that are connected to the brain. Together with changes in the olfactory system (smell), the overall sensory perception of food declines. It is, however, difficult to distinguish between taste and smell dysfunctions that are directly related to ageing and those resulting from diseases and medication. Individuals are not able to discriminate between the loss of taste and smell. Many taste complaints are actually olfactory disorders. These complaints may cause malnutrition. Despite taste and smell losses, however, palatability is just as valuable in old age to promote food intake as it is in the young adults. This means that pleasantness might not decrease and offering highly palatable foods in a stimulating ambiance increases food intake even in frail older adults. Difficulty in swallowing occurs in some older adults if neurological function is disturbed, e.g. after stroke.

Perhaps the most important change in gastrointestinal function with ageing is the reduction in gastric acid output in a subgroup of older people who have atrophic gastritis. Atrophy of the stomach mucosa becomes more common with ageing and appears to affect about one-third of those over 60 years. The result is lowered secretion of acid, intrinsic factor, and pepsin, which reduce the bioavailability of vitamin $B_{12,}$ calcium, iron, and folate. The implications are most profound for vitamin B_{12} due both to the diminished dissociation of the vitamin from food proteins and binding of the small amount of freed vitamin B_{l2} by the increased numbers of swallowed bacteria which are able to survive in the low-acid environment of the proximal small intestine. In recognition of this and the prevalence of atrophic gastritis in the older population, most of the current dietary reference intakes (DRIs) recommend that older adults meet their vitamin B_{12} needs

from supplements or foods fortified with crystalline, free vitamin B_{12}. However, research is needed to determine whether functionality is improved by normalizing low vitamin B_{12} status and to determine the dose required (see Section 13.8.5).

Another change is reduced intestinal motility, which causes a slower clearance of the intestinal contents. The altered motility and additional dystrophy in the large intestine may lead to constipation or diarrhoea; both disorders occur in the elderly. Especially prevalence of constipation increases and contributes significantly to morbidity and affects the individual's feeling of wellbeing. Sufficient fluid and dietary fibre may at least partly prevent this disorder.

35.5 Do nutritional needs change as we age?

Since the late 1990s, many countries published nutrient recommendations with separate data for adults 51–70 years and ≥70 years. Until more specific information becomes available on the nutritional requirements of older adults, these broad age groupings will have to suffice for the entire heterogeneous older population (see Chapter 37 for a more extensive discussion on requirements and recommended intakes). How are the nutritional needs of older adults currently thought to differ from those of younger adults?

Older adults have reduced needs for energy and, as a result, presumably also for the B vitamins which are involved in energy metabolism, and postmenopausal women have lower needs for iron, as a result of cessation of menstrual blood losses. These differences are reflected in lower recommended nutrient intakes for older adults. The lower energy needs of older adults are the result of declines in metabolic rate (secondary to reduced lean muscle mass) and in activity levels. Neither of these changes are inevitable; indeed, it can be argued that morbidity and mortality could be lowered if LBM and physical activity were maintained at more youthful levels, rather than diminished in older persons. The greater food intake needed to balance higher energy expenditure is more likely to ensure adequate intakes of essential nutrients. If older adults consume low energy intakes, then it is important that the foods they eat are nutrient-dense, rather than low nutrient-density (high in sugars, fats, or alcohol).

The body's requirements for iron are lowest in old age; however, other factors in the lives of many older people can increase the risk of iron deficiency; chronic blood loss from ulcers or other disease conditions, poor iron absorption due to reduced stomach acid secretion, or medications like aspirin, which can cause blood loss.

Calcium needs are also higher in postmenopausal women (with low oestrogen levels) and this is reflected in increased recommendations for calcium intakes. An abundant calcium intake throughout life helps protect against osteoporosis, particularly in women (see Chapter 9). There is also evidence accumulating that older adults may have greater needs for vitamin D (see Section 35.3), riboflavin, and vitamin B_6, and need higher doses of vitamin B_{12} to correct poor status (see Section 35.4). The increase in vitamin B_6 requirement with age does not appear to be an absorptive problem, and subclinical deficiency of this vitamin may result in immune dysfunction. Furthermore vitamin B_6, along with folate and vitamin B_{12}, favourably affects serum homocysteine. Higher homocysteine levels might be an independent risk factor for cardiovascular disease and impaired cognitive functions. The high levels generally observed in older adults can be reduced by an increased intake of folate, vitamin B_{12}, and vitamin B_6 (in that order of effectiveness). Riboflavin requirements, which had previously been thought to be lower in older than in younger persons, are now recognized to be the same or slightly higher in older age categories. Since vitamin E is the only lipid-soluble, chain-breaking antioxidant found in biological membranes, this vitamin might play an important role in maintaining neuronal integrity and preventing cell loss. Thus it is logical to consider whether

higher intakes may prove useful in neurological disorders where oxidative stress has been implicated. But three meta-analyses of randomized trials found that vitamin E supplementation did not reduce mortality.

Overall, compared with younger adults, most older adults need to obtain the same or even higher intakes of several micronutrients, but usually in substantially lower overall food intakes. Thus a nutrient-dense diet is a high priority in old age.

35.6 A look at the eating habits of older adults

A number of general conclusions can be drawn from studies of dietary intake conducted amongst older populations around the world. Contrary to the popular 'tea and toast' myth, it appears that most older adults outside institutions eat reasonably well. The dietary patterns of older adults have generally been found to be similar to those of younger adults, but vary within and between different cultures and regions. Energy intake decreases with ageing and only when the intake level falls below 1500 kcal or 6.3 MJ does it become difficult to fulfil the recommended daily requirements (Table 35.1).

Table 35.1 Daily consumption of type of foods and number of portions suggested in this table supply about 6.3 MJ and recommended daily intakes of micronutrients for populations over 70 years of age as suggested in several countries.

• Sandwiches with filling	4 slices (margarine, cheese, meat, marmalade)
• Milk products	3 cups
• Fruit	1 to 2 pieces
• Potatoes	1 to 2 pieces
• Vegetables	4 serving spoons
• Meat	75–100 g
• Oil for preparation cooked meal	15 g
• Fluid	8 servings
• Vitamin D	10–20 µg

Since dietary intake of foods and nutrients are related and as people do not eat single nutrients or foods, evaluating dietary patterns in relation to health has attracted considerable interest. Strictly defined prospective studies found strong evidence for protective factors such as vegetables, nuts, monounsaturated fatty acids, and Mediterranean, prudent, basically plant-based and high-quality diets. Evidence was also found for harmful factors such as *trans*-fatty acids, foods with a high glycaemic index or load, and 'Western' dietary pattern. Adherence to a Mediterranean diet appears to be relevant even in old age. Reductions of 9% in overall mortality, mortality from cardiovascular diseases (9%), cancer (6%), and incidence of Alzheimer's disease (13%) followed from a meta-analysis of eight cohort studies.

Fig. 35.7 shows that, in addition to adherence to a healthy diet, other healthful practices are important, such as no smoking, moderate alcohol use, and physical activity. However, even with an apparently adequate food intake there are some nutrients for which there is a greater risk of inadequate supply. These nutrients are calcium, zinc, magnesium, vitamin B_6, folate, vitamin B_{12}, vitamin C, and vitamins D and E. The low calcium intakes and vitamin D supply of many older people, particularly women, have important implications for bone health. Vitamin C intake often seems to be adequate in older adults, but unfortunately vitamin C is readily lost from foods during storage and preparation. Low vitamin C intake in addition to low intakes of other antioxidants, e.g. vitamin E and carotenoids, has been associated—but not confirmed in trials—with

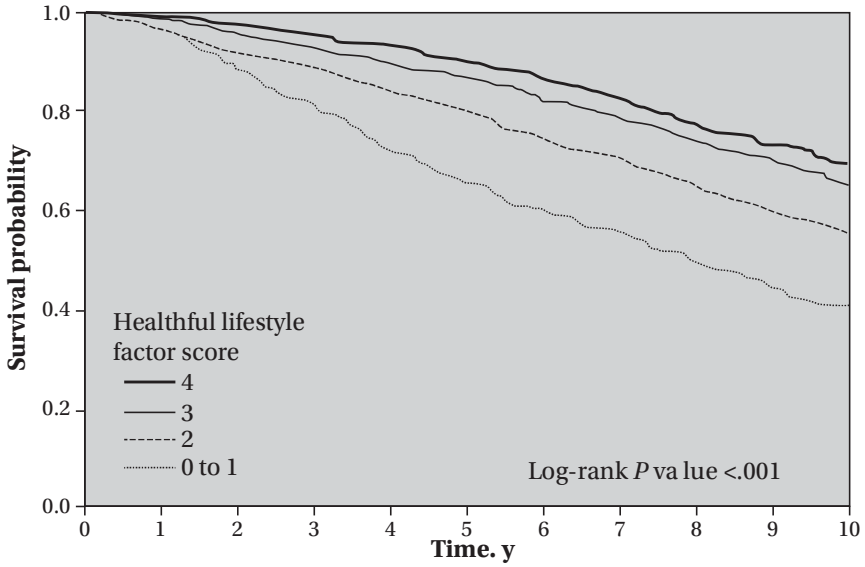


Fig. 35.7 Combined diet and lifestyle factors (smoking, alcohol consumption, and physical activity) for 10-year all-cause mortality in elderly Europeans. Note that individuals scored 1 or 0 points if they belonged to the low- or high-risk group, respectively, for diet or a particular lifestyle factor. For a maximum score, an individual could obtain 4 points: 1 point for the Mediterranean diet and 3 points for the lifestyle factors.

Source: Knoops, K.T., de Groot, L.C., and Kromhout, D. (2004) Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: The HALE project. *JAMA*, **292**, 1433–9.

increased risk for senile cataract and coronary artery disease.

Daily intake of fruits, vegetables, whole grains, and dairy products as well as the inclusion in the diet of lean meat, fish, poultry, and legumes will ensure provision of those nutrients found to be most 'at risk' in the diets of older people. If elderly people eat these foods in amounts as suggested in Table 35.1, then about 6.3 MJ covers the daily recommended intake of most countries. However, with such a lower energy intake, there is no place for so-called social foods or snacks.

Inadequate nutritional intake is the predominant cause of undernutrition in older persons. The diagnosis of undernutrition is made with different methods and the prevalence depends on the methods and cut-off values applied. The literature describes a prevalence of 5–10% in community-dwelling persons above 70 years of age and up to 30–60% in institutionalized people of that age. It is crucial to identify older persons at risk and to make an early diagnosis for effective intervention. For a first screening, tools have been developed from a number of parameters of the nutritional state. They are designed for self-assessment or for administering by healthcare professionals. Fig. 35.8 presents an example of a screening tool, that incorporates several domains including functionality, lifestyle, a few questions on diet, and subjective health and anthropometric indicators. The sensitivity and specificity of the tool validated against an extensive evaluation by clinicians were 96% and 98%, respectively.

Signs of poor nutrition in an older individual include recent weight loss, missing meals, infrequent grocery shopping, depression, loss of appetite, or declining food intake due to digestive problems, taste changes and chewing or swallowing difficulties. Table 35.2 shows other factors contributing to undernutrition in old age.

The three factors most consistently linked with poor dietary intake in old age are low socioeconomic status, depression, and, amongst older men, loneliness. Compared with men living with a spouse, older men living alone tend to have a poorer fruit

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Last name: First name:

Sex: Age: Weight, kg: Height, cm: Date:

Complete the screen by filling in the boxes with the appropriate numbers. Total the numbers for the final screening score.

Screening

A Has food intake declined over the past 3 months due to loss of appetite, digestive problems, chewing or swallowing difficulties?
0 = severe decrease in food intake
1 = moderate decrease in food intake
2 = no decrease in food intake ☐

B Weight loss during the last 3 months
0 = weight loss greater than 3 kg (6.6 lbs)
1 = does not know
2 = weight loss between 1 and 3 kg (2.2 and 6.6 lbs)
3 = no weight loss ☐

C Mobility
0 = bed or chair bound
1 = able to get out of bed / chair but does not go out
2 = goes out ☐

D Has suffered psychological stress or acute disease in the past 3 months?
0 = yes 2 = no ☐

E Neuropsychological problems
0 = severe dementia or depression
1 = mild dementia
2 = no psychological problems ☐

F1 Body Mass Index (BMI) (weight in kg) / (height in m^2)
0 = BMI less than 19
1 = BMI 19 to less than 21
2 = BMI 21 to less than 23
3 = BMI 23 or greater ☐

IF BMI IS NOT AVAILABLE, REPLACE QUESTION F1 WITH QUESTION F2.
DO NOT ANSWER QUESTION F2 IF QUESTION F1 IS ALREADY COMPLETED.

F2 Calf circumference (CC) in cm
0 = CC less than 31
3 = CC 31 or greater ☐

Screening score ☐☐
(max. 14 points)

12-14 points:	Normal nutritional status
8-11 points:	At risk of malnutrition
0-7 points:	Malnourished

For a more in-depth assessment, complete the full MNA® which is available at **www.mna-elderly.com**

Ref. Vellas B, Villars H, Abellan G, *et al. Overview of the MNA® — Its History and Challenges*. J Nutr Health Aging 2006;**10**:456-65.
Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. Screening for Undernutrition in Geriatric Practice: Developing the Short-Form Mini Nutritional Assessment (MNA-SF) . J. Geront 2001;**56A**: M366-377.
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Fig. 35.8 Mini-nutritional assessment.

Source: Guigoz, Y. (2006) Mini-nutritional assessment (MNA) Review of the literature—what does it tell us? *J Nutr Health Aging*, **10**, 466–87.

Table 35.2 Potential contributors to nutritional problems in older people

Physical factors
Reduced total energy needs
Declining absorptive and metabolic capacities
Chronic diseases
Poor appetite
Changes in taste or odour perception
Poor dental health
Reduced salivary flow
Difficulty in swallowing
Lack of exercise
Physical disability (restricting the capacity to purchase, cook, or eat a varied diet)
Side effects of drugs (anorexia, nausea, altered taste, drug–nutrient interactions)
Restrictive diets
Alcoholism
Social and psychological factors
Depression
Loneliness
Social isolation
Bereavement
Loss of interest in food or cooking
Memory loss
Food avoidances
Socioeconomic factors
Low income
Inadequate cooking or storage facilities
Limited nutrition knowledge
Lack of transport
Shopping difficulties
Cooking practices that result in nutrient losses (e.g. soaking vegetables)
Inadequate cooking skills (particularly in men)

and vegetable intake, and more frequently choose less nutrient-dense, easy-to-prepare foods which also tend to be higher in fat and lower in fibre. Limited cooking skills and reduced motivation when cooking just for one are probably important contributors. Institutionalized older people and those living independently in the community but restricted in their mobility or depressed elderly, also

tend to be at higher risk of poor dietary habits. Lack of social contact, loneliness, being less active socially and physically, and recent bereavement are also associated with poor dietary intake. On the other hand, a rich and varied lifestyle and maintenance of positive interests should lead to better dietary quality through an improvement in life satisfaction, a better social support network, and a lessening of the impact of some of the negative life events associated with growing older. In fact, participation in fewer activities outside the home is linked with higher mortality in old age.

35.7 Nutrition–disease relationships in old age

The role of diet in some chronic diseases is discussed elsewhere (see Chapters 18 and 21, for example). Outlined here are some special issues in older adults and differences in nutrition–disease relationships from those in younger adults.

It is often assumed that lifestyle changes to improve health are no longer worthwhile in old age, that the remaining years are not sufficient to reap the benefits of modifications which are often thought to lead to a reduction in enjoyment of food. Certainly very restrictive diets may impair the adequacy of dietary intake. However, benefits can be gained from nutrition education and lifestyle change in older people. In several studies, a high proportion of older men and women have been found to make dietary changes, often for health reasons, thus challenging the stereotyped view of older adults being 'set in their ways'.

The incidence and prevalence of coronary heart disease are highest in the older population. Smoking, hypertension, and diabetes continue to be strong risk factors for heart disease, and the prevalence of diabetes and impaired glucose tolerance rises steeply with age. Intervention trials clearly demonstrate that the health advantages of quitting smoking and managing hypertension remain in old age. The Dietary Approaches to Stop Hypertension, the so-called DASH diet, is high in fruits and vegetables, moderate in low-fat dairy products, and low in animal protein but with substantial amount of plant protein from legumes and nuts. Adherence to this diet, which is composed of almost the same items as the Mediterranean Diet, is associated with a lower risk of chronic heart disease and stroke, also in older adults.

The management of hypertension (i.e. weight reduction in the overweight, sodium restriction, limitation of alcohol) is particularly relevant for older adults who are more susceptible to severe adverse drug reactions and may be more responsive to sodium restriction. There appears to be further grounds for sodium restriction in older women from studies demonstrating increased obligatory urinary calcium loss and thus a higher dietary calcium requirement on high sodium intakes. Reducing salt intakes to 6g salt/day can lower dietary calcium needs by about a third. Non-insulin-dependent diabetes in older adults should be managed by weight reduction mainly by increased physical activity and hypoglycaemic agents. Even moderate weight reduction can have benefits for diabetic control in older people, when it occurs under professional guidance. The latter is important, because weight loss programmes may result in mainly loss of lean body mass instead of fat mass, which is detrimental for health. Other classic risk factors, such as serum cholesterol weaken in predicting cardiovascular risk. Cardiovascular disease is highly prevalent, even in older adults, even with low cholesterol levels, because those with the highest levels are more likely to have suffered early death. New biomarkers have been identified that are epidemiologically associated with cardiovascular diseases e.g. homocysteine, but they need to be validated more extensively.

We still have to consider the classic cardiovascular risk factors, because the absolute risk attributable to high cholesterol levels actually increases with age. Attributable risk infers the number of events or deaths that are avoided for people in the group with

low exposure to the risk factor. All major risk factors, including elevated LDL cholesterol, show an increased attributable risk with advancing age. Evidence from clinical trials suggests that older adults are as responsive to drug and dietary treatment of high cholesterol levels as younger adults. It seems appropriate to consider functional rather than chronological age when deciding whether an individual should be given dietary advice to lower cholesterol levels. Someone who is generally healthy and appears likely to have a reasonable life expectancy should not be denied dietary advice. Still, more research is needed on the effects of cholesterol lowering particularly in those 70 years and older, though cholesterol lowering in people over 80 years would not seem worthwhile.

In Western societies the common pattern of weight gain up to the age of around 50–60 years would imply that overweight and obesity are common problems in old age. However, rather than being an inevitable part of growing older, this pattern is linked with sedentary lifestyles. The increase in abdominal or central obesity with advancing age is linked with greater risk of insulin resistance, hypertension, and dyslipidaemia. Overweight and obesity can also aggravate arthritis and impair physical mobility. Mortality too, among healthy adults who have never smoked, is greater in those with high body mass index (BMI) at least up until 75 years of age.

Surprisingly, systematic reviews conducted to determine the effect of an elevated BMI on all-cause mortality risk in men and women aged over 65 years concluded that those with overweight (25–29 kg/m^2) do not have increased risk of mortality. A BMI in the obese range is associated with only a modest increase in mortality, regardless of sex, disease status, and smoking. Of several explanations, the most important might be that BMI is not a good indicator of body composition. Kyphosis in old age makes it difficult to measure height reliably to estimate the BMI. Another suggestion is that an excess fat mass is less detrimental in old age. However, recent views on proinflammatory factors related to adiposity indicate that fat loss ameliorates some catabolic conditions of ageing since some cytokines may directly affect muscle protein synthesis and breakdown. Moderate intentional weight loss may also ease mechanical burden on weak joints and muscle, and improve mobility. Therefore, in obese (not overweight) elderly weight-loss therapy is recommended, but on the condition that muscle and bone mass remain stable.

Another link between nutrition and disease in older people is that between the antioxidant nutrients and risk of cataracts (clouding of the lens of the eye resulting in diminished vision) and macular degeneration (for the latter, see Section 12.8.2). Cataracts afflict nearly half of the American population aged 75–85 years, and are a major cause of blindness worldwide. In the prevention of these eye diseases nutrients of interest may be the vitamins C and E, the carotenoids lutein and zeaxanthin, zinc, and ω-3 fatty acids. There is biological plausibility to support a role of these dietary components in the protection of the lens and the macula lutea from sunlight damage. Osmotic stress due to high glucose levels is believed to be why people with diabetes are particularly prone to cataracts.

Constipation and diverticular disease are common problems, and awareness of the need to increase fibre intake is high, as reflected in widespread use of unprocessed bran supplements in older populations. However, it is preferable for fibre intakes to be increased through the consumption of a variety of cereals and vegetables rather than relying on extensive use of bran supplements. These may have adverse effects on the bioavailability of zinc and calcium, which may be marginally supplied in the diets of many older adults.

Severe nutrient deficiencies clearly impair both brain and immune function, and researchers are exploring the possibility that long-term moderate (subclinical) nutrient deficiencies also produce memory impairments or declining immunity in older adults. On the other hand, dementia can also have nutritional consequences. Dementia may lead to difficulty in shopping or cooking, or an older person with dementia may forget to eat or experience changes in taste, and may even not recognize food or eat non-food items.

For older adults, probably the single most important health message is to achieve or maintain at least

moderate levels of physical activity next to a balanced diet. There are numerous health benefits from exercise in old age: cardiovascular, musculoskeletal, and psychological benefits, improvements in fat and carbohydrate metabolism, and promotion of good bowel function. There are similarities between the deterioration accompanying ageing and that occurring with physical inactivity. Randomized controlled trials demonstrate that high-intensity strength-training exercises are effective and feasible means of preserving bone density while improving muscle mass, strength, and balance in old age.

35.8 Supplements for older adults

The use of supplements in the USA, Canada, Australia, and New Zealand is widespread amongst older men (35–60%) and women (45–79%). Advertisers often target older people, claiming their products prevent disease or promote longevity. Unfortunately, the nutrient supplements most commonly used are rarely those in shortest supply in the diet, and furthermore supplement users generally tend to have better dietary intakes than non-users. Particular concerns are the risk of supplement interference with drug absorption in an age group that heavily consumes both prescription and over-the-counter drugs.

There are, nevertheless, recommendations for specific supplement use by older adults: nutritional doses of vitamin D (15 µg per day) for all older adults, or general multivitamin including B vitamins and mineral supplements (at recommended intake levels) for those with very low food intakes (i.e. less than 6.3 MJ/day).The advice of vitamin B_{12} supplements is still under discussion (see Section 35.4). But a well-balanced diet will provide most healthy older people with the nutrients they need (except vitamin D), and for those whose food intakes are very low, the more important priority is to identify and try to correct any underlying physical or psychosocial reasons for eating problems or poor nutritional state (Table 35.2).

35.9 Drug–nutrient interactions

Drug–nutrient interactions should be considered as an issue of high clinical relevance for the older population first, because drugs may have different effects and side effects due to changes in body composition and functionality that occur with ageing. Second, dietary intake decreases and nutrient–nutrient interactions change as well as drug–nutrient interactions. Third, the use of (multi)medicinal preparations, including over-the-counter sold products and food supplement, is, on average, very high in this age segment. There are a number of means by which drugs can affect nutrition, usually increasing nutrient need. Many drugs can reduce appetite, produce nausea, gastrointestinal disturbances, or alter the senses of taste or smell and hence affect food intake; long-term laxative use can impair intestinal function; and laxatives and diuretics can lead to severe loss of potassium. As many as 30% of older adults complain that drugs change their sense of taste. It is very likely that undesirable drug–nutrient interactions are underdiagnosed, especially in frail, elderly people taking several drugs at a time and having low dietary intakes.

Conclusions

Logically, preventative measures to reduce diet-related disease should begin early in life; however,

that is not to say that lifestyle modifications are worthless in old age. Improvements in diet and maintenance of exercise have been shown to benefit health, regardless of age. Behavioural risk factors (e.g. not regularly eating breakfast, lack of regular physical activity, unhealthy weight changes, smoking) remain predictors of 10-year mortality even at older ages (i.e. 70+). As the older population is more heterogeneous than any other age-group, individual judgement is critical in deciding on the advisability of dietary and lifestyle changes. Physiological, psychological, and sociological factors need to be considered. At one extreme are independent, vigorous, healthy people in their 70s, 80s, and even 90s. At the other extreme are patients who are dependent and have multiple diseases and limited reserves. For the latter, diet and lifestyle advice should focus on function and quality of life. It is, however, often overlooked that although average life expectancy at birth may only be to the late 70s, at age 65 men and women in developed countries still have a life expectancy of some 15 and 19 years, respectively. Furthermore, at age 75 these life expectancies are around 10 years, and recent studies have shown that a healthy diet and lifestyle may make these years healthier, more active, and independent.

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