Feeding in the First Year of Life

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Scientific Advisory Committee on Nutrition

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Summary

Background and context

S.1 Between 1974 and 1994, the Committee on Medical Aspects of Food and Nutrition Policy (COMA) published a series of reports on infant feeding practices in the United Kingdom (UK) and made recommendations for infant and young child feeding. The last of these reports, 'Weaning and the weaning diet', was published in 1994 and provides the basis for much of the advice in the UK (DH, 1994).

S.2 Subsequent recommendations made by the Scientific Advisory Committee on Nutrition (SACN) and by international expert committees have carried implications for current infant feeding policy. These include the adoption of World Health Organization (WHO) Growth Standards (WHO MGRS, 2006a; WHO MGRS, 2006b; SACN/RCPCH, 2007) and revisions to energy requirements (FAO, 2004; SACN, 2011a).

S.3 This report covers the infant period, from birth up to 12 months of age. In particular, it considers evidence on developmental stages and other factors that influence eating behaviour and diversification of the diet, and makes recommendations on feeding in the first year of life. In keeping with SACN's terms of reference, only healthy term infants have been considered. This report forms part of a wider piece of work considering the scientific basis of current recommendations for feeding children up to 5 years of age.

S.4 Breastfeeding makes an important contribution to infant and lifelong health and is the physiological norm. Therefore, when considering evidence regarding the transition to infant formula and/or complementary feeding, the implications for breastfeeding must be considered and the potential benefits balanced against the risks.

Terms of reference

S.5 The terms of reference are defined below.

a) To review the scientific basis of current recommendations for complementary and young child feeding up to 5 years (60 months) of age. This report covers infants aged 0 to 12 months.
b) To consider evidence on developmental stages and other factors that influence eating behaviour and diversification of the diet in the early years.
c) To review the nutritional basis for current dietary recommendations applying to breastfeeding mothers (where relevant to the health of the infant).
d) To make recommendations for policy, practice and research.

Methodology

S.6 The SACN Framework for the Evaluation of Evidence (SACN, 2012) was used as the basis for considering appropriate evidence for inclusion in the review. Consideration of the evidence was primarily focussed on systematic reviews, prospective cohort studies and randomised controlled trials (RCTs) where available.

S.7 In parallel with SACN, the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) considered: a) the effects of early exposure to food antigens on the development of immune tolerance and b) exposure to food contaminants in breast milk, commercially available infant foods and other constituents of the infant diet.

S.8 Information on dietary patterns and nutritional status in infancy was derived from the 5-yearly Infant Feeding Surveys (IFS) (McAndrew et al, 2012), which provided a unique perspective on infant feeding practices in the UK over the period 1975-2010 and from the 2013 Diet and Nutrition Survey of Infants and Young Children (DNSIYC) (Lennox et al, 2013).

S.9 Key outcomes indicating the adequacy of nutrient intake in infancy were considered to be the rate of linear growth and weight gain, and biochemical and haematological measures of nutritional status. The effects of not breastfeeding on infant and maternal health outcomes were also considered. The Committee also considered how the infant's neurological and developmental progression during the first year of life influences the acceptance of foods other than breast milk (or infant formula).

S.10 The Committee noted and took account of a number of limitations associated with infant feeding studies. Principally these were: inconsistent characterisation of the frequency and consistency of exposure to breast milk; a paucity of RCTs; and often inadequate consideration of: the strength and complexity of socio-demographic confounding; the rapid pace of change in the diet during the first year of life; and, the marked variability between infants in their rate of development.

Conclusions

S.11 The main findings from this review of the evidence on feeding in the first year of life, upon which SACN has based its recommendations, are set out below. The report provides a detailed consideration of all the evidence considered by SACN.

Infant and complementary feeding in the UK

S.12 Successive UK IFS up to 2010 have shown increases in the proportion of women initiating breastfeeding, particularly since 2000. However, successive surveys have also shown that the proportion of women who discontinued breastfeeding before their infant was 6 weeks old had remained between 32% and 39% since 1995.

S.13 The proportion of women in the UK who breastfed exclusively to 6 months of age or who were still breastfeeding at 1 year remained very low in 2010 compared with other high income countries (HIC).

S.14 Surveillance data from the IFS indicate that there was a reduction in the proportion of infants receiving solid foods before 4 months of age between 2000 and 2010. This followed a change in advice from the UK health departments in 2003 to recommend exclusive breastfeeding for around the first 6 months of life. The previous policy recommendation was to exclusively breastfeed for the first 4 to 6 months of life.

S.15 In the UK, breastfeeding and age of introduction of solid foods are patterned by parental social and educational status, which may lead to confounding in their associations. This is also the case for the quality of the complementary diet. Parents of breastfed infants are more likely to follow complementary feeding guidance and other health and lifestyle guidance.

Breastfeeding

S.16 Breastfeeding makes an important contribution to infant and lifelong health and represents the physiological norm for early infant feeding. The available evidence indicates that breastfeeding exclusively for the first 6 months of life does not constrain infant energy intakes or weight gain. Breastfeeding has an important role in the development of the infant immune system through the provision of passive specific and non-specific immune factors. There is evidence that not breastfeeding is associated with a higher risk of infant hospital admission for infectious illness. There is evidence that not breastfeeding may also be associated with disadvantages for certain neurodevelopmental outcomes during childhood, as shown in one RCT and a range of observational studies, but residual confounding cannot be ruled out.

S.17 The available evidence indicates that breastfeeding is associated with improved maternal health: lower risk of breast cancer and endometriosis, and greater postpartum weight loss and lower body mass index (BMI) in the longer term. Breastfeeding is not associated with an increased risk of low bone mineral density or osteoporosis in later life.

Acceptance of solid foods

S.18 By around 6 months of age, infants are usually developmentally ready to actively accept foods other than breast milk (or infant formula). The available evidence indicates that the introduction of solid foods or infant formula before 6 months of age reduces the amount of breast milk consumed and is associated with greater risk of infectious illness in infants.

S.19 The existence of a 'critical window' for the acceptance of solid foods between 4 and 6 months is not supported by experimental evidence. Deferring the start of complementary feeding to around 6 months is not associated with later difficulty in accepting solid foods.

S.20 A range of evidence indicates that repeated exposure to new foods enhances their acceptance. Offering a variety of foods also helps to increase acceptance of new flavours by infants. A single trial reported that a 'baby-led weaning (BLW) approach' resulted in earlier self-feeding, less food fussiness and greater enjoyment of food (secondary outcomes self-reported by parents).

Growth and energy requirements

S.21 The estimated average requirements (EAR) for dietary energy for UK infants were derived using the WHO growth standards which describe the growth pattern of infants who were exclusively or predominantly breastfed for at least the first 4 months of life and breastfed for at least the first 12 months of life. In DNSIYC (2013), around 75% of the children (aged 4 to 18 months) surveyed had parent-reported intakes that exceeded the EAR for energy. The same proportion exceeded the WHO growth standard median for weight. These findings suggest that UK infants are exceeding their energy requirements. This is of concern in relation to wider evidence on the prevalence and risk of overweight and obesity in childhood.

S.22 Regarding the observed relationship between the age of first solid foods and later adiposity, most prospective studies have identified rapid early weight gain as a predictor rather than a consequence of the early introduction of solid foods.

Micronutrients

S.23 Iron status at birth is the most important determinant of iron status throughout infancy. Factors associated with lower iron status at birth include low infant birthweight, and maternal iron deficiency anaemia, obesity, smoking status and gestational hypertension. Delaying clamping of the umbilical cord until it has stopped pulsating is an effective intervention to increase iron status at birth.

S.24 Healthy term infants are born with sufficient body iron stores, which along with iron in breast milk, are sufficient to meet their needs for growth and development for the first 6 months of life. From around 6 months of age, a diverse complementary diet is needed to meet the increasing iron requirements of older infants. Breast milk (or infant formula) should be the main drink throughout the first year of life; the consumption of unmodified cows' milk as a main drink by infants younger than 12 months is associated with lower iron status.

S.25 Data from DNSIYC (2013) indicated that 6% of infants were at risk of vitamin D deficiency. SACN recommends a 'safe intake' of vitamin D (8.5-10µg/d) for all infants from birth (except for those consuming more than 500ml of infant formula a day), however data from both IFS (2010) and DNSIYC (2013) indicated that the proportion of infants receiving vitamin supplements was low (less than 14%).

S.26 Regarding vitamin A, data from DNSIYC (2013) indicated that no infant had intakes below the lower reference nutrient intake (LRNI) at age 4 to 11 months. However, COT concluded that there is potential for some infants to exceed the tolerable upper level (TUL) for vitamin A if "exclusively breastfed by mothers taking dietary supplements containing high levels of vitamin A" or if infants are "fed infant formula at the upper limit of the retinol content allowed by regulation, given high dose vitamin A supplements, or consume liver more than once per week".

Oral health

S.27 Breastfeeding during the first year of life has oral health benefits. The available evidence indicates that breastfeeding up to 12 months of age is associated with a decreased risk of dental caries and may offer protection when compared with infant formula feeding. However, some limited observational evidence suggests that once the primary teeth erupt, factors such as breastfeeding ad libitum, nocturnal feeding and sleeping with the breast in the mouth may be associated with an increased risk of dental caries. The one available systematic review with meta-analysis found that 'ever breastfed' children may be less likely to develop malocclusions[1] compared with 'never breastfed' children up to 12 years of age.

Risks of allergic and autoimmune diseases

S.28 There was insufficient evidence to indicate that breastfeeding influences the development of allergic or autoimmune diseases.

S.29 The available evidence indicates that the deliberate exclusion or delayed introduction of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods.

S.30 The available evidence indicates that allergenic foods such as peanut, hen's egg, gluten or fish can be introduced from around 6 months of age and need not be differentiated from other solid foods:

- there is insufficient evidence to demonstrate that the introduction of peanut or hen's egg into the infant diet before 6 months of age reduces the risk of developing food allergy to any greater extent than introduction from around 6 months of age

[1] Malocclusion describes the alignment of teeth which are considered not to be in a normal position in relation to adjacent teeth (that is, the teeth are not correctly aligned).

- there is high quality evidence that the timing of introduction of gluten is not associated with the risk of developing coeliac disease
- there is low to very low quality evidence that early fish introduction (before 6 to 12 months of age) was associated with reduced allergic rhinitis and sensitisation
- there is insufficient evidence for conclusions to be drawn on the effect of timing of introduction of other allergenic foods in relation to developing an allergy to that food.

S.31 There was no indication that avoidance or consumption of allergenic foods by mothers during pregnancy or lactation would help reduce allergic or autoimmune diseases in their children.

S.32 The available evidence does not support the use of extensively hydrolysed or partially hydrolysed protein formula to influence the risk of developing allergic or autoimmune disease.

S.33 There was little evidence that maternal and other infant dietary exposures increased children's future risk of developing allergic or autoimmune diseases.

Risks of chemical toxicity

S.34 COT assessed toxicity issues from the infant diet for a number of nutrients, substances and contaminants in breast milk, infant formula and solid foods. They concluded there were unlikely to be concerns over toxicity in the diet of infants for substances considered at current levels of exposure. Issues where COT has identified that there is potential concern are described in chapter 10.

Recommendations

Breastfeeding

S.35 The totality of the evidence reviewed for this report supports current guidance to breastfeed exclusively for around the first 6 months of an infant's life and to continue breastfeeding for at least the first year of life. Each makes an important contribution to infant and maternal health.

S.36 Given the rapid decline in the proportion of women breastfeeding over the first few weeks of an infant's life in the UK, greater focus should be given to:

- reducing attrition rates
- supporting women who make the informed choice to breastfeed.

S.37 Increasing the proportion of women who continue to breastfeed or express breast milk beyond 6 months of age would yield additional health benefits.

S.38 Infant formula (based on either cows' or goats' milk) is the only suitable alternative to breast milk for babies who are under 12 months of age. The use of soya-based formula should only be on medical advice and the possible health effects of soya-based formula should be kept under review.

Introduction of complementary feeding

S.39 Current advice on the age of introduction of complementary feeding should remain unchanged. That is, most infants should not start solid foods until around the age of 6 months, having achieved developmental readiness.

S.40 Breast milk, infant formula and water should be the only drinks offered after 6 months of age. Unmodified cows' milk should not be given as a main drink to infants under 12 months of age. This is because cows' milk consumption in infancy is associated with lower iron status as a result of gastrointestinal blood loss and because the iron content and bioavailability of cows' milk is low.

S.41 A wide range of solid foods, including iron-containing foods, should be introduced in an age-appropriate form[2] from around 6 months of age, alongside continued breastfeeding, at a time and in a manner to suit both the family and individual child.

S.42 Dietary, flavour and texture diversification should proceed incrementally throughout the complementary feeding period, taking into account the variability between infants in developmental attainment and the need to satisfy nutritional requirements. When introducing new foods it should be recognised that they may need to be presented to infants on many occasions before they are accepted, particularly as infants get older.

S.43 In view of the high intakes of salt (sodium chloride) and free sugars in this age group, there is a need to re-emphasise the risks associated with added salt and free sugars in foods given to infants during the complementary feeding period and to keep reported intakes under review.

S.44 Healthy infants do not require iron supplements. To optimise iron status throughout the first year of life, SACN and National Institute for Health and Care Excellence (NICE) recommendations on delayed cord clamping should be implemented and monitored.

S.45 All infants from birth to 1 year of age who are being exclusively or partially breastfed should be given a daily supplement containing 8.5 to 10µg of vitamin D (340-400 IU/d). Infants who are fed infant formula should not be given a vitamin D supplement unless they are consuming less than 500ml (about one pint) of infant formula a day, as infant formula is fortified with vitamin D.

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[2] Safety advice on the introduction of solid foods can be found on http://www.nhs.uk/conditions/pregnancy-and-baby/foods-to-avoid-baby/

S.46 The low prevalence of vitamin A deficiency in the healthy infant population, despite the current low uptake of supplements, suggests the need to review recommendations on routine vitamin A supplementation, particularly in light of the COT conclusion that there is the potential for some infants to exceed the TUL for vitamin A. It is recommended that government consider opportunities to review advice on supplements and foods containing vitamin A during infancy.

S.47 Advice on complementary feeding should state that foods containing peanut and hen's egg can be introduced from around 6 months of age and need not be differentiated from other solid foods. The deliberate exclusion of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods. Once introduced, and where tolerated, these foods should be part of an infant's usual diet, to suit both the individual child and family. If initial exposure is not continued as part of an infant's usual diet, then this may increase the risk of sensitisation and subsequent food allergy. Families of infants with a history of early-onset eczema or suspected food allergy may wish to seek medical advice before introducing these foods.

S.48 Government should keep the risk from lead, acrylamide and arsenic under review. Efforts to reduce the levels of inorganic arsenic in food and water, and levels of acrylamide in commercially-produced and home-cooked foods should continue.

S.49 Government should consider public health messages to help ensure that infants are fed an appropriate and diverse complementary feeding diet.

S.50 Government should consider ways to monitor the prevalence of overweight and overfeeding in infants, and ways to address high energy intakes in this age group.

S.51 Government should consider how to address gaps in the evidence on infant feeding practices, in the absence of national monitoring of current practice. This includes evidence gaps on the prevalence and duration of breastfeeding, use of nutritional supplements, and use of foods other than breast milk in infancy. The questions and definitions previously adopted in the 5-yearly IFS would allow tracking of secular trends and changes in practice consequent to new recommendations and guidance.

Research recommendations

S.52 Throughout the development of this report, SACN noted a number of limitations in the study design for some of the available research. Significant gaps in the evidence relating to infant and complementary feeding were also identified. The Committee has therefore made a number of recommendations for research which are set out in chapter 13.

1 Background

Introduction

1.1 There has been no comprehensive risk assessment of infant and young child feeding in the United Kingdom (UK) since the Committee on Medical Aspects of Food and Nutrition Policy (COMA) published its report ‘Weaning and the weaning diet’ in 1994 (DH, 1994).

1.2 A number of recommendations made by the Scientific Advisory Committee on Nutrition (SACN) and by international scientific advisory committees following the COMA 1994 review have carried implications for current UK infant feeding policy (for example from the World Health Organization [WHO], Food and Agriculture Organization [FAO], European Food Safety Authority [EFSA], and the Royal College of Paediatrics and Child Health [RCPCH]).

1.3 Accordingly SACN requested its Subgroup on Maternal and Child Nutrition (SMCN) to review recent developments in this area. To complement this work, the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) was asked by the Department of Health (DH) to conduct a review of the risks of toxicity from chemicals in the infant diet, and examine the evidence relating to the influence of the infant diet on development of allergic and autoimmune disease.

1.4 This report summarises and evaluates the available evidence on feeding infants in the first year of life to enable risk managers to make appropriate recommendations for the UK population. In particular, current advice to breastfeed exclusively for around the first 6 months of life and on the timing of introduction of complementary feeding to the infant diet is considered in the context of the variation in infant feeding practices. The health consequences for the mother associated with not breastfeeding are also considered in the context of changes in the prevalence and duration of breastfeeding in the UK.

1.5 Breastfeeding represents the physiological norm for early infant feeding. Historically the terms ‘weaning foods’ or ‘solids’ were commonly used to describe the foods introduced to infants alongside breast milk (or infant formula). ‘Weaning’ can be interpreted as the cessation of breastfeeding (or milk feeding). **Therefore, throughout this report the term ‘complementary feeding’ has been used to indicate that the purpose of introducing foods other than breast milk (or infant formula) is to complement the nutrients provided by breast milk (and/or infant formula) when breast milk (and/or infant formula) alone is not sufficient to meet the nutritional requirements of the growing infant.** The introduction of complementary feeding diversifies the infant diet whilst breastfeeding (and/or infant formula feeding) continues during the early years of life. In the UK literature ‘complementary feeding’ usually implies the solid food component of the infant diet but the WHO definition would include liquid complementary feeding such as infant formula (Kramer & Kakuma, 2002; PAHO, 2003).

Terms of reference

1.6 The terms of reference for the report are defined below.

a) To review the scientific basis of current recommendations for complementary and young child feeding up to 5 years (60 months) of age. This report covers infants aged 0 to 12 months of age.

b) To consider evidence on developmental stages and other factors that influence eating behaviour and diversification of the diet in the early years.

c) To review the nutritional basis for current dietary recommendations applying to breastfeeding mothers (where relevant to the health of the infant).

d) To make recommendations for policy, practice and research.

1.7 In keeping with SACN's terms of reference, this report is restricted to risk assessment and only healthy term infants have been considered. The report considers: infant feeding in relation to infant and maternal health; infant feeding, body composition and health outcomes; energy and micronutrient requirements during the first year of life; the eating and feeding of solid foods; and infant oral health. Risks of chemical toxicity arising from the infant diet and those relating to infant diet and the development of allergic and autoimmune diseases are also covered. In line with the SACN Framework for the Evaluation of Evidence (SACN, 2012), the report does not provide advice on how recommendations are taken forwards for policy, that is, risk management. The role of government, the health service, and non-governmental organisations in protecting, promoting and supporting breastfeeding fall under risk management and are therefore not in the scope of this report.

History of policy development

UK recommendations

1.8 Over the last fifty years there have been significant changes to UK infant feeding policy and practice. UK recommendations for breastfeeding and the introduction of complementary feeding since 1974 are summarised in Table A.1.

1.9 During the 1970s there was particular concern about excessive weight gain in infancy (Taitz, 1971; Shukla et al, 1972) and the high incidence of infantile hypernatraemic dehydration, either in an isolated form or associated with acute gastroenteritis (Taitz & Byers, 1972; Davies, 1973; Chambers & Steel, 1975). These conditions were linked to early use of cows' milk, errors in the reconstitution of infant formula, and early introduction of solid foods (Wilkinson et al, 1973), often within the first few weeks of life.

1.10 Accordingly, in 1974, a working party set up by COMA considered infant feeding practices and recommended breastfeeding for a minimum of 2 weeks and preferably for the first 4 to 6 months of life. It strongly discouraged the introduction of solid foods before 4 months of age and made recommendations about vitamin supplementation, highlighting the need for further research (DHSS, 1974).

1.11 Following these recommendations, the Department of Health and Social Security (DHSS) commissioned a nationally representative survey of infants born in England, Wales and Scotland in September and October 1975 (Martin, 1978). In 1980, a further sample of infants born in England, Wales and Scotland during August and September in 1980 were surveyed. These surveys showed that the percentage of infants who were breastfed (that is, ever put to the breast) increased from 51% in 1975 to 67% in 1980. Moreover, the proportion of infants receiving solid foods before 3 months of age fell from 85% to 55%.

1.12 A further working party endorsed the recommendations made by the previous report in relation to breastfeeding and advised that the introduction of complementary feeding should be no later than 6 months (DHSS, 1980). The working party also reviewed evidence on gluten sensitisation and stated that for the majority of infants there was no evidence that wheat-based cereals posed a risk. For the potentially allergic child, they advised that it is reasonable to avoid early introduction of foods that are commonly considered allergenic. As the child gets older, they recommended a greater diversity of foods could be cautiously introduced until an unrestricted diet is eventually achieved.

1.13 A third report of the working party on practices in infant feeding reaffirmed earlier recommendations and endorsed conclusions of the 1980 report in relation to vitamin supplementation and the introduction of allergenic foods (DHSS, 1988). In addition, the working party stated that a dietitian's expert advice was essential if dietary restriction was considered in relation to foods commonly considered allergenic.

1.14 In 1991, COMA convened a working group to review the scientific evidence in relation to nutritional adequacy of the weaning diet. While previous 'Present day practice' reports addressed the diet of infants in the first months after birth, 'Weaning and the weaning diet' (DH, 1994) included recommendations on when and what types of first foods to introduce and the progression of complementary feeding. The report endorsed breastfeeding for the first 4 to 6 months of life, followed by the introduction of non-wheat cereals, fruit, vegetables and potatoes as suitable first solid foods. It recommended delaying the introduction of potentially allergenic foods (for example, eggs, nuts and wheat) until 6 months at the earliest. Earlier recommendations on vitamin supplementation were revised to state that from the age of 6 months, infants receiving breast milk as their main drink, or less than 500ml/day of infant formula, should be given supplements of vitamins A, C and D.

1.15 In 1999, COMA undertook a review of the Welfare Food Scheme (DH, 2002). Based on recommendations made by COMA, the scheme (which had been in place since 1940) was changed in a number of respects and re-designated 'Healthy Start'. Healthy Start replaced the means-tested elements of the Welfare Food Scheme throughout the UK in 2006. Important aspects were the obligation for beneficiaries to register during pregnancy with a health professional (thus enabling nutrition counselling) and rebranding of the vitamin preparations as 'Healthy Start' vitamin supplements for young children and mothers. The range of foods offered was also widened through the introduction of exchangeable vouchers. Under previous arrangements, eligible beneficiaries received milk tokens to use at participating retailers, or received tins of infant formula at health clinics, while Healthy Start vouchers can be used at participating retailers towards the cost of plain cow's milk, infant formula suitable from birth, and fresh fruit and vegetables.

World Health Organization recommendations

1.16 In 1979, a joint meeting was held with participants from governments, non-governmental organisations, the United Nations system, the infant food industry and scientists to discuss recommendations for infant and child feeding. The outcome, published by the WHO and the United Nations International Children's Fund (UNICEF), was to recommend that fully breastfed infants should not need to be introduced to complementary feeding before around 4 to 6 months of age (WHO/UNICEF, 1980).

1.17 Since 2001, the WHO has recommended that mothers worldwide exclusively breastfeed infants for the first 6 months to achieve optimal growth, development and health (WHO, 2001). Thereafter they should be given nutritious solid foods as breastfeeding continues up to the age of 2 years or beyond. These guidelines were reiterated in the WHO's Global Strategy (WHO/UNICEF, 2003).

1.18 The WHO published guidelines in relation to infant and child feeding specifically for the European region in 2003 (WHO Europe, 2003). These recommended that all infants should be exclusively breastfed from birth to around 6 months of age, with complementary feeding introduced at about 6 months of age, acknowledging that some infants may need solid foods earlier, though not before 4 months of age. Recommendations about the type and consistency of first solid foods were also made.

1.19 In 2003 the WHO and Pan American Health Organization (PAHO) published guiding principles for complementary feeding of the breastfed child (PAHO, 2003). These were followed in 2004 by principles for complementary feeding of the non-breastfed child (WHO, 2005). Both reports recommended the introduction of solid foods at 6 months of age.

1.20 Following a systematic review of the scientific evidence, WHO published the most recent recommendations for complementary feeding (WHO, 2013). These do not differ from the

2003 and 2005 guidance. WHO recommendations for breastfeeding and the introduction of complementary feeding since 1980 are summarised in Table A.2.

UK policy on exclusive breastfeeding and infant feeding

1.21 In 2001, SACN endorsed the WHO's recommendation of exclusive breastfeeding for the first 6 months of an infant's life (see above). SACN advised:

> "That there is sufficient scientific evidence that exclusive breastfeeding for 6 months is nutritionally adequate. However the group[3] noted that early introduction of complementary foods is normal practice in the UK and that mothers do this for many valid personal, social and economic reasons."

SACN therefore recommended that there should be some flexibility in the advice, but that any complementary feeding should not be introduced before the end of 4 completed months (17 weeks).

1.22 Since 2003, it has been UK policy to recommend exclusive breastfeeding for around the first 6 months of life with continued breastfeeding alongside appropriate complementary feeding after that (DH, 2003; SACN/SMCN, 2003). Around 80% of UK infants are now at least initially breastfed (McAndrew et al, 2012). Data from the Infant Feeding Survey (IFS) 2010 show that following the change in infant feeding policy in 2003, there has been a 5-fold increase in the number of mothers introducing solid foods between 4 and 6 months compared with when the policy recommendation was 4 to 6 months exclusive breastfeeding, when a high percentage of mothers introduced complementary feeding before 4 months.

1.23 Existing guidance relating to dental caries prevention in under 3 year olds includes the bullet points below.

- From 6 months of age infants should be introduced to drinking from a non-valve free-flowing cup to enable children to learn the skill of sipping, which is important in the development of the muscles used for talking. From age one year onwards, feeding from a bottle should be discouraged.
- Sugars should not be added to solid foods or drinks.
- The frequency and amount of sugary food and drinks should be as low as possible: only plain milk or water should be provided between meals and offering baby juices or sugary drinks should be particularly discouraged at bedtime.

[3] The Ad hoc Expert Group on Child and Maternal Nutrition which was convened in December 2000 under the Chairmanship of Professor Alan Jackson in light of the WHO activity on the optimal duration of breastfeeding. The Ad hoc Group included members of the former COMA panel on Child and Maternal Nutrition.

1.24 Policy and advice on infant feeding in the UK is now largely devolved. In England, the issue falls under the remit of the Department of Health and Social Care and Public Health England (PHE); guidance is also available from the National Institute for Health and Care Excellence (NICE). In Scotland, the issue falls under the remit of the Scottish Government and Food Standards Scotland, while in Wales infant feeding policy and guidance is the responsibility of the Welsh Government, with the support of Public Health Wales (NHS Wales, 2014a; NHS Wales, 2014b; NHS Wales, 2015). In Northern Ireland, infant feeding policy and guidance is provided by the Department of Health, Northern Ireland and the Public Health Agency (NI Department of Health, 2013).

1.25 In England, Wales and Northern Ireland, it is the role of the Food Standards Agency (FSA) to protect public health from risks which may arise in connection with the consumption of food (including risks caused by the way in which it is produced or supplied) and otherwise to protect the interests of consumers in relation to food. In Scotland, this function is the remit of Food Standards Scotland.

2 Methodology

Key outcomes

2.1 The key outcomes considered in this report are:

- displacement of breast milk
- growth
- infectious illnesses
- micronutrient status
- the acceptance of new foods
- oral health
- food allergies and autoimmune diseases
- chemical toxicity.

2.2 Complementary feeding is required when breast milk (and/or infant formula) is no longer sufficient to meet the nutritional needs of the growing infant. The introduction of solid foods, in addition to breast milk, may reduce the amount of breast milk consumed, and this may be associated with a reduction in the quality and amount of an infant's total nutrient intake.

2.3 Infant growth is assessed by weight-for-age, length-for-age, weight-for-length, body mass index (BMI), and adiposity. Growth is a sensitive measure of nutrient supply (both deficiency and excess); there is also increasing understanding of the relationship between patterns of early growth and health risks in later life (SACN, 2011b). There is consensus that the pattern of growth associated with least risk of both current and long-term ill-health is that defined by the WHO Multicentre Growth Reference Study (WHO MGRS, 2006b), which the UK adopted in 2007 for the purpose of clinical and population growth monitoring (SACN/RCPCH, 2007). The current report thus regards achievement of the growth pattern described by the WHO Standard as a key indicator of health.

2.4 Infectious illnesses, particularly of the gastrointestinal and respiratory tracts, are leading causes of infant morbidity and mortality, including in the UK. Feeding practices in infancy have an important bearing on the risk of such illnesses.

2.5 Micronutrients play a vital role in metabolism and in the maintenance of tissue function. An adequate dietary intake, or in the case of vitamin D, adequate exposure of the skin to sunlight containing sufficient ultraviolet B (UVB) radiation, is therefore required. A diet that contains too little of one or more vitamins or minerals over a prolonged period, or when there is an inability to absorb sufficient amounts of these nutrients, results in nutrient deficiency. Likewise, inadequate skin exposure to UVB radiation leads to vitamin D deficiency. Poor micronutrient status negatively impacts health outcomes in both the short and the longer term.

2.6 The second half of infancy (6-12 months) in particular can be a challenging period nutritionally. Widening the range of foods accepted introduces considerations about the energy and nutrient density of the diet, its macronutrient balance, and the adequacy of micronutrient balance. Demands vary as the infant grows and levels of physical activity increase with the development of independent mobility. There may also be short-term variation in nutrient demands, for example, loss of appetite and subsequent catch-up growth associated with illness.

2.7 The acceptance of new foods is influenced by a number of biological and social factors. The nature of the relationship between the dependent child and the caregiver, which evolves during the early years of life, is a key determinant of the child's nutritional intake. What the child needs may not always match the caregiver's perceptions. The way in which food is offered or administered has to take account of the individual child's developmental progression which is particularly rapid in the first year. The way in which food is offered or administered, and the age at which foods are presented, may also modify acceptance and either help or hinder diversification of the diet, perhaps with long-term implications for eating behaviour.

2.8 Oral health is part of general health and wellbeing and contributes to the development of a healthy child. Tooth decay is the most common oral disease affecting children and yet it is largely preventable. Infant and complementary feeding practices are among the many factors influencing oral health in the first 12 months of life.

2.9 Allergy to food constituents is increasingly appreciated as a cause of ill-health in children and adults. In the UK, it is estimated that 6 to 8% of children have a proven food allergy (Rona et al, 2007). Increases in the prevalence of food allergy are reflected by a documented increase in hospital admission rates for very severe reactions (anaphylaxis); between 1998 and 2012, food anaphylaxis admission rates in the UK rose from 1.2 to 2.4/100,000 population (Turner et al, 2015). The origins of food allergy are unclear; a number of environmental factors may be operative, and it is speculated that the timing of exposure to food antigens in early life may modify the development of immune tolerance to food constituents.

2.10 Chemical contaminants or the risks of chemical toxicity may be a concern for infants. They have a proportionately high food intake per unit of body weight. This can expose them to relatively greater intakes of environmental food contaminants, notably some metals and persistent organic pollutants, than other age groups.

Eligibility criteria and literature search

2.11 A range of approaches were employed to identify literature for consideration, as outlined below. Ahead of public consultation on the report (July-September 2017), the cut-off date for inclusion of evidence was a publication date before 2016.

2.12 Key published systematic reviews, the Cochrane Review on 'Optimal Duration of Exclusive Breastfeeding' (Kramer & Kakuma, 2012) and the US Agency for Healthcare Research and Quality Evidence Report/Technology Assessment on 'Breastfeeding and Maternal and Infant Health Outcomes in Developed Countries' (Ip et al, 2007) represented important sources for the consideration of evidence on feeding in the first year of life and health outcomes. Additional systematic reviews were identified using PubMed and hand searches and are cited where relevant in this report.

2.13 Supplemental searches were conducted using PubMed to identify primary studies not included in key systematic reviews. Additional studies were identified by hand searches. Abstracts, conference proceedings and grey literature (such as round table reports) were excluded.

2.14 A separate literature search was undertaken to identify evidence on the influence of infant feeding practices on the development of early childhood caries and malocclusion. A search was conducted using Ovid MEDLINE to identify the most recent systematic reviews of relevance to the UK population and which included evidence judged to be of sufficient quality. Individual studies were also considered where systematic reviews were not available or did not fully address the questions posed.

2.15 Evaluation of the evidence was based on SACN's 'Framework for the Evaluation of Evidence' (SACN, 2012) which recognises the contribution of different study types in making an overall assessment. The evidence examined was mainly restricted to prospective cohort studies, and randomised controlled trials (RCTs) where these were available, but cross sectional studies and case reports were also considered where these informed interpretation of the evidence. The evidence considered derived from studies conducted in high income countries (HIC) unless otherwise stated. Only systematic reviews or primary studies published in the English language were reviewed.

2.16 COT was asked to examine the risks of toxicity from chemicals in the diet of infants and to consider whether current government advice should be revised. COT has published its findings and associated advice in a series of statements. Details of the approach taken and weblinks to the COT statements are provided in chapter 10.

2.17 The FSA commissioned a series of systematic reviews which represented key sources of evidence to inform consideration of the risks arising from the infant diet and development of allergic and autoimmune diseases. These reviews were evaluated by COT and their conclusions were published in accompanying COT statements. A joint SACN/COT working group was established to undertake a benefit-risk assessment on the timing of introduction of peanut and hen's egg into the infant diet and risk of developing allergy to these foods.

2.18 In addition to the literature searches outlined above, previously published SACN reports[4] of relevance were considered and searches were undertaken to update evidence that might have accrued since their publication. Two large national surveys informed the sections describing current infant feeding practice in the UK. These were the IFS 2010 (McAndrew et al, 2012) and the Diet and Nutrition Survey of Infants and Young Children (DNSIYC) aged 4 to 18 months (Lennox et al, 2013).

2.19 The draft report was made available for public consultation (July to September 2017). The comments received from interested parties were taken into consideration before the report was finalised. In addition, evidence highlighted through the consultation process or that had been published from the start of 2016 was considered by the committee. The report was amended where newly available evidence had an impact on the committee's overall conclusions. Studies that provided further corroborative evidence in support of the conclusions were not included.

Data extraction

2.20 Relevant data from each of the included studies were extracted into tables (see Annex C). This included: the name of the first author, year of publication, total number of participants, demographics, study design, outcome measures, confounders and study findings. Where available, definitions of exclusive breastfeeding and complementary feeding were also included.

Limitations of evidence

2.21 A number of limitations were identified in some of the available evidence and considered as part of the assessment of the evidence. These are briefly summarised below.

Appropriateness of RCTs

2.22 RCTs, if properly conducted and designed, provide the best evidence on the relationship between an exposure and health outcome (Horta & Victora, 2013). RCTs are designed to minimise the risk of confounding as participants differ only in the randomised treatment

[4] SACN reports on: Salt and health, 2003; Review of dietary advice on vitamin A, 2005; Iron and health, 2010; Dietary Reference Values for energy, 2011; The influence of maternal, fetal and child nutrition on the development of chronic disease in later life, 2011; Vitamin D and Health, 2016. Joint SACN/RCPCH report on: Application of WHO growth standards in the UK, 2007.

or exposure (SACN, 2012). A key aspect of this is blinding assessors and participants to their random allocation (a double blind trial). However, it is usually not possible to conduct double blind trials investigating infant feeding practices. Additionally, many consider it unethical to allocate healthy infants randomly to a dietary regimen other than exclusive breastfeeding for around the first 6 months of life. Accordingly there are relatively few RCTs in young infants (Cohen et al, 1994; Dewey et al, 1999; Wells et al, 2012) and existing studies were predominantly undertaken in low and middle income countries (LMIC) which may not be directly applicable to the UK population.

2.23 An alternative approach in this field has been to allocate parents to an intervention that may increase the prevalence of exclusive breastfeeding (from 0-6 months). A key example of this approach was the Promotion of Breastfeeding Intervention Trial (PROBIT) conducted in the Republic of Belarus in which cluster randomisation was applied to allocate over 17,000 mothers and their infants to a novel intervention (the UNICEF Baby Friendly Hospital Initiative) that might increase both the incidence and prevalence of breastfeeding (Kramer et al, 2001). The cohort arising from PROBIT has subsequently provided informative data on a range of breastfeeding-related outcomes, extending from infancy to later childhood.

Retrospective and prospective data collection

2.24 Due to the paucity of trial data in relation to infant feeding, it is necessary to use additional evidence from observational cohort studies. This type of evidence has limitations when used to infer causation. Data collection for these may be prospective or retrospective.

2.25 Patterns of feeding evolve rapidly in infancy and there is considerable variation between individuals, in keeping with the pace and nature of infant development. In this context, knowledge of the exact age at which individual participants first encountered exposures of interest is of considerable value. Retrospective collection of such data is unlikely to be accurate, particularly after intervals of months or years. Retrospective data collection may also be susceptible to recall bias due to the time lapse when obtaining feeding histories (Horta & Victora, 2013). Parents may be influenced in their reporting by their subsequent experience. Prospective data collection, sampling at frequent points during the early months of life (for example weekly or at least monthly) is more reliable.

2.26 Prospective data collection also assists in the detection of reverse causality, a common source of bias in infant feeding studies (Bauchner et al, 1986). For example, infants who are heavier and/or perceived as being hungrier may be introduced to foods other than breast milk earlier than their peers. This may be because they are perceived to be more demanding or less ‘satisfied’. In this example, potential associations between the subsequent development of obesity in such infants would be confounded in an analysis of incomplete retrospective data. Without accurate measurement of the infant’s size or assessment of appetite, links to early feeding could erroneously imply causality (Heinig et al, 1993; Kramer et al, 2001).

Measurement issues

2.27 Measurement of exposure is a significant problem for infant feeding research. This particularly relates to the definition of 'breastfeeding' and to measuring the age at which interventions of interest are made.

2.28 Both the duration and the degree of exclusivity of breastfeeding may vary considerably, even within the same population. Breast milk may be given alone for 6 months, on only one occasion, or be combined in varying amounts with infant formula and other foods. Participants following any of these patterns are sometimes described as 'ever breastfed' when data are reported. Outcomes in breastfed infants (and mothers who breastfeed) are, however, frequently dose-dependent and will not be adequately demonstrated unless the intensity of exposure is measured.

2.29 In order to address the inconsistencies and lack of precision in how breastfeeding and breast milk exposure are described, WHO recommend that the standardised definitions provided below should be applied for research and health survey purposes (WHO/UNICEF, 2003).

- 'Exclusive breastfeeding' indicates that the infant has received only breast milk (from the mother or a wet nurse), or expressed breast milk. No other liquid or solid foods have been given, though drops and syrups containing medicines, mineral supplements or vitamins, and oral rehydration solutions may be given.
- 'Predominant breastfeeding' indicates that breast milk is the main source of nutrition though other liquids (such as drinks, teas or oral rehydration solutions) may be given provided that they are not food-based.
- 'Full breastfeeding' is a term often used to describe groups of infants who individually are either exclusively or predominantly breastfed.
- 'Partial breastfeeding' or 'mixed feeding' describes the use of breast milk alongside other liquid or solid foods, for example infant formula or weaning foods.

2.30 However, even when standard definitions are used, consideration must be given to the research context in which data were collected. For example, demographic health surveys may describe the pattern of feeding recalled in the last 24-hours (WHO, 2003) while the UK IFS definition of 'exclusive breastfeeding' at all infant ages required nothing other than breast milk to have been given since birth (McAndrew et al, 2012).

Confounding

2.31 In many HIC, such as the UK, patterns of infant feeding are strongly confounded by socio-demographic factors, such as smoking, parental education, socio-economic status (SES) and family size (Ip et al, 2007; SACN, 2011b; Horta & Victora, 2013).

2.32 The extent to which confounding factors have been controlled for varies between studies and is an important consideration when judging the quality of evidence.

2.33 Breastfeeding mothers are more likely to be health-conscious and, therefore, also more likely to promote healthy habits to their children as they grow up, including promotion of physical activity and intellectual stimulation (Horta & Victora, 2013). Information on potential confounding factors should therefore be collected and taken into account in the analysis of study findings. This can be difficult, however, because individual socio-economic measures are unlikely to fully characterise SES. For example, in the Gateshead Millennium Study, 3 different markers of deprivation or educational level were all independently associated with breastfeeding initiation in a multivariate prediction model, when mutually adjusted (Parkinson et al, 2011). Thus, if only one of these measures was collected there would be residual confounding even after apparent adjustment for socio-economic group.

2.34 Sometimes it may be useful to consider studies which have examined the links between breast milk exposure and health outcomes in LMIC because socio-demographic determinants of breastfeeding in these settings are much less apparent or may even operate in the opposite direction to those encountered in the UK.

Outcomes

2.35 Where alternatives to breast milk are evaluated in trials, it may be unclear where outcomes directly reflect the intervention or indirectly reflect the lack of breast milk. For this reason it remains important that any trials of infant formula incorporate a breastfeeding reference group. Preferably this should be contemporaneously studied but, alternatively, reference data may be applied if recruiting a reference group is infeasible (DH, 1996).

Timing of introduction of complementary feeding to formula fed infants

2.36 Evidence on the timing of introduction of complementary feeding to exclusively formula fed or mixed fed infants is scarce. As a result, the deliberation of the long term health impacts associated with timing of introduction of solid foods for these groups is limited.

3 Infant feeding, growth and health

Assessing infant growth

3.1 The achievement of linear and ponderal growth rates compatible with both short and long-term health is a key aim of early life nutrition. For many years the National Centre for Health Statistics (NCHS) growth reference formed the principal international descriptor of growth outcomes until a number of criticisms were raised. The infant data used to compile NCHS charts were from the Fels Institute growth study (USA) that included low birthweight infants and over-represented multiple births (two or more infants born from one pregnancy). Infant measurements were taken at relatively infrequent intervals (birth, 1 month, 3 months, 9 months and 1 year) and the method of feeding was not specified.

World Health Organization Growth Standards

3.2 These criticisms led to the planning and implementation of the WHO MGRS which was conducted in 6 countries between 1997 and 2003. Longitudinal and cross-sectional data were used to develop new standards describing physiological growth for all children from birth to 5 years of age and establish the breastfed infant as the normative model for growth and development (WHO MGRS, 2006a; WHO MGRS, 2006b). These replace the previous WHO/NCHS growth reference.

3.3 The criteria applied to ensure that the infants recruited to the WHO MGRS were not affected by growth restriction in utero and were adequately fed during infancy are described below.

- All infants were born at term to healthy, non-smoking mothers who had been well throughout the pregnancy.
- Multiple births (two or more infants born from one pregnancy) were excluded.
- Infants were exclusively or predominantly breastfed for at least the first 4 months of life, were introduced to complementary feeding by around the age of 6 months (180 days) and continued partial breastfeeding up to at least 12 months.

3.4 The resulting growth standards (WHO MGRS, 2006b) describe the growth of a large international sample of healthy breastfed infants (with a mean age of 5.4 months at introduction of complementary feeding), thereby establishing this growth pattern as an international standard.

3.5 The growth standards have been incorporated into age-based charts for length, weight and BMI, which prescribe a growth outcome to be achieved in the pursuit of health. These charts are intended for use by parents, doctors and public health officials to monitor the growth of children and assess whether a child is too short, underweight, or overweight, for age (WHO MGRS, 2006a; WHO MGRS, 2006b).

UK/WHO growth charts

3.6 In 2006, SACN, in collaboration with the RCPCH, undertook a risk assessment of the new standards. SACN/RCPCH found that after 2 weeks of age the WHO MGRS data were comparable with measurements of early growth obtained in two UK cohorts. Differences were noted, however, between the birthweights of the MGRS and UK cohorts. These differences would have made the interpretation of weight changes from birth problematic. Accordingly it was recommended that the UK combine national data for birthweight from the existing UK 1990 dataset with WHO MGRS data from 2 weeks of age onwards (SACN/RCPCH, 2007).

3.7 The resulting UK/WHO charts prescribe the healthy growth pattern for all UK children aged 2 weeks to 4 years including those from ethnic minority groups, irrespective of whether they are breast or formula fed. Patterns of early life weight gain which deviate from these standards may have implications for future health (see Chapter 5).

Physiological development and infant feeding

3.8 Maturation of the gastrointestinal, renal and neurological systems influences the infant's ability to accept foods other than breast milk or infant formula (WHO/UNICEF, 1998).

Gastrointestinal function

3.9 During the first year of life, normal luminal digestion and mucosal absorption change considerably. Over the first 6 months of life, healthy infants develop the capacity to absorb sufficient amounts of macro- and micronutrients from solid foods provided that these foods are of adequate nutrient density and do not contain levels of other dietary constituents that interfere with absorption (WHO/UNICEF, 1998).

3.10 Following birth, the human intestine is rapidly colonised by microbes; factors including gestational age, mode of delivery, infant feeding, sanitation and antibiotic treatment are known to influence colonisation (Adlerberth & Wold, 2009; Marques et al, 2010). The intestinal microbiota of newborn infants is characterised by low diversity, which increases during infancy so that by about 2 years of age, the microbiota fully resembles that of an adult. Both habitual and acute dietary exposures have been shown to influence composition of the gut microbiota (Claesson et al, 2011; Claesson et al, 2012), and the health impact of these compositional changes remains under investigation.

3.11 Diet plays a major role in the development of the microbiota during infancy; breastfed infants are exposed to the human milk microbiome which has been reported to contain more than 700 species of bacteria (Cabrera-Rubio et al, 2012). Human milk also contains an abundance of complex oligosaccharides and other factors with prebiotic activity, stimulating the growth of beneficial bacteria such as Bifidobacteria (Zivkovic et al, 2011).

3.12 The intestinal microbiota plays important functional roles in a diverse range of processes including, for example, the development of immune tolerance, the nitrogen economy of the young infant, and endogenous production of vitamin K.

Renal function

3.13 The renal function of healthy term infants is well developed at birth and matures rapidly during the first 6 months (Guignard, 1982). The kidneys play an important regulatory role in maintaining fluid and electrolyte balance in the body and are the primary route for elimination of potentially toxic metabolic waste products such as urea.

3.14 Urea is one of the main end products of protein metabolism. When proteins are metabolised they are first broken down into their constituent amino acids in the gastrointestinal tract, absorbed into the blood stream, and finally used to synthesis new proteins. The amino acids that are not used for the synthesis of proteins and other biological substances are oxidized by the body as an alternative source of energy, yielding urea and carbon dioxide.

3.15 Urea can be hydrolysed by the microbiome for the synthesis of amino acids to help meet the needs of the infant. Both essential and non-essential amino acids are formed by the microbiome and are available to the infant, contributing to the effective ‘intake’. The amounts made available through these processes may be substantial. In breastfed infants their contribution may exceed 50% of the dietary intake of amino acids during the early months of life, making an important contribution to the nitrogen economy of the young infant (Jackson, 1994; Steinbrecher et al, 1996; Millward et al, 2000; Jackson et al, 2004).

3.16 Historically there has been concern about the safe maximum protein and electrolyte content of some breast milk substitutes such as energy-dense infant formulas. The protein and electrolyte content of infant formula is greater than that of human milk and this increases the renal solute load presented to the kidney for excretion (Fomon & Ziegler, 1999). Moreover, reconstitution of commercially available powdered infant formula is frequently inaccurate with a tendency to over concentrate feeds and this further increases energy density and renal solute load (Renfrew et al, 2003). As a result, the amount of water required to eliminate urea generated by amino acid oxidation is further increased in formula fed infants and depends upon the effective partitioning of urea nitrogen between urinary excretion and salvage through the metabolic activity of the colonic microbiome (Waterlow, 1999).

Neurological development

3.17 During the first year of life there is rapid neurological maturation accompanied by an increase in brain size and the number of synaptic connections. The brain doubles in overall size though there is considerable variation in the rate of regional growth. For example, cerebellar volume increases by 240% and cerebral grey matter by 149% but white matter by only 11% (Knickmeyer et al, 2008). An adequately balanced supply of nutrients is essential to support this ordered process.

3.18 Coordinated, synchronous development of social, speech and language, visual or fine motor and gross motor functioning is essential to the gradual achievement of independent feeding. Progress is usually measured by the achievement of 'milestones' (Phatak & Phatak, 1991; Wijnhoven et al, 2004), the average ages at which particular skills become apparent. Within populations there is considerable inter-individual variation in the attainment of skills. Moreover, between population differences may arise from cultural variations in infant feeding practices, for example, in the timing of when finger foods are offered (Wright et al, 2011).

3.19 Gross motor milestones key to independent feeding include 'sitting up without support' and 'crawling on hands and knees'. In the WHO Motor Development Study, part of the WHO MGRS, the average ages at which children sat without support and crawled were 5.9 months and 8.3 months respectively (de Onis et al, 2006) but 95% confidence intervals for each were very wide: sitting without support, 3.8-9.2 months; crawling 5.2-13.5 months. This emphasises a need for responsiveness to the individual infant's developmental pace when interpreting population guidance.

3.20 Certain feeding reflexes facilitate the acceptance of solid foods. The process by which infants ingest and process foods can be described using 4 types of age-related behaviours: suckling, sucking, munching and chewing. Whilst suckling and sucking are innate, munching and chewing appear to be learned as a result of exposure to different textured foods introduced once the infant is developmentally ready. Early munching can occur at around 4 to 7 months, with movement of the gag reflex from mid to posterior third of the tongue. Chewing develops from 7 months, typically from tip and groove of the tongue to move food across the mouth as well as up (WHO/UNICEF, 1998). Mastication efficiency gradually increases through the first few years of life and is initially (at about 6 to 8 months) greater for softer than harder foods (Le Reverend et al, 2014).

3.21 Half the infants in a UK cohort were reported by parents to be reaching for food and beginning to eat 'finger foods' by 6 months of age; 20% reached out for food as early as 4 to 5 months and only 6% had not done so by 8 months. Generally infants whose development was most advanced in other fields also reached for food earlier (Wright et al, 2011). This behaviour may also be affected by cultural background and the type of food offered (Carruth & Skinner, 2002; Carruth et al, 2004b; Hetzner et al, 2009; Khan et al, 2009).

Breastfeeding and infant health

3.22 One of the difficulties encountered in evaluating the contribution of breastfeeding to infant health is that foods, liquids or nutrients may be given to the infant in addition to breast milk. This may reduce the amount of breast milk consumed as well as increasing the risk of contamination.

Breastfeeding and infectious illness in the infant

3.23 The healthy neonate is born with an immature immune system that develops over several years (Gasparoni et al, 2003; Remington & Klein, 2006). In this context, breastfeeding provides infants and young children with passive specific immune protection and bears positively upon the development of immunological defence and antigenic tolerance (Grimshaw et al, 2017).

3.24 Respiratory and gastrointestinal tract infections and acute otitis media (AOM) are important causes of morbidity in infancy (Yuan et al, 2001). For example, in England in 2015/16 there were 38,566 emergency hospital admissions for respiratory tract infections in infants under 12 months (a rate of 582 per 10,000 infants under 1 year) and 10,098 admissions for gastroenteritis (a rate of 152 per 10,000) (PHE, 2017)[5].

3.25 The U.S. Department of Health and Human Services Office on Women's Health has compiled evidence from systematic reviews/meta-analyses, randomised and non-randomised comparative trials, prospective cohort and case-control studies quantifying the effects of breastfeeding on short and long term infant and maternal health outcomes in HIC (Ip et al, 2007).

3.26 For AOM, pooled data from 5 cohort studies of good and moderate methodological quality comparing breastfeeding to not breastfeeding, showed a significant reduction in risk of AOM associated with breastfeeding (odds ratio [OR] 0.60; 95% confidence interval [CI] 0.46 to 0.78). Comparing ever breastfed with never breastfed, the pooled OR of AOM was 0.77 (95% CI 0.64 to 0.91). Comparing exclusive breastfeeding for more than 3 or 6 months with never breastfeeding, the pooled OR was 0.50 (95% CI 0.36 to 0.70) (Ip et al, 2007).

3.27 Ip et al identified one systematic review with meta-analysis (Chien & Howie, 2001) that explored the relationship between breastfeeding and the development of gastrointestinal infections in children under one year of age living in HIC. It was considered of fair methodological quality. Sixteen studies from HIC met the inclusion criteria set by Chien and Howie: 12 prospective cohort studies, 2 retrospective cohort studies and 2 case-control studies. The authors defined gastrointestinal infection as "any illness associated with

[5] Further information on the health of children aged 0-5 years, including key early years indicators and breastfeeding indicators, is available on PHE's Public Health Profiles (Fingertips): https://fingertips.phe.org.uk

vomiting, change in consistency or frequency of stools, or isolation of a known enteropathogenic bacterial or viral agent". Subjects were split into two groups for the final data analysis, 1) exclusive breastfeeding and partial/mixed feeding, and 2) no breastfeeding (Chien & Howie, 2001).

3.28 Of the 16 studies included in the review by Chien and Howie, 5 found a significant increased risk of gastrointestinal infection in infants who were not breastfed. Most studies, however, had methodological weaknesses, such as not adequately controlling for potential confounding factors and not having clear definitions for infant feeding practices and infectious outcomes (see Methodology chapter 2) (Chien & Howie, 2001).

3.29 Evidence from 3 studies that controlled for potential confounders suggested that breastfeeding was associated with a reduction in non-specific gastrointestinal infection during the first year of life in infants in HIC (Fergusson et al, 1978; Eaton-Evans & Dugdale, 1987; Howie et al, 1990).

3.30 Ip et al also identified a meta-analysis comparing risk of hospitalisation for lower respiratory tract disease (LRTD) in healthy term infants who were breastfed with those who were not (Bachrach et al, 2003). LRTD was defined to include bronchiolitis, asthma, bronchitis, pneumonia, empyema and infections due to specific agents (for example, respiratory syncytial virus). Ip et al rated the methodological quality of the meta-analysis as grade A/good (Ip et al, 2007).

3.31 Bachrach et al considered evidence from primary studies published between 1981 and 2001, and identified 7 cohort (5 prospective and 2 retrospective) studies assessing the relationship between breastfeeding and hospitalisation risk secondary to respiratory disease, which met their inclusion criteria (Bachrach et al, 2003). These were pooled for meta-analysis and summary relative risk (RR) ratios reported.

3.32 Using a random effects model, infants exclusively breastfed for 4 or more months were significantly less likely to be hospitalised as a consequence of respiratory disease than those not breastfed (RR 0.28; 95% CI 0.14 to 0.54). This finding remained statistically significant after adjusting for potential confounders (SES and smoking). Infants not breastfed were 3.6 times more likely to be hospitalised compared with those exclusively breastfed for a minimum of 4 months. For every 26 infants exclusively breastfed for 4 months or more, one hospital episode secondary to respiratory disease could be prevented (Bachrach et al, 2003; Ip et al, 2007).

3.33 Since publication of the Ip et al review, the relationship between breastfeeding and risk of hospitalisation for diarrhoeal and respiratory infection in the first 8 months of life has been investigated in 15,980 healthy term infants in the UK Millennium Cohort Study (Quigley et al, 2007; Quigley et al, 2009). The main outcome measures were parental reports of hospitalisation for diarrhoea (defined as 'gastroenteritis') and lower respiratory tract infection (LRTI) (defined as 'chest infection or pneumonia').

3.34 In the UK Millennium Cohort Study (Quigley et al, 2007; Quigley et al, 2009), information on infant feeding obtained through parental interview was categorised by type of milk received in the previous month (not breastfed, partially breastfed, or exclusively breastfed). Breastfeeding duration and the age at introduction of other types of milk and solid foods was stratified by one month age bands to estimate monthly risk of hospitalisation according to whether the infant had received solid foods in that month and the type of milk received in that month. The impact of age at introduction of solid foods on risk of hospitalisation in the presence of different milk feeding patterns was also investigated. Adjustment was made for a range of potential confounding factors (see Table C.3 for details).

3.35 Infants who drank only breast milk had a significantly lower risk of hospitalisation for both diarrhoea (OR 0.37; 95% CI 0.18 to 0.78) and LRTI (OR 0.66; 95% CI 0.47 to 0.92) compared with those not breastfed at all in the preceding month (Quigley et al, 2007).

3.36 Quigley et al estimated that if, in a west European context, all infants were exclusively breastfed, 53% of diarrhoea hospitalisations could be prevented and 31% could be prevented by partial breastfeeding (Quigley et al, 2007). Likewise for LRTI, 27% of hospitalisations could be prevented with each month of exclusive breastfeeding, and 25% by partial breastfeeding.

3.37 In a similar prospective cohort study conducted in Spain (Paricio-Talayero et al, 2006), 1,385 infants were followed from birth to 1 year of age to measure the association between not breastfeeding and hospital admission as a result of respiratory tract and gastrointestinal tract infections. Data on the incidence and duration of full breastfeeding (defined as exclusive or almost exclusive) were collected by maternal interview at discharge after delivery and at 3, 4 and 6 months of age. The main outcome measure was hospital admission resulting from non-perinatal infection during the first year of life according to hospital records.

3.38 After adjustment for potential confounding variables, Paricio-Talayero et al found that infants who were not breastfed were at significantly greater risk of hospitalisation for infections. When compared with infants fully breastfed for 4 or more months the risk of hospital admission for infection in the first year of life was 5 times higher (hazard ratio [HR] 4.91; 95% CI 2.41 to 9.99) among never breastfed infants and over 2 times higher (HR 2.45; 95% CI 1.28 to 4.66) among those fully breastfed up to 4 months. It was estimated that every additional month of full breastfeeding would prevent 30% of hospital admissions due to infections among those who had not received full breastfeeding; if the whole infant population were fully breastfed for 4 or more months 56% (95% CI 30.9 to 69.4%) of hospital admissions in infants under 1 year could be prevented (Paricio-Talayero et al, 2006).

3.39 The Southampton Women's Survey (SWS), a prospective UK birth cohort study, assessed the relationship between the duration of any breastfeeding (including mixed feeding; breast milk alongside infant formula and other food and drinks) and the prevalence of LRTI, ear infections and gastrointestinal morbidity during the first year of life (Fisk et al, 2011). One thousand seven hundred and sixty four infants born to SWS participants were followed up at 6 and 12 months of age by trained research nurses. At both visits, a detailed history of milk feeding was obtained along with data on whether the infant had suffered symptoms of the infectious diseases under investigation and whether a doctor had diagnosed the infant as having a chest infection, bronchitis, bronchiolitis, pneumonia or an ear infection. Data were collected at 6 months on the age at which solid foods were first regularly introduced.

3.40 Fisk et al reported that there were graded decreases in the prevalence of respiratory and gastrointestinal symptoms over the first 6 months of life among infants who breastfed for longer (Fisk et al, 2011). This dose-dependent relationship persisted after adjustment for a number of potential confounders (including maternal age, smoking in pregnancy and age at which solid foods were first regularly introduced). For infants breastfed for 6 months or more, compared with those who were never breastfed, the relative risks for general respiratory morbidity, diarrhoea and vomiting were 0.72 (95% CI 0.58 to 0.89), 0.43 (95% CI 0.03 to 0.61) and 0.60 (95% CI 0.39 to 0.92), respectively. In the second half of infancy, the inverse relationship between breastfeeding duration and diagnosed respiratory infections and gastrointestinal morbidity remained but was weaker. No significant dose-dependent association between breastfeeding duration and risk of diagnosed ear infections was observed in either the first or second 6 months of infancy (Fisk et al, 2011).

Introduction of solid foods or infant formula before 6 months of age

3.41 An extensive systematic review by Kramer and Kakuma assessed the effects of exclusive breastfeeding for 6 months compared with exclusive breastfeeding for 3-4 months followed by introduction of complementary liquids (for example, infant formula) or solid foods with continued breastfeeding until at least 6 months of age (Kramer & Kakuma, 2002). A number of infant and maternal health outcomes were studied. The review included 16 independent studies: 7 were conducted in LMIC (2 of which were controlled trials) and 9 in HIC. The authors reported that neither the trials nor the observational studies suggested that exclusive breastfeeding for 6 months was associated with deficits in weight or length gain. Exclusive breastfeeding for 6 months was associated with a significantly reduced risk of one or more episode of gastrointestinal infection in the infants as well as with a more rapid postpartum weight loss in the mother. However, exclusive breastfeeding for 6 months was not associated with a reduced risk of atopic eczema, asthma, or other atopic outcomes (Kramer & Kakuma, 2002).

3.42 An update to the review by Kramer and Kakuma (2002) was published in 2012 (Kramer & Kakuma, 2012). This updated review included 7 new independent studies (4 from LMIC and 3 from HIC) and data from 2 independent studies were updated (both from HIC). In total, 23 independent studies were included in this updated review: 11 were conducted in LMIC (2 of which were controlled trials) and 12 in HIC. The authors' conclusions remained unchanged:

exclusive breastfeeding during the first 6 months of life, as opposed to the first 4 with mixed feeding thereafter, does not adversely affect infant growth and it is advantageous for infant health. In particular, exclusive breastfeeding for 6 months or more is associated with a significantly reduced risk of gastrointestinal and respiratory infection (Kramer & Kakuma, 2012).

3.43 Data from a cluster randomised trial in Belarus (Kramer et al, 2001) showed that infants exclusively breastfed for the first 6 months were at lower risk of gastrointestinal infection in the first year of life (RR 0.67; 95% CI 0.46 to 0.97) than those mixed fed from 4 months (Kramer & Kakuma, 2012). Similar observations were made in a Nigerian prospective cohort study (Onayade et al, 2004): infants exclusively breastfed during the first 6 months experienced less morbidity from gastrointestinal infection than those exclusively breastfed for 3-4 months and mixed fed thereafter. An Iranian prospective cohort study (Khadivzadeh & Parsai, 2004) observed that infants mixed fed after 4 months were at greater risk of both gastrointestinal and respiratory infection between 4 and 6 months of age than their exclusively breastfed counterparts.

3.44 Quigley et al (2009) examined the independent effects of solid foods and breastfeeding on the risk of hospitalisation for infection in term, singleton infants in the Millennium Cohort Study (n=15,980). Information on first solid foods and hospitalisation was collected via retrospective interview at age 8 months: the mean age of introduction of solid foods was 3.8 months; 1.1% of the infants were hospitalised in the first 8 months for diarrhoea and 3.2% for LRTI. As described in paragraphs 3.33 to 3.36 (Quigley et al, 2007), the monthly risk of hospitalisation for diarrhoea and LRTI was significantly lower in exclusively breastfed infants compared with those receiving infant formula but, after adjustment for breastfeeding and other confounders, the risk was not significantly higher in those who had received solid foods before age 6 months compared with those who had not (for diarrhoea, OR 1.39; 95% CI 0.75 to 2.59; for LRTI, OR 1.14; 95% CI 0.76 to 1.70). However, the number hospitalised was low and there was little variability in age at first solid foods (Quigley et al, 2009).

3.45 Wright et al (2004) also examined the independent effects of solid foods in the Gateshead Millennium Study. Term infants born in 1999 and 2000 in a defined geographical area were studied prospectively and 707 parents (77%) replied to a questionnaire at age 4 months, which included questions about feeding and minor ailments. At this age, 94% of infants had already started solid foods while 21% had started before 3 months (Wright et al, 2004).

3.46 In contrast to the findings from Quigley et al (2009), Wright et al observed a graded association between earlier age of first solid foods and a greater number of reported episodes of diarrhoea and GP consultations. After adjustment for other significant predictors, including duration of breastfeeding, the increased risk of diarrhoea associated with the introduction of solid foods before 3 months of age compared with after 4 months of age remained significant (OR 1.65; p=0.02) but the association with GP consultations did not (OR 1.32; p=0.1). There was no association with other minor infections (Wright et al, 2004).

3.47 Most studies considering the effects of breastfeeding compared with other milk or solid feeding on the risk of infectious illness have not distinguished between complementary solid feeding and infant formula. There is therefore little evidence beyond the two studies highlighted above (Wright et al, 2004; Quigley et al, 2009) to inform the question of whether solid foods, consumed alongside breast milk or infant formula, increase the risk of infection.

Continued breastfeeding following introduction of complementary feeding

3.48 A systematic review by Sankar et al identified 8 cohort studies and 2 case control studies, all from LMIC, reporting all-cause mortality associated with not breastfeeding after the age of 6 months (Sankar et al, 2015). Relative risk of mortality among infants and children who were not breastfed, compared with those receiving any breast milk, was 1.76 (95% CI 1.28 to 2.41) between 6 and 12 months of age. No studies from HIC were identified.

3.49 An analysis of UK Millennium Cohort Study data on hospitalisation for diarrhoeal disease or lower respiratory infection before 8 months of age showed that breastfed infants were at significantly lower risk than those not breastfed even after the introduction of non-milk foods (Quigley et al, 2009).

3.50 A meta-analysis of 12 cohort studies showed that the risk of AOM in the first 2 years of life was significantly lower in infants breastfed for longer periods (OR 0.67; 95% CI 0.59 to 0.76). After the age of 2 years there was no effect (Bowatte et al, 2015).

Breastfeeding and neurodevelopmental outcomes

3.51 The relationship between breastfeeding and/or infant formula feeding and different aspects of cognitive function in later life has been reported in many studies from HIC.

3.52 Patterns of infant feeding in the UK and other HIC are strongly determined by demographic variables including social class and mother's educational attainment (Ip et al, 2007; SACN, 2011b; Horta & Victora, 2013). Observed relationships between infant feeding method and cognitive development might therefore be explained by the confounding effects of related factors, such as differences in the quality of the home environment (Bradley & Corwyn, 2002; Hackman & Farah, 2009), and maternal factors including intelligence quotient (IQ) and responsiveness (Der et al, 2006; Jacobson et al, 2014). However, the associations with breastfeeding are also seen in populations where patterns of confounding influences differ (Brion et al, 2011). Brion et al developed a standardised approach to compare a cohort from a HIC (the Avon Longitudinal Study of Pregnancy and Childhood [ALSPAC], UK) with a cohort from a LMIC (the 1993 Pelotas cohort, Brazil). They reported that breastfeeding was positively associated with performance in intelligence tests in both the Pelotas and the

ALSPAC birth cohorts. While breastfeeding was positively associated with family income in ALSPAC, it was inversely associated in the Pelotas cohort, suggesting that breastfeeding may have causal effects on IQ (Brion et al, 2011).

3.53 In 2013, Horta and Victora published a systematic review on the long-term effects of breastfeeding, including performance in intelligence tests. A meta-analysis of 13 observational studies (providing 14 estimates) suggested that breastfeeding (defined as ever versus never or by duration) was associated with higher performance in intelligence tests in childhood and adolescence, by an average of 3.45 IQ points (95% CI 1.92 to 4.98 IQ points). In studies that controlled for maternal intelligence, the difference was 2.19 IQ points (95% CI 0.89 to 3.50 IQ points) (Horta & Victora, 2013).

3.54 An updated systematic review with meta-analysis on the association between breastfeeding and performance in intelligence tests by Horta et al (2015) included 17 studies and reported 18 estimates of an association between breastfeeding (ever versus never or by duration) and performance in intelligence tests. It found that for children who had been breastfed there was an average difference of 3.44 (95% CI 2.30 to 4.58) IQ points. The difference remained, although attenuated, in studies controlling for maternal IQ (mean difference 2.62 (95% CI 1.25 to 3.98) IQ points (Horta et al, 2015).

3.55 This positive finding is supported by data from a cluster randomised trial of breastfeeding promotion. Kramer et al (2008) assessed children's cognitive ability (Wechsler Abbreviated Scales of Intelligence) at 6.5 years of age. Children in the breastfeeding promotion group had higher means on all of the Wechsler Abbreviated Scales of Intelligence, which was significant for verbal IQ with a cluster-adjusted mean difference of +7.5 (95% CI +0.8 to +14.3). The differences for performance IQ or for full scale IQ were not significant (Kramer et al, 2008).

Breastfeeding and maternal health

Maternal BMI

3.56 Analysis of pooled data from two Honduran randomised trials (Cohen et al, 1994; Dewey et al, 1999) showed that mothers who breastfed exclusively during the first 6 months lost more weight postpartum than those who introduced other foods after 4 months (mean difference 0.42kg; 95% CI 0.33 to 1.03kg).

3.57 The impact of breastfeeding on British women's later BMI has been investigated by the Million Women Study, a prospective study of 740,628 women aged 50 to 64 years attending the NHS breast screening programme (Bobrow et al, 2013). Data on duration but not exclusivity of breastfeeding were collected by questionnaire. Among parous women, 70% had ever breastfed with a mean total duration of 7.7 ± 8.8 months. Post-menopausal BMI was significantly correlated with both parity (mean BMI increased progressively with number of births) and with breastfeeding. At each level of parity, mean BMI was significantly lower ($p<0.0001$) for women who had breastfed compared with those who had not; mean BMI decreased by 0.22kg/m^2 for every 6 months breastfeeding.

Breast cancer

3.58 Individual data from more than 147,000 women from 47 epidemiological studies conducted in both LMIC and HIC, including the UK, were analysed to estimate the relative risk for breast cancer associated with breastfeeding (Collaborative Group on Hormonal Factors in Breast Cancer, 2002). This collaborative reanalysis reported that women with breast cancer had had fewer pregnancies than controls (2.2 versus 2.6) and a greater proportion were nulliparous (16% versus 14%), were less likely to have ever breastfed (71% versus 79%), and had a shorter average lifetime duration of breastfeeding (9.8 versus 15.6 months). The relative risk of breast cancer decreased by 4.3% (95% CI 2.9 to 5.8%; $p<0.0001$) for every 12 months of breastfeeding in addition to a decrease of 7.0% (95% CI 5.0 to 9.0%; $p<0.0001$) for each birth. The authors concluded that "the lack of or short lifetime duration of breastfeeding typical of women in developed countries makes a major contribution to the high incidence of breast cancer in these countries" (Collaborative Group on Hormonal Factors in Breast Cancer, 2002).

3.59 The European Code against Cancer programme (4th Edition) (ECaC) similarly estimated that there is a 2% reduction in breast cancer risk for every additional 5 months of breastfeeding during a mother's lifetime (Scoccianti et al, 2015). ECaC also ranked (from highest to lowest) 30 HIC by proportion of children ever breastfed; the UK was placed twenty-fifth.

Bone health

3.60 In 2011, the US Institute of Medicine (IOM) Committee was tasked with assessing the newly available data on vitamin D and calcium and updating, where appropriate, the dietary reference intakes for these nutrients. The following paragraphs are based on findings from the IOM (IOM, 2011) and from a review by Olausson et al (Olausson et al, 2012).

3.61 Breast milk calcium content is homeostatically regulated, and maternal calcium intake does not alter breast milk calcium content (Olausson et al, 2012). The calcium demands of lactation are met by physiological changes including upregulation of maternal bone resorption (Olausson et al, 2012) so that most of the calcium in milk derives from the maternal skeleton. Maternal bone mineral density (BMD) can decline by 5% to 10% during the first 6 months of exclusive breastfeeding but normally returns to baseline in the 6 to 12 months following the introduction of solid foods when the infant is around 6 months of age (Kalkwarf, 1999; Olausson et al, 2012). Therefore, a history of lactation does not appear to increase risk of low BMD or osteoporosis in later life (Olausson et al, 2012).

3.62 Analysis using National Health and Nutrition Examination Survey (NHANES) III data compared BMD from dual-energy X-ray absorptiometry (DEXA) measures in 819 women ages 20 to 25 years (Chantry et al, 2004), and found that young women who had breastfed as adolescents had higher BMD than those who had not breastfed, even after controlling for obstetric variables.

Endometriosis

3.63 A prospective cohort study of 72,394 women investigated the association between lifetime breastfeeding, exclusive breastfeeding, postpartum amenorrhea, and incidence of endometriosis, among parous women (Farland et al, 2017). The study found that duration of total and exclusive breastfeeding was associated with a significantly decreased risk of endometriosis. For every additional 3 months of total breastfeeding, women experienced an 8% lower risk of endometriosis (HR 0.92; 95% CI 0.90 to 0.94; $p<0.001$ for trend) and 14% lower risk with every additional 3 months exclusive breastfeeding per pregnancy (HR 0.86; 95% CI 0.81 to 0.90; $p<0.001$ for trend). Women who breastfed for a total of more than 36 months across their reproductive lifetime had a 40% reduced risk of endometriosis compared with women who never breastfed (HR 0.60; 95% CI 0.50 to 0.72). The findings of this study suggest that any breastfeeding, and especially exclusive breastfeeding, is associated with a lower risk of endometriosis.

Conclusions

3.64 By around 6 months of age, infants are usually developmentally ready to actively accept solid foods. There is, however, wide variation between individuals in the age at which fine and gross motor skills are attained as well as varying expectations between cultures.

3.65 The WHO growth standards (2006) describe the linear and ponderal growth pattern of infants exclusively or predominantly breastfed for at least the first 4 months of life and breastfed for at least the first 12 months of life. They describe a pattern of growth to be attained by all infants whether or not breastfed.

3.66 Breastfeeding has an important role in the development of the infant immune system through the provision of passive specific and non-specific immune factors. There is evidence that not breastfeeding is associated with a higher risk of infant hospital admission as a consequence of gastrointestinal or respiratory illness even in HIC such as the UK.

3.67 The introduction of solid foods or infant formula before 6 months of age is associated with greater risk of gastrointestinal, and lower and upper respiratory infections than continuing to breastfeed exclusively.

3.68 There is evidence that not breastfeeding may be associated with disadvantages for certain neurodevelopmental outcomes during childhood, as shown in one large RCT and a range of observational studies, but residual confounding cannot be ruled out.

3.69 The available evidence indicates that breastfeeding is associated with improved maternal health. Women who breastfeed for longer are at lower risk of breast cancer and endometriosis. Breastfeeding is not associated with an increased risk of low BMD or osteoporosis in later life.

3.70 Exclusive breastfeeding is associated with greater postpartum weight loss, and the duration of any breastfeeding is associated with lower maternal BMI in the longer term.

3.71 Once solid foods have been introduced at around 6 months, continued breastfeeding alongside solid foods for at least the first year of life is also associated with improved infant and maternal health.

4 Energy requirements

Dietary reference values for energy

4.1 In 2011, SACN published revised dietary reference values (DRVs) for energy, which replaced the previous DRVs for energy set by COMA in 1991 (DH, 1991). For dietary energy, DRVs are set at the average reference value, the estimated average requirement (EAR). SACN has set new EAR values for dietary energy for all age groups, including infants aged 1 to 12 months (SACN, 2011a).

Energy reference values for infants aged 1 to12 months

4.2 Following the approach of the FAO/WHO/UNU Expert Consultation (FAO, 2004), SACN calculated the energy reference values for infants from total energy expenditure (TEE) plus energy deposited in newly synthesised tissue during growth.

4.3 TEE was predicted from a simple equation expressing TEE as a function of weight. This was derived from a longitudinal study (Butte, 2005) in which TEE was measured by the doubly labelled water (DLW) method in healthy, well-nourished, non-stunted infants, born at full term with adequate birthweight, and growing along the trajectory of the UK/WHO growth standard (SACN/RCPCH, 2007). TEEs were calculated separately for breastfed, formula fed, and for those infants where feeding is mixed or unknown.

4.4 Costs of tissue deposition (see Table B.1) were calculated by applying data on the body composition of a population of healthy US infants to weight increments taken from the UK/WHO growth standards (SACN/RCPCH, 2007).

4.5 Table B.2 shows the EAR for energy calculated by adding the estimated energy costs of tissue deposition to TEEs for breastfed infants, formula fed infants and mixed fed infants. EARs for breastfed infants are lower than those for non-breastfed infants at all ages but particularly in the first 3 months of life.

Comparison between SACN (2011) and COMA (1991) DRVs for energy

4.6 Table 4.1 shows energy reference values for infants in the SACN 2011 report (SACN, 2011a) compared with summary values reported by COMA in 1991 (in Table 2.6 of the COMA report (DH, 1991)), with the change from the COMA to the SACN report expressed in percentage. Some of the body weights at the various ages used to calculate values in the two reports vary slightly and this explains some of the difference although it is principally due to the different method of calculation.

Table 4.1 SACN energy reference values for infants, children and adolescents compared with values reported by COMA

Age	Energy reference values (MJ/d)					
	COMA (1991)[a]		SACN (2011)		Change (%)	
	Boys	Girls	Boys	Girls	Boys	Girls
0-3 months	2.3	2.2	2.6 [b]	2.4 [b]	13	9
4-6 months	2.9	2.7	2.7[b]	2.5 [b]	-7	-7
7-9 months	3.4	3.2	2.9[b]	2.7 [b]	-15	-16
10-12 months	3.9	3.6	3.2[b]	3.0[b]	-18	-17

[a] (DH, 1991)

[b] Using the comparable values for formula fed infants (see Table B.2).

4.7 The new energy reference values described in the SACN 2011 report are 9 to 13% higher at 0 to 3 months compared with the COMA 1991 values but are more than 15% lower at 7 to 12 months.

Observed energy intake and exclusive breastfeeding to 6 months of age

4.8 Some have questioned whether exclusive breastfeeding until 6 months of age provides sufficient dietary energy and micronutrients to meet the nutritional requirements of the healthy infant born at term (Reilly et al, 2005; Reilly & Wells, 2005; Fewtrell et al, 2011; Fewtrell, 2011).

4.9 Reilly et al (2005) conducted a systematic review to describe the metabolisable energy consumption of exclusively breastfed infants in HIC at around the age when complementary feeding is introduced. Thirty-three eligible studies of 1,041 mother-infant pairs measuring breast milk transfer at 3 to 4 months of age were identified (weighted mean transfer was 779g/d; standard deviation [SD] 40); 6 studies (99 pairs) reported transfer at 5 months of age (weighted mean transfer was 827g/d; SD 39); and 5 studies (72 pairs) reported transfer at 6 months of age (weighted mean transfer was 894g/d; SD 87). Using data from 25 studies on 777 mother-infant pairs, the weighted mean metabolisable energy content of breast milk was estimated as 2.6 (SD 0.2) kJ/g (0.62kcal/g) (Reilly et al, 2005).

4.10 Using these data, the mean metabolisable energy intake of exclusively breastfed infants at 6 months was calculated as 2.2-2.4MJ/d (526-574kcal/d) (Reilly & Wells, 2005), which was less than the reference mean energy intake of 2.6-2.7MJ/d (621-649kcal/d) set by FAO/UNU/WHO (FAO, 2004). The authors suggested that the energy needs of the average 6 month old infant would not be met by exclusive breastfeeding (Reilly & Wells, 2005).

4.11 A subsequent study using more robust methodology indicates that exclusive breastfeeding does provide sufficient energy for around the first 6 months of life. Nielsen et al recruited 50 healthy, relatively affluent, exclusively breastfeeding mother-infant pairs from breastfeeding support groups in the greater Glasgow area. Compared with earlier literature values which were based primarily on the test-weight method, breast milk intakes (and energy intakes) in this study were measured using the DLW method. Breast milk intake, energy intake, anthropometry and breastfeeding practices (frequency and duration of feeds) were measured at around 15 and 25 weeks of age. Forty-seven pairs completed the study, of whom 41 exclusively breastfed to 25 weeks of age (Nielsen et al, 2011).

4.12 At both time points assessed, mean milk intakes were higher than values previously reported in the literature. At 15 weeks, Nielsen et al reported mean milk intake was 923 (SD 122) g/d compared with 779 (SD 40) g/d at 3 to 4 months reported by Reilly et al (Reilly et al, 2005), and had increased by 25 weeks to 999 (SD 146) g/d; (compared with literature values of 894 (SD 87) g/d at 6 months) (Nielsen et al, 2011). The differences in milk intake reported in this study compared with literature values may be due to the use of different methodologies (see previous paragraph).

4.13 Nielsen et al reported that infant growth reflected WHO Child Growth Standards and energy intakes were adequate compared with reference values (Nielsen et al, 2011). Questionnaire and diary data on maternal perceptions of breastfeeding and infant behaviour indicated small and insignificant changes in feeding frequency between the two time points and did not indicate that more time was spent on feeding with increasing age.

Feeding and regulation of intake

4.14 Even very young infants can regulate their intake to meet their needs. Five-day old breastfed infants randomly allocated to feed first from the left or right breast at a feed took significantly less milk from the second breast than the first. This suggested that intake was governed by the infant’s appetite rather than the availability of breast milk (Drewett & Woolridge, 1981).

4.15 Four-week old infants adjust breast milk intake to conserve their energy intake when mothers change their pattern of breast usage. Offering one breast only or two breasts at each feed in random order over one-week periods led to changes in the volume of milk consumed and its mean fat concentration but not the net fat intake of the infant (Woolridge et al, 1990).

4.16 Fomon et al fed ad libitum formula containing 280kJ/100ml (67kcal/100ml) or 557kJ/100ml (133kcal/100ml) to infants for the first 3 months of life (Fomon et al, 1969; Fomon et al, 1975). Those receiving the higher energy formula took lower volumes of milk but consumed more energy overall and gained more weight until the age of 6 weeks. Thereafter the energy intake and weight gain of the 2 groups were similar. This suggests that energy density may influence the weight gain of non-breastfed infants in the early weeks of life but that they are able to regulate intake more effectively after 6 weeks of age.

4.17 Caregiver control and responsiveness to the infant and young child's feeding cues may also affect intake as the child develops socially during the early years of life. Feeding style may vary in a number of ways that may influence energy intakes. For example infants may be fed to a schedule or be fed on demand; bottle fed infants may be given fixed volumes of milk regardless of cues; parents may attempt to encourage greater consumption if their infant is considered underweight, or offer less if considered overweight.

4.18 Caregiver responsiveness has been implicated in infant weight gain and obesity risk, and interventions to promote caregiver responsive feeding and anticipatory guidance around infant feeding behaviours have reported beneficial effects on infant feeding practices and lower infant weight gain in the context of obesity prevention. A systematic review by Redsell et al (2016) described 4 interventions that contained components related to caregiver responsiveness to infants' cues: trials by Black et al (2001) and Kavanagh et al (2008), which showed benefits of caregiver feeding behaviours, and the NOURISH (Daniels et al, 2012; Daniels et al, 2013) and SLIMTIME interventions (Paul et al, 2011), which also improved infant weight gain. Additionally, the INSIGHT responsive parenting intervention was reported to reduce rapid infant weight gain and overweight status at age 1 year (Savage et al, 2016).

Introduction of solid foods and energy intake

Breastfed infants

4.19 In 2 RCTs conducted in Honduras, exclusively breastfed infants were allocated either to continue breastfeeding from 4 to 6 months of age or to receive solid foods alongside breastfeeding from 4 months (Cohen et al, 1994; Dewey et al, 1999). No growth differences were observed between groups in either of the studies. In both studies, breast milk intake fell in the groups given solid foods but total energy intake of the two groups was no different. This suggests that the introduction of solid foods before around 6 months displaces breast milk energy intake, without increasing overall energy intake.

4.20 An RCT in Iceland (Wells et al, 2012) recruited 119 mother-infant pairs exclusively breastfeeding at 4 months and randomly assigned them to continue breastfeeding exclusively (EBF: n=61; completed n=50) or to receive solid foods from 4 months with continued breastfeeding (CF: n=59; completed n=50). All mothers were counselled by lactation specialists. Breast milk intake was estimated using the stable isotope deuterium dose-to-the-mother method. Anthropometric outcomes were also measured and intakes of solid foods in the complementary feeding group were assessed using 3-day weighed records.

4.21 The exclusively breastfeeding group consumed 83g/d (95% CI 19 to 148g/d) more breast milk than did the complementary feeding group (p=0.012), equivalent to 53kcal/d. Infants in the complementary feeding group obtained a mean daily energy intake of 63 $\pm$ 52kcal/d from solid foods. Estimated total energy intakes were similar (EBF: 560 ± 98kcal/d; CF: 571 ± 97kcal/d) and there were no significant differences in anthropometric outcomes (height, weight and head circumference) and body composition between the 2 groups (Wells et al, 2012).

4.22 The evidence above indicates that solid foods displace breast milk intakes. Therefore, there is a risk that the premature introduction of solid foods may lead to early cessation of breastfeeding. Conversely, deferring the introduction of solid foods may support continued breastfeeding. This is supported by the results of the IFS 2010 (see chapter 11) which noted that after the change to a later recommended age of introduction of complementary feeding in 2003 (DH, 2003; SACN/SMCN, 2003), there was not only an increase in the age of introduction of solid foods but also an increase in the proportion of mothers still breastfeeding at 6 months.

Non breastfed infants

4.23 In the one study identified that investigated the introduction of solid foods in formula fed infants, Mehta et al randomly allocated 165 non-breastfed infants to 4 diet groups: 1) introduction of commercial solid foods at 3 to 12 months of age, 2) parental choice of solid foods at 3 to 12 months of age, 3) commercial solid foods at 6 to 12 months of age, and 4) parental choice of solid foods at 6 to 12 months of age. Energy intake from solid foods and from infant formula was measured at 3, 6, 9 and 12 months. Measurements of weight, length, head circumference and body composition (DEXA) were also made at these intervals (Mehta et al, 1998).

4.24 There were no between-group differences in total energy intake, growth or body composition measurements at any age but infants given solid foods at 3 months took significantly less infant formula than those introduced to solid foods from 6 months.

Conclusions

4.25 The EARs for dietary energy for UK infants are based on achievement of the growth pattern of infants exclusively or predominantly breastfed for around the first 4 months of life and breastfed for at least the first 12 months of life.

4.26 The best estimates to date indicate that breast milk production increases between 4 and 6 months of age and that this meets the increasing energy demands of the growing infant.

4.27 The available evidence suggests that breastfeeding exclusively for the first 6 months of life does not constrain infant energy intake or infant growth. Giving solid foods or infant formula to breastfed infants before 6 months of age may reduce breast milk intake without increasing total energy intake or altering growth or weight gain.

4.28 Some limited evidence suggests that formula fed and breastfed infants differ in their ability to regulate milk intake. While behavioural experiments suggest that breastfed infants regulate energy intake as early as the first week of life, infant formula fed infants may not do so until they are over 6 weeks of age.

5 Infant feeding, body composition and health

Rate of weight gain in infancy

5.1 Systematic reviews of observational studies have indicated that rapid weight gain in infancy (displayed as upward crossing of centiles) is consistently associated with an increased risk of later obesity in childhood and adulthood (Baird et al, 2005; Monteiro & Victora, 2005; Ong & Loos, 2006; Druet et al, 2012). 'Catch-up growth' is the term used to describe the rapid growth or weight gain that occurs following a period of growth restriction, either as seen in children who are born small-for-gestational-age, or after a period of growth faltering after birth. Whilst catch-up weight gain may be beneficial in the short-term, for example by reducing the risk of hospitalisation, it has also been associated with increased adiposity in later childhood and adulthood (Ong et al, 2000; SACN, 2011a).

5.2 Weight gain in infancy, however, also reflects growth in bone and muscle as well as fat, and rapid infancy weight gain may also be associated with later tall stature (Cameron et al, 2003; Wright et al, 2012) and acquisition of lean mass (Wells et al, 2005; Chomtho et al, 2008). Furthermore, historical cohort studies that have examined the association between patterns of infant growth and obesity-related cardio-metabolic disease outcomes in adults have found no association (Jeffery et al, 2006) or an association with small birth size without catch-up in infancy (Eriksson, 2011).

Age at introduction of solid foods and risk of later overweight or obesity

5.3 Evidence on early feeding (breastfeeding relative to infant formula feeding) in relation to later body composition, including risk of later obesity, was considered by SACN in its report on 'The influence of maternal, fetal and child nutrition on the development of chronic disease in later life' (SACN, 2011b). The following section examines the evidence relating to the age of introduction of solid foods and risk of overweight and obesity in later life.

Systematic review evidence

5.4 Moorcroft et al conducted a systematic review of the association between the age at which solid foods were introduced to healthy term infants (≥37 weeks gestation) and obesity in infancy and childhood. The authors identified 24 eligible studies in HIC, including 21 prospective cohort studies, 1 RCT, 1 reanalysis of data from 2 infant formula trials and 1 case-control study (Moorcroft et al, 2011). Meta-analysis was not possible because studies varied in duration of follow-up and in the categorisation of age at introduction of solid foods. Some studies independently analysed data from the same cohorts.

5.5 Overall, the review did not identify consistent associations. Findings from the 8 studies that measured outcomes in infancy (up to 12 months of age) were mixed. Four studies observed that infants introduced to solid foods earlier were heavier or showed a higher weight gain (at various time points up to and including 12 months), but no overall association between age at introduction of solid foods and weight or length measures in infancy was detected. Of the 19 studies that collected anthropometric data in childhood (12 months of age to 18 years), 5 found an association with later risk of obesity. Fourteen found no association between the age at which solid foods were introduced and obesity risk. Two studies, including 1 prospective cohort study and a case-control study, reported on obesity in adolescence (12 to 18 years) and neither found an association (Moorcroft et al, 2011).

5.6 It is difficult in observational research to separate the effects of duration and prevalence of breastfeeding from the age at introduction of complementary feeding. Most of the cohort studies identified by Moorcroft et al did not separate infant formula fed, breastfed and mixed fed infants, however, Haschke and van't Hof examined the effect of age at introduction of solid foods on the growth of exclusively breastfed infants from the longitudinal multi-centre Euro-Growth Study. Those infants whose only milk was breast milk but who were given solid foods before 4 to 5 months of age were longer and had lower BMI in the first 12 months of life compared with exclusively breastfed infants introduced to solid foods at 4 to 5 months or older[6]. In multiple regression analysis, later introduction of solid foods was associated with higher weight gain and BMI until 12 months of age, while longer duration of breastfeeding was negatively correlated with gains in weight and in length and change in BMI between 1 and 24 months of age. The effects of different infant feeding patterns on growth were no longer detectable after 24 months of age (Haschke & van't Hof, 2000).

5.7 Another systematic review by Pearce et al investigated the relationship between the timing of introduction of complementary feeding and overweight or obesity in childhood (Pearce et al, 2013). Twenty three studies were identified: 14 cohort studies, 8 cross-sectional studies and 1 case-control study. Twenty one of these studies considered the association with childhood BMI, of which 4 reported that a higher BMI in childhood was associated with introducing solid foods <3 months or ≤4 months. Seven of the studies considered the association with body composition but only 1 reported an increase in percentage body fat among 7 year old children given solid foods before 15 weeks of age (Pearce et al, 2013).

Experimental evidence

5.8 One American trial by Mehta et al (1998), included in the systematic review by Moorcroft et al (2011), randomised 165 healthy term infants aged less than 3 months to receive solid

[6] At the time of publication, the World Health Organization recommended that infants should be exclusively breastfed from birth to 4 to 6 months of age.

foods from 3 to 4 months or 6 months (see paragraph 4.23 for study detail). All infants were formula fed at recruitment but were not excluded if they had been breastfed previously. Anthropometric measurements were made throughout the first year of life and no differences between the groups were found in weight, length or fat mass (measured by DEXA) when the infants were 12 months old. The authors concluded that early introduction of solid foods did not alter growth or body composition during the first year of life (Mehta et al, 1998).

5.9 Of the 3 trials that investigated early introduction of solid foods to breastfed infants, also considered in chapter 4 of this report in relation to energy (Cohen et al, 1994; Dewey et al, 1999; Wells et al, 2012), only Dewey et al provided growth data beyond 6 months of age. They reported that weight-for-age and length-for-age (calculated using (National Center for Health Statistics, 1977) were similar at 12 months of age in the groups that received solid foods from 4 or from 6 months of age (Dewey et al, 1999).

Observational evidence

5.10 Since the 2 systematic reviews by Moorcroft et al (2011) and Pearce et al (2013) were completed, further prospective cohort studies from HIC have reported on age at solid food introduction and subsequent risk of overweight or obesity.

5.11 Abraham et al reported the complementary feeding practices of 3,462 infants aged 9 to 12 months in the Growing Up in Scotland longitudinal birth cohort study (2005-2008). Introduction of solid foods at 4 to 5 months of age, compared with 0 to 3 months of age was associated with a lower risk of overweight or obesity in the fourth year of life (OR 0.74; 95% CI 0.57 to 0.97) after adjusting for birthweight, educational attainment of respondents and quintile of Scottish Index of Multiple Deprivation score (Abraham et al, 2012).

5.12 The Global Exploration of Human Milk Study is a prospective cohort of predominantly breastfeeding mother-infant pairs recruited shortly after birth in 2007 and 2008 from 3 urban sites: Cincinnatti (USA), Mexico City (Mexico) and Shanghai (China). Age at solid food introduction was not significantly associated with weight and length measurements at 1 year of age (n=285), although full results were not reported (Woo et al, 2013).

5.13 Durmus et al (2012) and van Rossem et al (2013) have reported data from a longitudinal cohort of children born in Rotterdam. The age at which solid foods were introduced was not correlated with skinfold thickness at 6 or 12 months of age (Durmus et al, 2012), nor was it associated with weight-for-height z-scores after 1 year of age (van Rossem et al, 2013). The two studies differed, however, in the categorisation of age at solid food introduction: Durmus et al grouped infants into those introduced to solid foods before 4 months, between 4 and 5 months, or after 5 months of age, whereas van Rossem et al described 'very early' (before 3 months), 'early' (between 3 and 6 months) and 'timely' (after 6 months) introduction. Van Rossem et al reported that infants in the 'early' introduction group had a higher weight gain before solid foods were introduced (z=0.65; 95% CI 0.34 to 0.95) than did infants introduced to solid foods after 6 months (z=-0.04; 95% CI -0.05 to -0.03).

5.14 In the Cambridge Baby Growth Study cohort, age at commencement of complementary feeding between 3 and 7 months was inversely associated with weight and length at 12 months ($p<0.01$) after adjustment for maternal and demographic factors (Vail et al, 2015). Associations were, however, attenuated after adjustment for weight and length at 3 months of age (that is, before introduction of solid food). Moreover, rapid weight gain before 3 months of age predicted earlier introduction of solid foods ($p=0.01$). These findings were interpreted as indicating reverse causality, that is, more rapidly growing infants were hungrier and signalled a need for earlier introduction of solid foods. Wright et al, in the Gateshead Millennium Baby Study, also identified rapid weight gain before the age of 6 weeks as a strong independent predictor of early solid food introduction, together with lower socio-economic status, not breastfeeding, and parental perception that their infant was hungry (Wright et al, 2004).

5.15 Grote et al pooled and analysed data from 671 healthy, formula fed children participating in a randomised controlled trial conducted in Belgium, Germany, Poland, Italy and Spain (Grote et al, 2011). Infants were recruited shortly after birth and followed until they were 24 months old. At 3, 6 and 9 months of age, parents were asked about the introduction of solid foods and data were grouped as: ≤3 months (≤13 weeks), 3-4 months (14-17 weeks), 4-5 months (18-21 weeks) and ≥5 months (≥22 weeks). Significant differences in the pattern of growth were apparent between groups. Children introduced to solid foods ≤3 months were lighter at birth and grew faster between 3 and 6 months of age; those introduced to solid foods ≥5 months grew more slowly in the first 3 months and followed a lower weight percentile over the remainder of the study period than children introduced to solid foods earlier. There was no significant association between age of solid food introduction and anthropometric measurements at 24 months. Three-day food diaries suggested that solid foods were providing additional energy rather than replacing formula (Grote et al, 2011).

5.16 Four of these prospective cohort studies (Wright et al, 2004; Grote et al, 2011; van Rossem et al, 2013; Vail et al, 2015) suggest that greater infant size or weight gain precedes the earlier introduction of complementary feeding. That is, associations between early age at introduction of solid foods and later overweight or adiposity are likely to reflect reverse causation.

5.17 Some of the inconsistencies between observational studies may be due to differing effects on breastfed versus formula fed infants (Huh et al, 2011). The timing of solid food introduction was not associated with later obesity risk (BMI ≥95th percentile for age and gender) at 3 years of age among breastfed children participating in the Project Viva cohort study but an association was apparent amongst the children who were formula fed. Formula fed infants introduced to solid foods before 4 months of age were significantly more likely to be obese at 3 years than those who started between the ages of 4 and 5 months or at 6 months or later (OR 6.3; 95% CI 2.3 to 16.9). This remained true even when the results were adjusted for rapid early growth. Breastfeeding mothers introduced solid foods later: 8% of breastfed infants but 33% of formula fed infants received solid foods before 4 months. Seventeen per cent of breastfed infants started solid foods after 6 months of age compared with 9% of formula fed infants (p<0.0001). Several other cohort studies have also reported that breastfed infants are introduced to solid foods later than formula fed infants (Baker et al, 2004; Scott et al, 2009).

5.18 Birth and baseline data from 612 healthy term infants enrolled in the NOURISH trial did not indicate relationships between early introduction of solid foods and weight gain during the study period (Mihrshahi et al, 2011). About one-third (32.5%) of infants had already started on solid foods by the time of the baseline assessment at mean age 4.3 months (SD 1.0) and of these infants, 24% had been introduced to solid foods before 4 months. Although the age at solid food introduction was not related to weight gain, infants in the study who were formula fed were more likely to have been introduced to solid foods early (OR 2.54; 95% CI 1.26 to 5.13; p=0.009) and formula feeding was associated with rapid weight gain during the study period (OR 1.72; 95% CI 1.01 to 2.94; p=0.047). Feeding on schedule, rather than on demand, was also associated with rapid weight gain (OR 2.29; 95% CI 1.14 to 4.61; p=0.020).

5.19 The 'Hong Kong Children of 1997' birth cohort (Lin et al, 2013) reported no clear association between the age of introduction of solid foods and BMI z-score, overweight or obesity in infancy (birth to 2 years of age), childhood (2 to 8 years of age) or puberty (8 to 14 years of age) (n=7,809 at follow-up). Data on the age of introduction of solid foods were, however, collected retrospectively via postal survey in 2008, and exposure data were missing for about half of the children whose BMI z-scores were available. This suggests a high likelihood of selection and recall bias.

Quantity and quality of the infant diet

Systematic review evidence

5.20 A systematic review conducted by Pearce and Langley-Evans examined the relationships between later overweight or adiposity and macronutrient intake, food type/group, or concordance with dietary guidelines in the first year of life. The review cited 8 prospective and 2 retrospective studies conducted between 1959 and 2009 (Pearce & Langley-Evans, 2013).

5.21 Four studies examined the association between high protein intake during the complementary feeding period and BMI or percentage body fat later in childhood. Studies by Hoppe et al in Danish infants (Hoppe et al, 2004) and Gunther et al in German infants (Gunther et al, 2007a) found no significant association with high protein intake at 6 to 12 months of age and BMI or body composition in childhood. Gunther et al also investigated the impact of different types of protein (total, animal, dairy, meat or cereal) and found that infants with the highest animal protein intake (as percentage of total energy intake) at the age of 12 months had a higher percentage body fat, while those in the highest tertiles of total, animal and dairy protein intake had a higher BMI standard deviation score at the age of 7 years (Gunther et al, 2007b). Protein intake at 6 months was not predictive. A longitudinal observational study of infant feeding and growth involving 90 Icelandic children (Gunnarsdottir & Thorsdottir, 2003) found that boys in the highest quartile of protein intake at 9 to 12 months of age had a significantly higher BMI at 6 years of age compared with boys in the lowest and the second lowest quartiles of protein intakes. There was no similar association observed in girls.

5.22 A further UK study identified by the review (Ong et al, 2006) found that each 420kJ/day increment in the energy intake of mixed fed or formula fed (but not breastfed) infants aged 4 months was associated with a 25% increase in the risk of overweight at 5 years of age.

5.23 Pearce and Langley-Evans also identified one paper from the large Southampton Women's Survey (UK) birth cohort that described associations between adherence to dietary patterns during the complementary feeding period and later body composition outcomes (Robinson et al, 2009). This study found that dietary patterns reflecting adherence to infant feeding guidelines were positively associated with lean mass (but were not associated with either fat mass or BMI) at 4 years of age, suggesting that children following infant feeding guidelines are more likely to continue to eat a diet that follows dietary guidelines in childhood, allowing a greater growth in lean mass (Pearce & Langley-Evans, 2013).

Randomised controlled trial evidence

5.24 In the European Childhood Obesity Project, Koletzko et al conducted a multi-centre European RCT that assigned infants to receive infant and follow-on formula of differing protein concentrations for the first year of life (Koletzko et al, 2009). At the age of 2 years, children in the low-protein group had lower weight-for-length and BMI z-scores than those in the higher protein group (0.23; 95% CI 0.089 to 0.36 and 0.20; 95% CI 0.06 to 0.34, respectively). Furthermore, the low-protein group did not differ significantly in these outcomes from a breastfed reference group. The authors concluded that the difference in weight-for-length and BMI was likely to be due to a difference in adiposity because length at 24 months did not differ between the 2 groups. In a follow-up analysis of this trial, Weber et al reported higher BMI and risk of obesity at 6 years of age in the high-protein group versus the low-protein and observational breastfed group (Weber et al, 2014).

5.25 Two further RCTs in healthy term infants (Inostroza et al, 2014; Ziegler et al, 2015) reported that infant formulae with lower total protein content (1.61g/100kcal and 1.65g/100kcal, respectively), given from age 3 months onwards, promoted less rapid infant weight gain compared to formulae with higher total protein content (2.15g/100kcal and 2.70g/100kcal, respectively). The weight gain of infants in the lower protein groups was more similar to that in the breastfed reference groups.

Cardio-metabolic outcomes

Observational evidence

5.26 Very few studies have investigated whether age at introduction of solid foods influences the risk of either cardiovascular disease or type 2 diabetes, or has an effect on measures of risk such as hypertension, blood cholesterol concentrations and insulin resistance.

5.27 Wilson et al followed up 301 children from a Dundee cohort and found, after adjustment for sex, BMI and maternal blood pressure, that being exclusively or partially breastfed as an infant was associated with a lower systolic blood pressure at the age of 7 years (Wilson et al, 1998). No significant association between blood pressure and the age of introduction of solid foods was reported.

5.28 An analysis of pooled data from birth cohort studies conducted in Brazil, India, the Philippines and South Africa (n=9,640) found that the age at solid food introduction (treated as a continuous variable in linear regression models) was unrelated to blood pressure and fasting plasma glucose concentrations in young adults (Fall et al, 2011).

5.29 Similarly, in a birth cohort of children in Mysore, India (90% of whom were breastfed for 6 months or more) there was no association between the age at starting 'regular' complementary feeding and blood glucose concentrations or insulin resistance, either at 5 or 9.5 years of age (n=518) (Veena et al, 2011). A longer duration of breastfeeding was, however, associated with better glucose tolerance at 9.5 years but not at 5 years of age.

5.30 Studies of dietary patterns during the early years have also investigated the relationship with cardio-metabolic outcomes. Using data from the UK ALSPAC study, Brazionis et al observed that diet during the first 2 years of life was associated with blood pressure at 7.5 years of age; a higher score for a 'less healthy' transition diet, identified using principal components analysis, was associated with an increase in systolic and diastolic blood pressure (0.62mmHg; 95% CI 0.00 to 1.24mmHg; and 0.55mmHg; 95% CI 0.10 to 1.00mmHg, respectively, for each one standard deviation increase in diet score) (Brazionis et al, 2013). The positive association remained for diastolic (but not systolic) blood pressure after adjustment for child height, BMI and waist circumference.

5.31 Golley et al analysed data from the same cohort and calculated a Complementary Feeding Utility Index score to measure adherence to complementary feeding guidelines when infants were 6 months of age (Golley et al, 2013). This incorporated breastfeeding duration, age at solid food introduction, feeding to appetite, fruit and vegetables, minimising exposure to ready-made infant foods and food high in fat, salt or sugar, in addition to other components. After adjustment for factors such as birthweight and maternal education, smoking and weight status, the index score showed a weak inverse association with diastolic blood pressure at 7 years of age (β=-0.24; 95% CI -0.47 to -0.01; p=0.043). No association was observed with blood lipid measurements or BMI.

5.32 The relationship between infant feeding patterns and cardiovascular development and metabolic outcomes in childhood has been investigated as part of the Generation R Study (Jaddoe et al, 2012), a large population-based prospective cohort study from the Netherlands designed to identify early environmental and genetic causes of normal and abnormal growth, development and health, from fetal life until young adulthood. Data on breastfeeding initiation and continuation were collected by questionnaire at the infant ages of 2, 6 and 12 months of age. These provided information on breastfeeding status (never versus ever breastfed), breastfeeding duration (<2, 2 to <4, 4 to <6, and ≥6 months) and duration of exclusive breastfeeding (never breastfed, partially breastfed for at least 4 months, and exclusively breastfed for at least 4 months). Timing of introduction of solid foods was determined by the age at which a fruit or vegetable snack was given for the first time (categorised as <4 months, 4-5 months). At a mean age of 6 years, cardiovascular measurements were conducted including systolic and diastolic blood pressure, carotid-femoral pulse wave velocity (PWV; an index of aortic stiffness), and a number of measures of cardiovascular structures (left atrial diameter [LAD], aortic root diameter [AOD], left ventricular [LV] mass, fractional shortening [FS]) (de Jonge et al, 2013). Fasting blood samples were collected to measure the following metabolic outcomes: high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol, triglycerides, insulin and C-peptide concentrations. Total body and regional fat mass were also measured (Gishti et al, 2014).

5.33 Based on analyses of 5003 children, de Jonge et al found that the introduction of solid foods at 4 to 5 months was associated with significantly higher systolic and diastolic blood pressure (p<0.01) compared with introduction after 5 months of age, and was associated with smaller LAD but not with other structural measures (de Jonge et al, 2013). Age at introduction of solid foods was also not associated with carotid-femoral PWV.

5.34 Cardiovascular development differed between children who were ever breastfed and those who were never breastfed, with the latter having a higher carotid-femoral PWV, a smaller LAD, and less LV mass at 6 years of age. However, a dose response association with differing duration and exclusivity of breastfeeding was not observed (de Jonge et al, 2013).

5.35 The authors concluded that feeding patterns in infancy may affect cardiovascular development in childhood, however, further research is required to investigate whether these findings are replicated and to help elucidate the potential underlying mechanisms linking early nutrition with cardiovascular adaptations (de Jonge et al, 2013).

5.36 In another study embedded in the Generation R Study (n=3,417), Gishti et al examined the associations between infant feeding patterns and metabolic outcomes at the median age of 6 years, and found that duration and exclusivity of breastfeeding were not consistently associated with metabolic outcomes, while the introduction of solid foods before 4 months of age was positively associated with higher blood levels of total cholesterol but not with HDL and LDL cholesterol, triglycerides and insulin levels (Gishti et al, 2014). Shorter duration of breastfeeding (<2 months) and non-exclusive breastfeeding were associated with higher risks of childhood clustering of cardio-metabolic risk factors, however, after adjusting for confounding factors, none of the associations remained significant. The authors therefore concluded that there was a lack of consistent associations between infant feeding patterns and metabolic outcomes and that further research was required to investigate this relationship.

5.37 Two further studies have investigated the association between body composition at 6 years of age and early dietary patterns (n=2,026) (Voortman et al, 2016a) and protein intakes (n=2,911) (Voortman et al, 2016b) in children from the Generation R Study. Dietary intake was assessed at a median age of 12.9 months (95% CI 12.2 to 19.2 months) using a semi-quantitative food frequency questionnaire comprising 221 foods commonly consumed by Dutch children between 9 and 18 months of age. At 6 years of age, body composition (fat mass [FM] and fat-free mass [FFM]; assessed by DEXA) and BMI were measured. Dietary patterns were assessed using 3 approaches: a-priori-defined diet quality score, dietary patterns based on variation in food intake (using principal components analysis), and dietary patterns based on variation in FM and FFM indices. Assessment of protein intake was divided into animal or plant protein.

5.38 Dietary patterns characterised by high intakes of fruit, vegetables, grains and vegetable oils were associated with higher FFM at 6 years of age (0.19 SD; 95% CI 0.08 to 0.30 per SD increase in diet score). No differences were seen in FM. In the reduced-rank-regression, FFM index was positively associated with a pattern characterised by intakes of whole grains, pasta and rice, and vegetable oils. The authors concluded that healthier dietary patterns in early childhood are associated with higher FFM but not with FM later in childhood (Voortman et al, 2016a). With regards to protein intakes, a 10g per day higher total protein intake at 1 year was associated with a 0.05 SD (95% CI 0.00 to 0.09) higher BMI and a 0.06 SD (95% CI 0.01 to 0.11) higher FM index at 6 years, but not with FFM. Associations between protein intakes and FM index were statistically significant for animal protein but not vegetable protein intake (Voortman et al, 2016b).

Conclusions

5.39 There is a body of observational evidence indicating that rapid weight gain in infancy may predict later obesity but also predicts tall stature.

5.40 There is evidence from observational studies regarding an association between the age at which solid foods are introduced and later adiposity or obesity. Many studies do not separate breastfed and non-breastfed infants who may differ in their ability to regulate intake, nor characterise exclusivity of breastfeeding and its duration. This makes it difficult to separate the direct effects of solid food intake from any indirect effect through curtailment of breastfeeding.

5.41 Most prospective studies that have examined infant weight or weight gain before commencement of complementary feeding have identified rapid early weight gain as a predictor rather than a consequence of the early introduction of solid foods. This indicates a likelihood of reverse causality in any relationship between early complementary feeding and subsequent overweight.

5.42 Three RCTs examined the effect of introducing complementary feeding at 3 to 4 months versus at 6 months. These suggest that introduction of foods other than breast milk or infant formula before 6 months of age displaces rather than increases energy intake. No effects on growth or body composition have been observed in the first 12 months.

5.43 Evidence from RCTs comparing higher versus lower infant formula protein contents supports observational evidence linking higher intakes of animal protein in infancy to rapid weight gain and later risk of obesity.

5.44 There are too few data to draw conclusions about relationships between age at introduction of complementary feeding and cardio-metabolic outcomes in childhood or adult life. While two studies from the same UK cohort reported an association between deviation from complementary feeding guidance and diastolic blood pressure, no effect of age at introduction of solid foods was apparent in another UK cohort or in several others from LMIC.

6 Micronutrients

6.1 Adequate intakes of micronutrients are vital in supporting the growth and development of infants and also have an impact on health outcomes throughout life. Deficiencies in micronutrients such as iron, iodine, zinc and vitamin A may particularly affect infants and young children; it is estimated that at least 50% of children worldwide aged 6 months to 5 years suffer from one or more micronutrient deficiency (Micronutrient Initiative, 2009).

6.2 While a wide range of micronutrients could have been considered, this chapter focusses on iron, vitamin D and vitamin A. These are the key micronutrients for which there is sufficient evidence to indicate potential concerns regarding deficiency or excess in healthy infancy in the UK. The available evidence for other micronutrients is either limited, insecure, or primarily from settings which are not directly relevant to the UK.

6.3 Extensive reports on 'Iron and health' (2010) and 'Vitamin D and health' (2016) have been published by SACN and provide more detailed information on biochemistry, biomarkers of exposure and toxicity (SACN, 2010; SACN, 2016). Vitamin A toxicity is considered in Chapter 10.

6.4 Internationally, zinc has also been identified as a micronutrient of potential concern. However, literature searches undertaken for this report revealed no new evidence to suggest a cause for concern from zinc deficiency in the UK setting.

6.5 Assessment of the role of dietary intake for any individual micronutrient must recognise the interaction with other micronutrients in the gut and for cellular function (for example, iron in relation to zinc and copper). Furthermore, micronutrient status in infancy may not be determined simply by current dietary intake but is also influenced by the extent to which critical reserves have been acquired in utero in relation to maternal micronutrient status and duration of pregnancy. Dietary intake is inherently variable and an assessment of usual intake is less secure for relatively short periods of assessment, especially for micronutrients which are only consumed intermittently, are naturally accumulated over prolonged periods, or where absorption from the gut may be compromised as in poor states of nutrition.

Iron

6.6 Adequate iron status is of particular importance during development of the brain and nervous system (Kramer & Kakuma, 2002; PAHO, 2003; Georgieff, 2011). Iron deficiency (ID) in infancy and early childhood, with or without anaemia, may have long-term consequences for cognitive, motor and behavioural development (Lozoff & Georgieff, 2006).

6.7 Iron deficiency anaemia (IDA) affects approximately 20% of pregnant women and 25% of preschool-age children worldwide (Kramer & Kakuma, 2002; PAHO, 2003; McLean et al, 2009). In Europe, the prevalence of iron deficiency in preschool-age children ranges from 3%

to 48% (Eussen et al, 2015), however, rates of up to 80% iron deficiency have been observed in LMIC (Kramer & Kakuma, 2002; PAHO, 2003; Pasricha et al, 2010). For the UK, DNSIYC reported that the proportion of children with haemoglobin concentrations and serum ferritin concentrations below which iron deficiency anaemia is indicated was 3% for those aged 5 to 11 months and 2% at 12 to 18 months (Lennox et al, 2013). Further findings are provided in Chapter 11.

6.8 DRVs for iron were set by COMA in 1991 (DH, 1991) (Table 6.1) and reviewed by SACN in 2010 (SACN, 2010). An update of the evidence for the first year of life following term birth is provided in this section.

Table 6.1 DRVs for iron in the first year of life[a]

Age	Lower reference nutrient intake (LRNI)	Estimated average requirement (EAR)	Reference nutrient intake (RNI)
0 – 3 months	0.9 (15)	1.3 (20)	1.7 (30)
4 – 6 months	2.3 (40)	3.3 (60)	4.3 (80)
7 – 9 months	4.2 (75)	6.0 (110)	7.8 (140)
10 – 12 months	4.2 (75)	6.0 (110)	7.8 (140)

[a] Intakes depicted in the table are in mg/d (µmol/d)

6.9 Other national bodies, including from the US (IOM, 2001), Australia and New Zealand governments (Australian Government Department of Health and Ageing et al, 2006), Nordic Co-operation (Nordic Council of Ministers, 2014) and EFSA (Agostoni et al, 2013) have also issued dietary recommendations for iron. Most countries recommend intakes equivalent to the iron content of breast milk (around 0.2-0.3mg/L) (Domellof et al, 2004). Recommendations for infants from 3 to 12 months are in the order of around 8 mg/day, although higher intakes at 11 mg/day are recommended in the USA, Australia and New Zealand.

Assessment of iron status in infants and young children

6.10 Serum ferritin and haemoglobin concentrations are the most commonly cited markers of iron status but the thresholds chosen to indicate deficiency have been much debated (Table 6.2). Serum ferritin concentration reflects systemic ferritin depots. Low serum ferritin concentrations represent low depots but may not represent a functional deficiency of iron. Ferritin behaves as an acute phase reactant and concentrations are raised in response to acute and chronic inflammation including mild infections (Hulthen et al, 1998). Thus, acute phase markers (for example, high sensitivity C-reactive protein) are usually measured alongside serum ferritin to indicate the presence of infection and allow exclusion.

6.11 Additional biomarkers of iron status including transferrin saturation, soluble transferrin receptor, reticulocyte haemoglobin and hepcidin concentrations are becoming more widely available but require further evaluation in infants. For more details, see (SACN, 2010)) as well as the extensive reviews (Domellof et al, 2014) (Hernell et al, 2015).

Table 6.2 Comparison of international definitions of iron deficiency and iron deficiency anaemia in infants and young children

Indicator	Referenced by (Country)
Iron Deficiency	
SF <10 µg/L	NHANES (USA), NDNS (UK), Zhou et al (2012) (Australia)
SF <12 µg/L	WHO/CDCI (2004), SACN (2010) (UK)
SF <15 µg/L	Hay et al (2004) (Norway), Capozzi et al (2010) (Italy)
SF <12 µg/L + MCV <74 fl	Michaelsen et al (1995) (Denmark),Gunnarsson et al (2004) (Iceland)
Iron Deficiency Anaemia	
Hb <110 g/L + SF <10 µg/L	NHANES (USA), NDNS (UK)
Hb <110 g/L + SF <12 µg/L	(WHO/CDCI, 2004), SACN (2010) (UK)
Hb <110 g/L + SF <15 µg/L	Hay et al (2004) (Norway)
Hb <105 g/L + SF <10 µg/L	Zhou et al (2012) (Australia)
Hb <105 g/L + SF <12 µg/L + MCV <74 fl	Michaelsen et al (1995) (Denmark), Gunnarsson et al (2004) (Iceland)

Adapted from (McCarthy et al, 2017)

SF: serum ferritin; MCV: mean corpuscular volume; Hb: haemoglobin; NHANES: National Health and Nutrition Examination Survey; NDNS: National Diet and Nutrition Survey; SACN: Scientific Advisory Committee on Nutrition.

6.12 In 2014, the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) Committee on Nutrition recommended age-specific cut-offs for defining IDA from birth to 5 years (Domellof et al, 2014). During infancy, these values are Hb 135 g/L + SF 40 µg/L during the first week of life, decreasing to Hb 90 g/L + SF 40 µg/L at 2 months, Hb 105 g/L + SF 20 µg/L at 4 months and Hb 105 g/L + SF 10-12 µg/L from 6 to 12 months.

Iron status at birth

6.13 Fetal iron stores increase throughout gestation. At 20 and 40 weeks gestation, the fetus contains about 58 and 94µg of iron respectively per gram of lean tissue (Dallman et al, 1988). During the last trimester, the fetus accumulates about 2mg of iron daily and the mature term neonate contains 150 to 250mg of iron, of which almost 80% is in haemoglobin (1g of haemoglobin contains 3.47mg iron). Much of the remainder is in the reticuloendothelial and hepatic tissue iron depots.

6.14 Some studies have reported no significant associations between maternal and cord haemoglobin or ferritin concentrations (Kilbride et al, 1999; Hay et al, 2007), but others have observed that severe maternal iron deficiency, with and without anaemia, adversely affects fetal iron status. Infants of mothers with moderate (haemoglobin <85 g/L) or severe (haemoglobin <60 g/L) anaemia had significantly lower serum ferritin concentrations at birth (Singla et al, 1996). Infants born to mothers with depleted iron stores (serum ferritin < 12 µg/L) had lower cord ferritin than infants born to mothers with normal stores (Sweet et al, 2001; Jaime-Perez et al, 2005; Shao et al, 2012).

6.15 Additional factors including maternal obesity, smoking and pregnancy complications including gestational hypertension and growth restriction, are also associated with impaired intrauterine iron accretion, leading to low iron stores at birth (Hay et al, 2007; Rao & Georgieff, 2007).

6.16 A wide range of cord blood ferritin concentrations has been observed in newborn infants making it difficult to establish a reference range, but depleted iron stores (<76 µg/L) or severe iron deficiency (<35 µg/L) have been associated with low mental and psychomotor developmental scores up to 5 years of age (Tamura et al, 2002; Siddappa et al, 2004).

6.17 As cord blood ferritin levels track through early infancy, those with the lowest iron stores at birth continue to have significantly lower ferritin concentrations up to 2 years of age (Georgieff et al, 2002; Hay et al, 2007). Studies in Spain and Jordan observed that infants born to mothers who were anaemic during their pregnancy were more likely to develop iron deficiency and IDA in the first year of life, despite no apparent effect of maternal status on infant status at birth (Colomer et al, 1990; Kilbride et al, 1999).

6.18 These findings emphasize the important effect of maternal nutrition and health during pregnancy on iron stores both at birth and later in infancy.

Iron status during the first 6 months

6.19 Early clamping of the umbilical cord at delivery deprives the infant of iron, and SACN has recommended that clamping of the cord should be delayed until it has stopped pulsating (SACN, 2010). Waiting until the umbilical cord stops pulsating is associated with, on average, a 32% greater neonatal blood volume (Nelle et al, 1995) and a correspondingly increased transfer of iron (30-50 mg) to the neonate (Pisacane, 1996). McDonald et al (McDonald et al, 2013), in an update of an earlier Cochrane review (McDonald & Middleton, 2008), concluded that delayed cord clamping resulted in improved iron stores in early infancy without an increase in the risk of neonatal mortality or other neonatal morbidity outcomes. It should be noted that the timing of cord clamping is a confounder for all studies examining associations between infant iron status and maternal characteristics. ESPGHAN has recommended that delayed cord clamping should be considered for all newborns (Domellof et al, 2014) and the NICE guideline on intrapartum care for healthy women and babies

(CG190) also recommends no clamping of the cord until pulsating has stopped (NICE, 2014a).

6.20 An RCT in Sweden (Andersson et al, 2011) comparing the effects of delayed (>3 minutes after delivery) and early (<10 seconds after delivery) umbilical cord clamping observed a lower prevalence of iron deficiency (0.6% versus 5.7%; p=0.01) and higher serum ferritin (117 versus 81 μg/L; p<0.001) at 4 months of age in the delayed clamping group. It is worth noting that the delayed clamping group had better neurodevelopmental outcomes at 4 years of age (Andersson et al, 2015).

6.21 The prevalence of iron deficiency (ferritin <12μg/L) and IDA (ferritin <12μg/L and haemoglobin <105g/L) during the first 6 months of life in fully breastfed infants was identified in 6 RCTs in Honduras, Ghana, Mexico and Sweden (n=404, birthweight >2500g) (Yang et al, 2009). At 6 months (excluding participants with elevated C-reactive protein), a prevalence of 7.9% IDA and 19.7% iron deficiency was reported. This varied greatly by country: IDA was detected in 2% in Sweden, 5% in Mexico, 5 to 11% in Honduras and 8 to 16% in Ghana. Iron deficiency was present in 6% of participants in Sweden, 17% in Mexico, 13 to 25% in Honduras, and 12 to 37% in Ghana. The combination of birthweight 2500-2999 g or male sex had a sensitivity of 97% for identifying IDA and 91% for iron deficiency.

6.22 Assuming an adequate fetal iron supply and delayed cord clamping, healthy term infants of normal birthweight should have sufficient endogenous iron (in the form of haemoglobin iron, storage iron and functional tissue iron) to meet their requirements for around the first 6 months of life (Griffin & Abrams, 2001; Aggett et al, 2002). The recent position paper from ESPGHAN (Domellof et al, 2014) describes the initial transfer of iron from haemoglobin to iron stores during early life, making it available for redistribution back to the blood compartment as the infant grows and their blood volume expands. This process makes the infant self-sufficient with regard to iron until he or she has doubled their birthweight, which occurs at around 6 months of age (EFSA, 2015a).

6.23 This implies that healthy term infants of normal birthweight have little or no need for exogenous iron for around the first 6 months of life (SACN, 2010; Domellof et al, 2014; EFSA, 2015a). The iron content of breast milk (0.2-0.4mg/L) is not affected by maternal iron deficiency or maternal iron supplementation (Zavaleta et al, 1995). Stable isotope studies have reported fractional iron absorption (incorporation of iron into erythrocytes) from breast milk of 12 to 21% at 6 months of age (Davidsson et al, 1994; Abrams et al, 1997; Domellof et al, 2002). Thus an infant receiving 800ml/day of breast milk absorbs about 0.05mg/day of iron (assuming an iron content of 0.3mg/L breast milk and absorption efficiency of 20%).

6.24 The regulation of iron absorption is strict and highly dependent on an individual's iron status. In iron repletion, liver production of hepcidin blocks ferroportin and iron absorption in the gut, whereas in iron deficiency, hepcidin production is suppressed and intestinal absorption of iron increases. As they grow, infant iron requirements increase and iron absorption is upregulated. From around 6 months of age, it is recommended that infants receive iron from a variety of dietary sources.

6.25 All infant formula in the European Union is fortified with iron. In its Scientific opinion on the essential composition of infant and follow-on formula (EFSA, 2014), the EFSA Panel on Dietetic Products, Nutrition and Allergies has proposed a minimum content in infant formula of 0.3mg/100kcal. This is because the bioavailability of iron from formula is much lower than from human milk but does not take into consideration the point that infants born with adequate iron stores do not have a requirement for dietary iron in the first 6 months of life. In the absence of adequately powered RCTs, fortification of formula with iron remains controversial (Domellof et al, 2014).

6.26 An RCT among 119 healthy term infants in Iceland compared the introduction of solid foods at 4 months with 6 months exclusive breastfeeding to examine the effect on iron status and growth rate (Jonsdottir et al, 2012). Out of 100 infants who completed the trial, those in the complementary feeding group had higher mean serum ferritin levels at 6 months compared with those exclusively breastfed for 6 months ($p=0.02$). However, there was no difference between groups in the prevalence of iron deficiency anaemia, iron deficiency, or iron depletion and growth rate was the same in both groups at 4 and 6 months of age.

6.27 Similarly, in one trial conducted in Honduras (Dewey et al, 1998), the exclusively breastfed group showed lower mean haemoglobin concentration (mean difference -5g/L; 95% CI -8.5 to -1.5g/L) and lower serum ferritin concentration (mean difference -18.9mcg/L; 95% CI -37.3 to -0.5mcg/L) at 6 months than the group who were mixed fed after 4 months (Kramer & Kakuma, 2012).

Iron status in infancy - from 6 to 12 months

6.28 After 6 months of age, iron stores diminish and, even with up-regulation of intestinal absorption, the amount of iron provided from breast milk is no longer sufficient to meet the increasing demands for growth and blood volume expansion. Therefore, dietary requirements for iron increase and the introduction of iron-containing solid foods from a diverse diet is recommended.

6.29 Haem iron, which is the most bioavailable form of iron, is found almost entirely in food of animal origin. Non-haem iron is found in animal and plant tissues in the reduced ferrous form of iron (Fe^{2+}) bound to insoluble proteins, phytates, oxalates, phosphates and carbonates, and as ferritin. The sources of non-haem iron include cereals, vegetables, nuts, eggs, fish and meat (SACN, 2010). Iron is also added to infant formula and some foods as a fortificant and is available in supplemental form (Lennox et al, 2013). The complex interactions of the prevailing diet as well as specific meal components that can influence iron absorption are well documented (SACN, 2010). The evidence considered suggested that the iron intake and status of vegetarians was not significantly different to non-vegetarians

(SACN, 2010), however, these studies were conducted in adults and it is not known whether the findings can be extrapolated to infants.

6.30 After 6 months of age, iron requirements are driven by requirements for growth, which largely determine absorption of both haem and non-haem iron from the infant diet. To prevent low iron intakes, and to promote adequate iron status at this vulnerable life stage, dietary diversity is important for infants from around 6 months of age.

6.31 There is substantial evidence that unmodified cows' milk should not be used as a main milk drink in infants up to 12 months of age. Cows' milk contains about 0.5 to 0.6mg/L of iron (DH, 1994), which is poorly absorbed because it is complexed with ligands, principally phosphate. Introduction of cows' milk to infants aged 6 months has also been associated with small losses of blood from the intestinal tract (Ziegler et al, 1990).

6.32 Observational studies have consistently shown negative associations of unmodified cows' milk consumption with iron status indicators throughout infancy and early childhood (Freeman et al, 1998; Male et al, 2001; Gunnarsson et al, 2004; Thorisdottir et al, 2013), while others have shown negative effects on iron stores (Michaelsen et al, 1995; Bramhagen & Axelsson, 1999; Thorsdottir et al, 2003).

6.33 In a large European study of 12 month old infants, the duration of cows' milk consumption was the most consistent negative determinant of all iron status indicators; for every month of cows' milk consumption, an average decrease of 2g/l in haemoglobin concentrations was observed (Male et al, 2001). Several studies have reported that consumption of cows' milk in the second 6 months of life is associated with lower haemoglobin and ferritin concentrations (Zlotkin, 1993; Michaelsen et al, 1995).

6.34 In Iceland, dietary guidance to replace cows' milk in the latter part of infancy (from 6 months) with formula resulted in increases in the iron status of 6 to 12 month old infants (Thorisdottir et al, 2011). Subsequently it was shown that consumption of iron-fortified products by 9 to 12 month olds was associated with higher serum ferritin concentrations (Thorisdottir et al, 2013; Uijterschout et al, 2014).

6.35 Lozoff and colleagues compared the long term developmental outcomes of children who were randomised to receive iron-fortified or low-iron formula from 6 months until 12 months of age (Lozoff et al, 2012). Eight hundred and thirty-five healthy term infants were enrolled from community clinics in Santiago, Chile. All infants were weaned from the breast by around 6 months of age, and the norm in Chile at the time was mixed feeding with powdered cows' milk and breast milk during the first 6 months of life.

6.36 At follow-up 10 years later, developmental outcomes were assessed (IQ, spatial memory, arithmetic achievement, visual-motor integration, visual perception, motor coordination, and motor proficiency) in 473 (57%) participants. The study found that those infants in the group receiving iron-fortified formula, scored lower on every outcome (significant for spatial memory (effect size -0.21; 95% CI -0.38 to -0.04; p=0.022), visual-motor integration (effect size -0.21; 95% CI -0.40 to -0.02; p=0.046)). Children with high 6 month haemoglobin levels (>128g/l) showed poorer outcomes on the developmental outcomes assessed if they received iron-fortified formula. Those with low haemoglobin levels receiving iron-fortified formula (<105g/l) showed better results in the assessed outcome. The authors concluded that long term development may be adversely affected in infants with high haemoglobin who received iron-fortified formula (Lozoff et al, 2012).

Iron status and growth

6.37 Both body size and growth in infancy and early childhood influence iron status. Birthweight was positively associated with iron status up to one year of age (Persson et al, 1998; Sherriff et al, 1999), while weight gain in infancy was negatively associated with iron status at one year (Morton et al, 1988; Michaelsen et al, 1995; Thorsdottir et al, 2003).

6.38 Data from medicinal iron supplementation trials have been conflicting; a positive effect of iron supplementation on physical growth was observed in one study (Aukett et al, 1986), but others have found none (Rosado, 1999; Ramakrishnan et al, 2009).

6.39 Some studies have reported an adverse effect of medicinal iron supplements on growth in iron-replete infants (Idjradinata et al, 1994; Dewey et al, 2002; Majumdar et al, 2003; Lind et al, 2004).

6.40 Results from a double-blind RCT suggest a negative effect of medicinal iron supplements on linear growth and head circumference during infancy (Dewey et al, 2002). Full term infants in Sweden (n=101) and Honduras (n=131) were randomly assigned at 4 months of age to one of three interventions groups: iron supplement (1mg/kg/day) from 4 to 9 months of age; placebo from 4 to 6 months of age and iron supplement from 6 to 9 months of age; or placebo from 4 to 9 months of age. All infants were exclusively or near exclusively breastfed (≤15ml/day of foods/fluids other than breast milk and no iron-fortified foods) until 6 months of age. Among the Swedish infants, gains in length and head circumference were significantly lower in those receiving iron supplements compared with those receiving placebo between the ages of 4 to 9 months, particularly for the 6 to 9 month period. In Honduras, a negative effect of iron supplements on linear growth was only observed from 4 to 6 months among those with initial haemoglobin concentration of 110g/L or above. There were no differences in head circumference among treatment groups.

6.41 An RCT in India (Majumdar et al, 2003) of infants aged 6 to 24 months (n=150) reported that weight gain and linear growth were significantly decreased in iron-replete infants (haemoglobin>110 g/L; serum ferritin>12µg/L; n=50) supplemented with medicinal iron (2mg/kg/day). A significant improvement in weight gain and physical growth was seen with iron supplementation (6mg/kg/day) of iron deficient children (haemoglobin=50-110 g/L; serum ferritin <12µg/L) compared with placebo.

6.42 Lind et al examined the effect of medicinal iron supplementation (10mg/day) on the growth of Indonesian iron-replete infants (haemoglobin ≥113g/L; serum ferritin ≥33µg/L; n=154) (Lind et al, 2008). Weight gain from age 6 to 12 months and mean weight at 12 months were significantly lower ($p<0.001$) in iron-replete infants supplemented with iron compared with non-supplemented iron-replete infants. There was no difference in linear growth between the two groups. Serum zinc levels were lower in the supplemented iron-replete children (9.7µmol/L versus 10.5µmol/L; $p=0.04$).

6.43 In a controlled trial in Egypt (Abdelrazik et al, 2007), exclusively breastfed infants (n=248; age 4 to 6 months) were supplemented with medicinal iron (1mg/kg/day) or placebo for 12 months. Infants in the iron-treatment group were stratified according to whether or not they were malnourished (based on anthropometric parameters) and further stratified into those with haemoglobin concentration above or below 100g/L; all infants in the placebo group had haemoglobin values above 100g/L. After 6 months of treatment, weight and length gain was significantly higher ($p<0.05$) in the iron-treated group as a whole compared with the placebo group. Within the iron-treated group, the increments in weight and length were significantly higher ($p<0.05$) in malnourished than nourished infants. Weight gain was greater ($p<0.01$) in malnourished infants with haemoglobin <100g/L compared with those with haemoglobin >100g/L; this difference was not observed in well-nourished infants. No effects were reported on head circumference.

6.44 A randomised trial in Brazil (da Silva et al, 2008) examined the effects of different doses of medicinal iron (1mg/kg/day, 2mg/kg/day, or 25mg/week) on the growth of iron-replete infants (haemoglobin ≥110g/L; age 5 to 6.9 months; n=114) supplemented for 16 weeks. The study did not include a control group. At the end of the intervention there were no statistical differences between groups in weight and length gain.

6.45 Iron can exert a range of acute and chronic adverse effects by competing with other transition metals of nutritional importance (for example, zinc, copper) in a number of physiological processes. It is possible that medicinal iron supplementation of iron-replete children inhibits absorption of other essential nutrients required for growth, such as zinc. Although there were no differences in plasma zinc concentration between the iron-treated and placebo-treated groups in the study by Dewey et al, plasma zinc concentration is not an adequate indicator of marginal zinc deficiency (Dewey et al, 2002).

Iron status and development

6.46 Iron deficiency can be particularly detrimental if it occurs during critical periods of brain development, most notably the fetal or early neonatal and late infancy/early childhood periods. Depending on the timing of deficiency, different neurodevelopmental outcomes can be affected, relating to the regions of the brain developing at the time of the insult (Hensch, 2004).

6.47 SACN considered the extensive body of research on the relationship between IDA and cognitive, motor and behavioural development in children in its report 'Iron and health' (SACN, 2010). It concluded that iron deficient anaemic young children usually have poorer development than non-anaemic children, but that measured and unmeasured confounding environmental variables could explain these findings.

6.48 SACN also concluded that, whilst RCTs of iron supplementation suggest IDA is a cause of poor motor development in children in the first 3 years of life (Martins et al, 2001), the long term implications of these findings in the UK are unknown. RCTs examining the effect of ID or IDA on cognitive or language development in children aged <3 years were considered too few and follow-up too short to yield conclusions.

Interactions with other metals

6.49 Interactions between divalent minerals vary according to a wide range of factors (see paragraph 7.10 of the SACN 'Iron and health' report, 2010) and it is therefore difficult to determine the potential effects of increased iron intakes in early childhood on absorption and systemic use of zinc and copper and on growth. Antagonistic interactions between these minerals nevertheless have potential to negatively affect functional outcomes such as growth in infants (Sandstrom, 2001).

6.50 In vitro studies and studies in animal models have shown adverse effects of high levels of dietary iron on copper metabolism. Findings from the small number of human studies investigating the interactions between iron and copper also suggest that high iron intakes negatively affect serum copper concentrations and copper metabolism (see paragraph 7.15 of the SACN 'Iron and health' report, 2010).

6.51 Domellof et al measured the zinc and copper absorption of breastfed infants randomly allocated to receive placebo or 1mg/kg Fe/d between 4 and 9 months of age. No significant effect of iron on copper or zinc absorption was found at 6 or 9 months of age (Domellof et al, 2009).

Vitamin D

6.52 Vitamin D plays an important role in the regulation of calcium and phosphorus metabolism and is therefore important for bone health. It is synthesised in the skin upon exposure to sunlight containing sufficient UVB radiation and this is the main source for most people. It can also be obtained from foods or dietary supplements. Dietary sources are essential when sunlight containing UVB radiation is limited (for example, during the winter months) or exposure to it is restricted (for example, due to lack of time spent outdoors or little skin exposure).

6.53 Other than the prevention of nutritional rickets, data are not available to clearly relate vitamin D status in the infant to current or long term health. Safe intakes rather than reference nutrient intakes (RNIs) are therefore recommended for infants and children aged up to 4 years. Safe Intakes are based on a precautionary approach and reflect the insecurities of the data (SACN, 2016).

6.54 The UK health departments recommend that all infants from birth to 1 year of age who are being exclusively or partially breastfed should be given a daily supplement containing 8.5 to 10µg of vitamin D (340-400 IU/d) (SACN, 2016). Infants who are fed infant formula should not be given a vitamin D supplement unless they are consuming less than 500ml (about one pint) of infant formula a day, as infant formula is fortified with vitamin D. Previously there was not a recommendation for breastfed infants, as it was assumed that maternal vitamin D supplementation during pregnancy and then breast milk would provide the infant with adequate vitamin D for the period of exclusive breastfeeding.

Dietary intakes of vitamin D

6.55 Data from the UK DNSIYC reported average daily vitamin D intakes from all sources for ages 4 to 6 months (10.0µg); 7 to 9 months (8.9µg); and 10 to 11 months (7.7µg) (Lennox et al, 2013). The major contributor to vitamin D intake from food for all age groups of children not receiving any breast milk was infant formula (Lennox et al, 2013). Infant formula was the largest contributor to vitamin D intake for those aged 4 to 6 months; 7 to 9 months and 10 to 11 months (85%, 80% and 72%, respectively) followed by the food group 'commercial infant foods' (12%, 12% and 10%, respectively) (Lennox et al, 2013). Vitamin D intakes for breastfed infants were not presented because the vitamin D content of breast milk is not considered to be a significant source of vitamin D or its metabolites could not be quantified. The reported vitamin D content of breast milk differs across studies because it varies with the type of milk measured (foremilk or hindmilk) and the time of day it is collected (SACN, 2016).

Vitamin D status

6.56 Serum/plasma concentration of 25-hydroxyvitamin D (25(OH)D), which is the major circulating metabolite of vitamin D, reflects the availability of vitamin D in the body from both dietary and endogenous sources. In the UK, a serum/plasma 25(OH)D concentration <25nmol/L is used to indicate risk of vitamin D deficiency (DH, 1998). Data from UK DNSIYC showed that the mean serum 25(OH)D for infants aged 5-11 months was 68.6nmol/L, the lower 2.5 percentile was 12.1nmol/L and the upper 2.5 percentile was 110.0nmol/L. Six per cent of infants had a serum 25(OH)D concentration <25nmol/L and these were all being breastfed at the time of the survey (Lennox et al, 2013).

Vitamin A

6.57 Vitamin A is a fat-soluble vitamin and is required for vision, embryogenesis, growth, immune function, and for normal development and differentiation of tissues (SACN, 2005). DRVs for vitamin A were set by COMA in 1991 (DH, 1991) (Table 6.3) and dietary advice on foods and supplements containing retinol has subsequently been reviewed by SACN in its report 'Review of dietary advice of vitamin A' (SACN, 2005).

6.58 SACN noted that in dietary surveys, the recording of food intake is restricted to a short continuous time period and consequently, the habitual intake of rarely-consumed foods may be over or underestimated at an individual level (although estimates of population mean intake should be reliable). The retinol content of a few rarely-consumed foods, that is, liver and liver products, is particularly high. Consumption (or lack of consumption) of such foods during the recording period will have a substantial impact on estimates of habitual retinol intake; as a consequence, retinol intake may appear to be atypically high for some individuals and atypically low for others (SACN, 2005).

Table 6.3 DRVs for vitamin A in the first year of life[a]

Age	Lower reference nutrient intake (LRNI)	Estimated average requirement (EAR)	Reference nutrient intake (RNI)
0 – 3 months	150	250	350
4 – 6 months	150	250	350
7 – 9 months	150	250	350
10 – 12 months	150	250	350

[a] Intakes depicted in the table are in µg retinol equivalents/day

Dietary intakes of vitamin A

6.59 The UK DNSIYC reported vitamin A intakes (expressed as retinol equivalents [RE]) from all sources (including supplements) for 4 to 6 months, 7 to 9 months, and 10 to 11 (Lennox et al, 2013) (Table 6.4).

Table 6.4 Intake data for vitamin A, from all sources (including supplements), from the UK DNSIYC[a]

Age	Average daily intakes from all sources	Lower 2.5 percentile intakes from all sources	Upper 2.5 percentile intakes from all sources
4 – 6 months	952	427	2052
7 – 9 months	991	370	2081
10 – 11 months	946	278	2143

[a] Intakes depicted in the table are in µg retinol equivalents/day

6.60 These data show that for infants under 1 year, even those with the lowest intakes of vitamin A are consuming above the level of the EAR, suggesting that vitamin A insufficiency is not likely to be a public health concern for this age group.

6.61 Infant formula was the largest contributor to vitamin A intake for infants aged 4 to 6 months, 7 to 9 months, and 10 to 11 months (39%, 33% and 30%, respectively) followed by the food group 'commercial infant foods' (23%, 25% and 23%, respectively) (Lennox et al, 2013).

6.62 The government recommends that children from the age of 6 months to 5 years are given a daily supplement of vitamin A (233µg), unless they are consuming over 500ml of infant formula a day. This is a precautionary measure, to ensure that their requirements for this nutrient is met, at a time when it is difficult to be certain that the diet provides a reliable source (DH, 1994).

6.63 The COT assessment recommended a tolerable upper level (TUL) of 200µg RE/kg bw/day (COT, 2013). This would approximate to a total intake of around 700 RE at birth and 2000 RE by 1 year. Average intakes reported in UK DNSIYC were therefore close to the TUL in the first 6 months and at least 2.5% were above the TUL at all ages.

Conclusions

6.64 Iron, vitamin D and vitamin A were identified as the key micronutrients for which there were concerns regarding possible deficiency or excess in infancy in the UK.

6.65 Iron status at birth is the most important determinant of iron status throughout infancy. Cord blood ferritin concentrations are correlated with ferritin concentrations until at least 2 years of age.

6.66 Factors associated with lower iron status at birth include low birthweight, maternal iron deficiency anaemia, and other indicators of pregnancy risk including maternal obesity, smoking and gestational hypertension.

6.67 Delaying clamping of the umbilical cord until it has stopped pulsating (about 3 minutes after delivery) increases neonatal blood volume, red cell mass and therefore iron status at birth.

6.68 Healthy term infants are born with sufficient body iron stores, which along with iron in breast milk, are sufficient to meet their needs for growth and development for the first 6 months of life.

6.69 From around 6 months of age, a diverse complementary diet is needed to meet the increasing iron requirements of older infants. Complementary feeding should be given alongside continued breastfeeding or the use of infant formula as a main drink throughout the first year of life.

6.70 There is substantial evidence that consumption of unmodified cows' milk as a main drink is associated with lower iron status in infants younger than 12 months of age.

6.71 Experimental evidence on the effect of iron supplements on infant growth is mixed, with only some studies reporting a positive effect. There is evidence in infants who are iron replete that iron supplements in infancy are not protective against future deficiency and may have a detrimental effect on linear growth.

6.72 Evidence from adult studies suggests that vegetarian diets provide adequate dietary iron however there is a lack of evidence on the impact of different dietary patterns, such as vegetarian or vegan diets, on micronutrient intakes and status in infants.

6.73 In relation to vitamin D, other than the prevention of nutritional rickets, data are not available to clearly relate serum 25(OH)D concentration in the infant to current or long term health outcomes. Safe intakes rather than RNIs are therefore recommended for infants and children aged up to 4 years. Safe Intakes are based on a precautionary approach and reflect the insecurities of the data.

6.74 On this basis, a 'safe intake' of vitamin D is recommended in the range 8.5-10 µg/d (340-400 IU/d) for all infants from birth up to 1 year (whatever their mode of feeding) in the UK. Infants who consume more than 500ml of infant formula a day do not need a vitamin D supplement as infant formula is already fortified.

6.75 The UK infant diet provides ample vitamin A, even with low uptake of supplements. For some infants who habitually consume large amounts of fortified foods such as formula milk in addition to vitamin supplements, their vitamin A intake may exceed the TUL.

7 Eating and feeding of solid foods

Determinants of food acceptance

7.1 A number of biological and social factors influence food acceptance and preferences during infancy and early childhood.

7.2 The sensory characteristics of foods and the sensory stimulation produced through their ingestion, including flavour, aroma and the oral perception of food texture, are key biological determinants of eating behaviour (Small & Prescott, 2005).

7.3 The development of acceptance of the 5 basic tastes (sweet, salt, bitter, sour and umami [savoury]) is not fully understood, particularly after the first 6 months of life (Schwartz et al, 2009). Human newborns readily accept sweet taste and have the ability to distinguish quantitative differences between different sugar solutions, demonstrating a preference for sweeter solutions and those with higher sweetening power (Desor et al, 1973; Desor et al, 1977; Ganchrow et al, 1983). At birth, reactions to salty taste are neutral, ranging to rejection. However, by 6 to 24 months there is a well-marked preference for salty taste, which appears to decline by about 31 to 60 months (Beauchamp et al, 1986; Beauchamp et al, 1994). Data on the acceptance of bitter, sour and umami tastes are more equivocal. To help elucidate the development of taste acceptance, Schwartz et al investigated the development of preferences for the 5 basic tastes at 3, 6 and 12 months of age (Schwartz et al, 2009). They found that at each time point, sweet and salty tastes were most preferred, umami tastes produced neutral reactions, and bitter and sour tastes were the least accepted. In the same infants, Schwartz et al examined the impact of exclusive breastfeeding on taste acceptance (Schwartz et al, 2013). No association was found between the duration of exclusive breastfeeding and sweet, salty, sour and bitter taste acceptance at 6 or 12 months. The duration of breastfeeding was positively associated with acceptance of umami solution at 6 months but by 12 months this relationship was no longer observed.

7.4 In a systematic review of 20 studies (the majority of which are covered in this chapter), Nehring et al examined the hypothesis that fetuses and infants exposed to sweet, salty, sour, bitter, umami, or specific tastes (for example, garlic or caraway) show greater acceptance of that same taste later in life (Nehring et al, 2015). The studies comprised 38 subgroups which were considered according to the taste under investigation and the medium in which it was presented, whether the exposure was pre- or post-natal, the child's age at the start and end of the study, and the duration of exposure.

7.5 Prior exposure to bitter tastes appeared to improve acceptance of these tastes suggesting a programming effect. Findings for exposure to sweet and salty tastes and later acceptance were equivocal, while there were too few studies investigating sour taste acceptance to allow firm conclusions to be drawn (Nehring et al, 2015).

7.6 Heightened preference for sweet-tasting foods and beverages during infancy and childhood is observed globally and intakes of free sugars have risen consistently over recent years (Tedstone et al, 2015). It is speculated that the infant's predisposition to reject sour and bitter tastes represents an innate response that has evolved to protect infants against ingesting toxic foods (Rozin, 1976). Conversely, the preference for sweet tastes may have evolved to attract infants and children to sources of high energy (for example, breast milk and sweet-tasting foods such as fruit) during periods of maximal growth (Ventura & Mennella, 2011).

7.7 Innate responses to the basic tastes can nevertheless be modified by exposure to different flavours in early life (Beauchamp & Mennella, 2009; Mennella & Trabulsi, 2012).

7.8 Infants experience flavours before their first exposure to solid foods. Flavours present in the mother's diet (for example, fruit and vegetables, spices) during pregnancy, as well as those inhaled as aromas present in the environment (for example, tobacco and perfumes), may be transmitted to amniotic fluid and swallowed by the fetus (Mennella & Trabulsi, 2012).

7.9 Flavours will also be experienced by infants in breast milk, which like amniotic fluid, comprises flavours that may to some extent reflect the foods, spices and beverages consumed by the mother. Finally, the infant will be exposed to the smells of cooking and eating before the complementary feeding period commences. As a result, the types of food eaten by women during pregnancy and lactation, and therefore the characteristic flavours of their culture, may be experienced by their infants before their first exposure to solid foods and may influence infants' later acceptance of new foods (Schaal et al, 2000; Mennella et al, 2001). In this way, mothers may transmit food preferences, which have a strong cultural element, to their infants.

Environmental and social factors influencing new food acceptance

7.10 Wide cultural and regional differences in complementary feeding practices (Mennella et al, 2006) contribute to strong preferences for regional cuisines observed in infants and children (Mennella & Beauchamp, 2005).

7.11 The food preferences and eating habits of infants and young children are strongly shaped by their parents and caregivers' attitudes, beliefs and behaviour about food and feeding (Schwartz et al, 2011). Parents and carers act as models for eating behaviour which children learn to mirror (Savage et al, 2007). Parenting style is also associated with infant feeding habits, and can be defined by two main parental dimensions: demandingness (that is, behavioural control over the child) and responsiveness (that is, degree of warmth and supportiveness for the child) (Blissett, 2011). For example, a study by Moding et al found that greater caregiver responsiveness improved acceptance of new foods (Moding et al, 2014).

7.12 The feeding practices and strategies parents and carers adopt when introducing new foods impact on infants' acceptance. Restricting palatable or unhealthy foods by preventing access to and/or limiting the amount consumed is a common strategy to improve children's diets or reduce the risk of unhealthy weight gain but this may be associated with poorer self-regulation of appetite and decreased intakes of fruit and vegetables. Children may also show later preference for the restricted food and increases in consumption once prohibition is lifted (Blissett, 2011).

7.13 The use of rewards to encourage consumption of new foods can have either deleterious or positive outcomes depending on the type of reward and the behaviour that is, rewarded. For example, rewarding consumption of a new vegetable with a sweet treat tends to result in a preference for the latter and a decrease in consumption and liking for the former. Conversely, using non-food rewards tends to improve the likelihood of the new food being consumed, at least in the short-term (Birch et al, 1984).

7.14 Infant temperament is also associated with new food acceptance (Lindberg et al, 1991; Feldman et al, 2004; Haycraft et al, 2011; Forestell & Mennella, 2012; Moding et al, 2014). Infants who are less withdrawn, more approaching and exhibit less negative mood, display greater acceptance of new foods (as measured by increased consumption and feeding for longer periods). Infants' eating behaviour (enjoyment of food, slowness in eating, food and satiety responsiveness) also relates to food acceptance (Mallan et al, 2014).

New food acceptance

7.15 During the first few months, it has been suggested that infants tend to accept new foods with fewer exposures than at later ages. For example, infants younger than 3 to 4 months of age will more readily accept even quite bitter tasting formula (Mennella & Beauchamp, 1998; Mennella et al, 2011).

7.16 Moderate levels of food neophobia (defined as the reluctance to eat or the avoidance of new foods (Birch & Fisher, 1998) do not emerge until around 18 to 24 months (Cashdan, 1994; Dovey et al, 2008).

7.17 Being a 'picky' or 'fussy' eater also influences the acceptance of new foods. In contrast to neophobia, 'picky' or 'fussy' eaters are usually defined as children who consume a reduced variety of foods through rejection of a large proportion of foods that are either familiar, or unfamiliar, to them (Dovey et al, 2008). Although parents or carers may use the term 'pickiness' to describe food neophobic behaviour, evidence suggests that while inter-related, 'picky' or 'fussy' eating and neophobia are behaviourally distinct, with different factors predicting the severity and expression of the two constructs (Galloway et al, 2003). 'Picky' or 'fussy' eating can extend further than food neophobia through children rejecting not just a particular food, but also flavours and the textures and feel of foods (Smith et al, 2005). Understanding the developmental factors that hinder the acceptance and consumption of new foods is integral to determining how to positively influence children's food choices. In the US Feeding Infants and Toddler Study (among 4 to 24 month olds, n=3,022), the prevalence of children identified by their caregivers as 'picky' eaters rose from 19% to 50% from 4 to 24 months, and was nearly 30% among 7 to 11 month olds (Carruth et al, 2004a).

Evidence for a 'critical window' for the introduction of solid foods

7.18 It has been suggested that the period between 4 and 7 months of age represents a 'critical window' for the introduction of solid foods and that exclusive breastfeeding during the first 6 months might therefore constrain the window during which new flavours and textures can be successfully introduced and accepted (Fewtrell et al, 2011; Nicklaus, 2011; Mennella & Trabulsi, 2012). It is argued that if the opportunity to introduce foods is missed, there may be poorer food acceptance and more food refusal both during the complementary feeding period and later in childhood (Illingworth & Lister, 1964; Northstone et al, 2001; Mason et al, 2005; Coulthard et al, 2009; Coulthard et al, 2014). This view is, however, based on limited evidence which includes case studies (Illingworth & Lister, 1964), observational studies conducted at a time when solid foods were introduced at much younger ages and which may be prone to confounding (Northstone et al, 2001; Coulthard et al, 2009), and follow-up studies of feeding difficulties experienced by highly selected children who were tube fed prior to the introduction of solid foods (Mason et al, 2005). Conclusions drawn from this weak evidence base may not be applicable to a contemporary population of healthy term infants.

7.19 The following sections therefore:

a) explore the evidence for a 'critical window' for the introduction of solid foods
b) investigate the key factors driving the acceptance of solid foods introduced to complement the milk diet, including the effects of repeated exposure, dietary experience, and exposure to a variety of flavours and textures, to help identify potential strategies to enhance the uptake of new foods.

7.20 The difficulties in conducting experimental research on this topic should be noted. These include the ethical and feasibility issues associated with randomising infants to different feeding patterns over sufficiently long periods of time and in adequate numbers. Consequently, few trials have been conducted (Mennella & Beauchamp, 2005). Those that have been carried out vary considerably in design, sample size, age and age range, and study quality, making comparisons difficult.

Experimental evidence from studies of acceptance of protein hydrolysed formulae

7.21 Mennella et al have undertaken a series of experiments investigating the age-related changes in the acceptance of a protein hydrolysed formula (PHF). PHFs are described as extremely unpalatable, with a bitter and sour taste profile, and unpleasant odour and aftertaste (Mennella et al, 2004).

7.22 The first study (Mennella & Beauchamp, 1996), found that while infants younger than 2 months were able to detect the difference between PHF and their regular formula, they drank substantial amounts of the PHF and fed to satiation. In contrast, nearly all infants aged 7 to 8 months rejected the PHF ($p<0.001$). In a further study, Mennella and Beauchamp found a significant correlation between infants' age and PHF acceptance ($p<0.0001$), with rejection becoming apparent between the ages of 17 to 24 weeks ($p=0.003$) (Mennella & Beauchamp, 1998). They suggested that there may be a specific age window during which it is possible to introduce PHF successfully.

7.23 In subsequent RCTs Mennella et al showed that previous exposure to PHF improved its later acceptance with evidence of a dose effect (Mennella et al, 2004), and that infants exposed to PHF for 3 months were more accepting than those infants with no exposure but were less accepting than infants with 7 months exposure (Mennella et al, 2011). They also observed that infants who were first fed PHF at 3.5 months rejected it more than infants exposed at 1.5 or 2.5 months, and proposed that there may be a window for early acceptance at around 3.5 months of age (Mennella et al, 2011).

7.24 In a further RCT, Mennella and Castor found that infants fed PHF for 3 or 8 months, but not for 1 month, showed greater acceptance of a savoury broth compared with the plain broth ($p<0.01$) and consumed it at a faster rate ($p<0.01$) when tested at 8.5 months of age (Mennella & Castor, 2012).

7.25 The RCTs conducted by Mennella et al provide experimental evidence on a topic previously dominated by observational data. They have, however, all focused on the acceptance of a specific and unpalatable bitter tasting drink. It is not clear how these findings can be generalised to the broader diversification of the diet and acceptance of other tastes, or whether the findings would apply to breastfed infants who in general accept tastes more readily.

Experimental evidence from studies of acceptance of solid foods

7.26 Cohen et al conducted an RCT with the aim of determining whether the timing of introduction of solid foods to breastfed infants influenced infant appetite or acceptance of solid foods during the second half of the first year of life (Cohen et al, 1995). In a low income, Honduran population, mothers who had exclusively breastfed for 4 months were randomly assigned to continued exclusive breastfeeding to 6 months or to introduction of solid foods (either with ad libitum nursing or with maintenance of baseline nursing frequency).

7.27 By 9 months, infants in all 3 study groups were eating similar amounts and types of food, consuming a similar proportion of food offered and accepting new foods equally well. Therefore, results from this study did not support concerns that infants exclusively breastfed to 6 months would not accept a variety of foods as readily as those given solid foods at 4 months (Cohen et al, 1995).

7.28 A recent RCT in New Zealand comparing 'baby-led weaning' (BLW) with conventional feeding practice (see paragraphs 7.75 to 7.77 for more details) provides further evidence regarding the acceptance of flavours and textures (Taylor et al, 2017). In this trial, infants randomised to BLW continued exclusive breastfeeding for 4 weeks longer than conventionally fed infants (BLW median, 21.7 weeks; compared with 17.3 weeks for control infants p=0.002) and 65% of parents deferred complementary feeding to 6 months, compared with only 18% in the control arm.

7.29 At 12 months of age, parents of the BLW infants rated their infants as significantly less fussy and picky about food. These infants also displayed higher enjoyment of food at both 12 and 24 months. Even though the later introduction to foods was a consequence of following the BLW approach rather than an exposure of interest, these results suggest that the introduction to solid foods at around 6 months does not impair food acceptance and enjoyment (Taylor et al, 2017).

7.30 These RCTs reported that deferring the introduction of solid foods to around 6 months of age did not appear to impair later acceptance of food and that the age period between 4 and 6 months is not a crucial period for introduction of solid foods.

Repeated exposure and food acceptance

7.31 It is postulated that repeated consumption of new food and flavours, when not associated with a negative gastrointestinal consequence, improves acceptance (Birch et al, 1998) and a number of studies have been conducted to more closely ascertain the number and type of exposures required to achieve this.

7.32 It has also been proposed that vegetables should be introduced as the first solid foods to facilitate acceptance and improve intakes of vegetables in both the short and long term (Fildes et al, 2015). A number of studies have used first exposure to vegetables and fruit as an experimental model to examine the impact of repeated exposure and variety on food acceptance.

Experimental evidence

7.33 In a longitudinal study, Sullivan and Birch examined the impact of dietary experience and type of milk feeding on the acceptance of new vegetables in 36 infants aged between 4 and 6 months who were randomised to 4 treatment groups receiving green beans or peas which were either salted or unsalted, 10 times over 10 days (Sullivan & Birch, 1994).

7.34 All infants increased their intake ($p<0.001$) regardless of the type of vegetable consumed or whether salt was added. Although there was no initial difference, after repeated exposure breastfed infants had greater increases in intake of the vegetable and an overall higher intake compared with formula fed infants. No dietary data were collected from mothers and it was therefore not possible to investigate whether exposure to flavours transmitted through breast milk influenced the breastfed infants' acceptance or intake of other vegetables (Sullivan & Birch, 1994).

7.35 Birch et al further investigated infants' initial reluctance to consume new foods and the factors that might ameliorate this response by studying 39 infants aged 16 to 31 weeks, who were offered repeated exposures to a new food over 10 days. A significant increase in infants' intake of the target food was observed after one day and continued to increase during the exposure period. While intakes of the same and similar foods increased with target food exposure, intake of different foods was unchanged (Birch et al, 1998).

7.36 Maier et al investigated whether consumption of an initially disliked vegetable improves with repeated exposure. In the first few weeks of complementary feeding, 49 mothers were asked to identify a vegetable puree that their infant disliked and that they normally would not offer again. At a mean age 7.0 (±0.9) months mothers were asked to offer that vegetable on alternate days for 16 days, and to offer a well-liked one (carrot puree) on the other days. Over the following days, mean intake of the initially disliked vegetable increased ($p<0.0001$) and by the eighth exposure was similar to that of the liked vegetable. After 8 exposures more than 70% of the infants consumed the initially disliked vegetable (Maier et al, 2007a). Nine months after the exposure period, 63% of the infants (aged 15-19 months) were reported as still eating and liking the initially disliked vegetable.

7.37 These findings of Birch et al and Maier et al suggest that acceptance of new foods is enhanced by repeated presentations (Birch et al, 1998; Maier et al, 2007a). In contrast, observational evidence suggests that caregivers tend to present foods on relatively few occasions (usually less than 5) before concluding that the infant will not consume the food (Carruth et al, 2004a; Maier et al, 2007b).

7.38 Subsequent trials have sought to investigate the effects of repeated exposure exclusively to vegetable or fruit purees at the start of the complementary feeding period on later acceptance and intake of these foods (Barends et al, 2013; Barends et al, 2014). Infants (mean age 5.4±0.8 months) were randomly assigned to 4 treatment groups, 2 receiving vegetable (green beans or artichoke) purees and the other 2 receiving fruit (apple or plum) purees for 18 days. On day 19, the vegetable groups received their first fruit puree and the fruit groups their first vegetable puree. Repeated exposure to vegetables increased infants' vegetable intake but not fruit intake, while repeated exposure to fruits had no effect on vegetable intake but increased fruit intake. From the start, fruit intake was higher than vegetable intake (Barends et al, 2013).

7.39 In a follow-up study at 12 months of age, the authors reported daily intake of vegetables was 38% higher in the vegetable groups than in the fruit groups ($p=0.02$), but by 23 months of age, intakes were similar across vegetable and fruit groups (Barends et al, 2014).

7.40 This trial provided evidence that repeated exposure to vegetables improves acceptance, but that exposure to fruit does not result in improved acceptance of vegetables. This finding informed the design of studies investigating other factors influencing food acceptance during the complementary feeding period which are explored below.

Influence of exposure to a variety of flavours on new food acceptance

7.41 There is evidence that breastfed infants are more likely to accept new foods (Sullivan & Birch, 1994) and it is postulated that this may be because they experience a variety of flavours transmitted via breast milk (Mennella & Beauchamp, 1991; Forestell & Mennella, 2007; Maier et al, 2007b; Maier et al, 2008).

Experimental evidence

7.42 Forestell and Mennella randomly assigned 45 infants aged 4 to 8 months, of whom 44% were breastfed and had never received infant formula, to receive either green beans alone, or green beans followed by peaches, at the same time of day on 8 consecutive days (Forestell & Mennella, 2007). Initially, when first introduced to peaches, the breastfed infants consumed more and displayed fewer negative facial responses than the formula fed infants. However, there was no significant difference for the initial intake of green beans.

7.43 Repeated dietary exposure to green beans, with or without peaches, increased infants' consumption of green beans ($p<0.001$) in both breast and formula fed infants. There was a reduction in distaste facial expressions after 8 days in infants fed green beans and peaches together, but not in infants exposed only to green beans (Forestell & Mennella, 2007).

7.44 These findings are consistent with previous research suggesting that liking for a bitter tasting vegetable (or beverage) is enhanced if it is associated with sweet tastes (Stein et al, 2003; Havermans & Jansen, 2007).

7.45 Gerrish and Mennella randomised 48 formula fed infants to 3 groups who, over a 9 day exposure period, were fed only carrots, only potatoes or a variety of vegetables that did not include carrots, and then assessed their relative acceptance of carrot (assessed before and after exposure) and their acceptance of a new meat, chicken (assessed after exposure) (Gerrish & Mennella, 2001). Infants in the carrot and variety groups, but not those in the potato group, ate more carrots than at baseline (p=0.002 and p=0.003, respectively). Infants in the variety group also showed enhanced acceptance of chicken when compared with the carrot group (Gerrish & Mennella, 2001). However, a number of outcomes were assessed and therefore some of the findings may have occurred by chance.

7.46 Maier et al went on to study 147 breast or formula fed infants allocated to 3 groups at mean age 5.2 (Standard error of mean 0.1) months (Maier et al, 2008). All received carrot puree as a first meal and, over the next 9 days, group 1 received carrots daily, group 2 had 3 vegetables each given for 3 consecutive days, and group 3 had the same 3 vegetables but with daily changes. On the 12th and 23rd days, the infants' acceptance of 2 new vegetable purees was assessed, and around 22 days later acceptance of meat and fish was also assessed.

7.47 The high vegetable variety group (group 3) showed the greatest increase in intake of the new foods while breastfeeding infants had higher intakes with a significant interaction between type of milk feeding and degree of variety. This effect was still detectable 2 months later. Both breastfeeding and high variety were associated with higher liking scores as rated by mothers (p=0.005 and p<0.0001, respectively) and observers (p=0.008 and p<0.0001, respectively) (Maier et al, 2008).

7.48 As a follow up to this study at age 6 years, 75 (51%) children completed consumption and liking tests in an experimental setting (Maier-Noth et al, 2016). At this age, previously breastfed infants were reported as eating and liking more vegetables than those who had been formula fed, but after adjustment for this, children who had experienced high vegetable variety at the start of the complementary feeding process ate significantly more of the new vegetables, liked them more and were more willing to taste vegetables than those in the no or low variety group.

7.49 Findings from Gerrish and Mennella suggest that exposure to a variety of flavours (albeit still relatively limited at this stage) at the start of the complementary feeding period enhances the acceptance of new foods (Gerrish & Mennella, 2001). Maier's study similarly suggests that acceptance of new foods is enhanced by making frequent changes in the foods offered and that this effect may persist into mid childhood (Maier et al, 2008; Maier-Noth et al, 2016).

7.50 The impact of variety was further investigated in a European multi-centre intervention study (Fildes et al, 2015). Mothers of 146 infants aged 4 to 6 months were randomised to either receive advice to introduce 5 vegetables (one per day) as first foods over 15 days (n=75), or receive country-specific standard government complementary feeding guidance (n=71). One month after the intervention, infants' consumption and liking of a new, unfamiliar, vegetable was assessed.

7.51 The combined results for the 3 countries showed no significant intervention effect by individual country, however, in the UK sample there was a significant effect on intake and liking of the unfamiliar vegetable, while there was no effect in the Greek or Portuguese sample. The authors postulated that an effect was only seen in the UK sample because the Greek and Portuguese control families already had high intakes of vegetables as first foods (Fildes et al, 2015).

7.52 To explore the effect of exposure to a single food or variety of foods on new food acceptance, Mennella et al studied 74 infants aged 4 to 9 months (Mennella et al, 2008). In the fruits study, infants were exposed to one fruit (pears) or a variety of fruits (not including pears) at home for 8 days. At the end of this period, infants' acceptance of pears and of green beans was evaluated; intake of pear but not of green beans increased for both groups.

7.53 In the vegetables study, infants were split into three groups: 1) daily exposure to only green beans, 2) variety of vegetables between the target meals (given on days 1 and 11) (BM), and 3) variety of vegetables both between meals and within the target meals (BM-WM). The BM group received only one vegetable each day (green and orange vegetables alternated daily) while the BM-WM group were fed two vegetables each day (one green, one orange) (Mennella et al, 2008).

7.54 After 8 days of exposure, infants in the BM-WM vegetable variety group had increased their intake of green beans ($p=0.002$) as well as a carrots/spinach combination ($p=0.03$) but repeated exposure to a variety of vegetables between meals (BM group) did not affect acceptance of carrots and spinach. Intake of green beans tended to increase in infants exposed to green beans alone or to a variety of vegetables between meals ($p<0.08$) (Mennella et al, 2008).

7.55 This study demonstrated again that repeated exposure leads to greater acceptance, but did not find that exposure to other fruits and vegetables enhanced the acceptance of bitter foods such as green beans. The sample, however, was too small to detect any but the largest of treatment effects.

7.56 Coulthard et al recruited 60 infants one week after starting solid foods and compared those starting before or after 5.5 months (mean age of introduction 4.5 versus 5.9 months) (Coulthard et al, 2014). Infants' acceptance of carrot was measured at baseline. The 2 groups of infants were divided further so that half of each group received carrot every day while the other half were given a variety of vegetables for a 9 day exposure period. At the end of this period, neither age at introduction of solid foods, nor exposure type, affected consumption of carrot or of a new food, pea puree. Infants who had been introduced to complementary feeding later and exposed to a variety of vegetables, consumed more of the new food (pea puree) than those who had only received carrots, but the interaction was of only borderline significance and in the absence of a main effect may be a chance finding (Coulthard et al, 2014).

7.57 Hetherington et al recruited 36 infants before solid foods were introduced (Hetherington et al, 2015). Infants were randomised to receive 12 daily exposures to vegetable puree added to the infants' usual milk, followed by 12 x 2 daily exposures to vegetable puree added to rice (intervention group) or to receive plain milk and rice (control group). Both groups then received 11 daily exposures to vegetable puree.

7.58 At the end of this 35 day period, the intervention group consumed more vegetables than the control group, ate them more rapidly, and liked them more (according to investigator ratings). However the improvement was specific to the exposed vegetables, with no enhanced acceptance of an unfamiliar vegetable and there were no group differences at 6 and 18 months follow up (Hetherington et al, 2015).

7.59 This study suggests that repeated presentation of vegetables in one form enhances later acceptance in a different form, but that the effect does not persist beyond the first few weeks.

Observational evidence

7.60 In a longitudinal study of 203 French infants (Lange et al, 2013), mothers recorded each new food offered from the beginning of the complementary feeding period (mean age 5 months) to the age of 15 months and scored acceptance of each of the first 4 foods presented.

7.61 Neither the duration of exclusive breastfeeding nor the age at introduction of complementary feeding was related to infants' acceptance of new foods. Fruits and vegetables were the least well accepted food categories, but earlier introduction of vegetables was associated with better acceptance of subsequent new vegetables. The total number of new foods offered during the 2 month period after complementary feeding commenced (that is, food variety) was associated with the acceptance of new foods ($p=0.02$) until 15 months of age. This was most marked for fruit ($p=0.04$), vegetables ($p=0.002$) and meat ($p=0.02$) (Lange et al, 2013).

Effects of textural characteristics of food on new food acceptance

7.62 It is has been suggested that delay in the introduction of chewable, more lumpy textured foods may compromise acceptance of new textures at later ages, adversely affecting the variety of the diet (Nicklaus, 2011). The evidence supporting this hypothesis is limited, however, to 3 observational studies.

Experimental evidence

7.63 In 70 one year old infants, Blossfeld et al examined acceptance of cooked carrots presented in two different textures, pureed and chopped (Blossfeld et al, 2007). Infants consumed more of the pureed carrots than the chopped carrots ($p<0.001$) and mothers' rated their infants' enjoyment of this texture as higher (p<0.01). Being introduced earlier to complex textures or chopped foods was positively associated with the amount of chopped carrots eaten and children with more teeth and higher dietary variety also consumed more. Food responsiveness and willingness to consume new foods were positively associated with consumption of chopped carrots, while pickiness and fussiness were negatively associated (Blossfeld et al, 2007).

Observational evidence

7.64 Northstone et al used questionnaire data from the UK ALSPAC to describe the dietary patterns of infants in the UK at 6 and 15 months of age (Northstone et al, 2001). Infants were divided into 3 groups according to the age at which 'lumpy' solid foods were first introduced: 1) before 6 months of age (n=1,006), 2) between 6 and 9 months (n=6,711), and 3) after 10 months of age (n=1,643). The majority of infants had commenced complementary feeding between the ages of 3 and 4 months as was recommended at the time of the study (DHSS, 1988).

7.65 Compared with infants introduced between 6 and 9 months, infants given lumpy solid foods after 10 months were significantly less likely to be having family foods. However, there was very little difference between those introduced before 6 months and those introduced between 6 and 9 months in the proportion of children having family foods. At both 6 and 15 months, mothers reported more feeding difficulties in those infants subsequently introduced to lumpy solid foods at 10 months or older (Northstone et al, 2001).

7.66 Coulthard et al followed up 7,821 of these children up at age 7 years, using similar groups: 1) lumpy solid foods under 6 months of age, 2) 6 to 9 months, and 3) 10 months or older (Coulthard et al, 2014). Children starting lumpy solid foods after the age of 10 months ate significantly fewer of many of the food groups, notably fewer fruit and vegetables, and had significantly more feeding problems compared with children starting lumpy foods between 6 and 9 months of age.

7.67 This study found an association between delayed introduction of lumpy foods with acceptance at later ages and feeding problems at school age. Being observational there is a possibility of confounding and reverse causation, although the authors did adjust for baseline demographic and some dietary and behavioural factors (Coulthard et al, 2014).

7.68 The SWS examined the timing of introduction of solid foods in relation to later feeding difficulties (Hollis et al, 2016). Parents were surveyed when children were 3 years of age, using the same ALSPAC questionnaire. The 2,389 infants were grouped according to whether they were introduced to any solid foods 1) before 4 months, 2) between 4 and 6 months (reference group), and 3) at or after 6 months of age.

7.69 Concerns about feeding were common at 3 years of age but, after adjusting for potential child and maternal confounding factors, there were no significant differences between the 3 feeding groups for 5 specific feeding difficulties (not eating sufficient foods, refusing to eat the right food, being choosy with food, over eating or being difficult to get into a routine). However, an inverse association was found between the general feeding difficulty question and age of introduction of solid foods, with children introduced to solid foods at or after 6 months of age having a lower relative risk of feeding difficulties (RR 0.73; 95% CI 0.59 to 0.91; p=0.004) than children introduced to solid foods earlier.

7.70 These observational studies report associations between the age of introduction of all solid foods and of lumpy or textured foods with food acceptance and feeding problems at later ages. The SWS found little relationship between when solid foods were introduced and later individual feeding problems, but did find a tendency to fewer problems in those starting solid foods later (Hollis et al, 2016). Blossfeld et al found that the longer the experience of textured foods the better they were accepted at age 1 year, but that fussier infants or neophobic infants were less likely to accept them (Blossfeld et al, 2007). However, the ALSPAC found that children who started more lumpy solid foods after the age of 10 months were slightly more likely to have feeding problems later in childhood (Northstone et al, 2001; Coulthard et al, 2009). This suggests that some children may be inherently less willing to accept textured foods than others, but that as with flavour acceptance, repeated exposure is likely to be important.

Caregiver feeding practices

7.71 Research in humans (Mennella & Beauchamp, 1996; Mennella & Beauchamp, 1997) and in animal models (Kuo, 1967; Capretta et al, 1975; Hennessy et al, 1977) suggests that exposure to a variety of flavours during complementary feeding enhances the acceptance of new foods leading to consumption of a varied diet.

Responsive feeding

7.72 'Responsive feeding' is a form of 'responsive parenting', in which parents are aware of their child's emotional and physical needs and react appropriately to their child's signals of hunger and fullness (Black & Aboud, 2011). Responsive feeding avoids over-controlling feeding practices, such as strict rules on how much to feed and forcing or pressuring children to eat, and also discourages indulgent and uninvolved feeding styles, in which the parent feeds the child in response to any sign of upset or in a disorganised manner. Interventions to promote caregiver responsive feeding have reported beneficial effects on caregiver feeding behaviour and on the quality of the infant diet (Redsell et al, 2016; Hohman et al, 2017).

7.73 The INSIGHT randomised clinical trial, initiated in 2012 in the USA (n=291), investigated the effect of a responsive parenting intervention (including responsive feeding) on childhood obesity (Savage et al, 2016; Hohman et al, 2017). In particular, Savage et al examined the effect of the INSIGHT intervention on infant weight gain at 6 months and on overweight status at 1 year compared with a control group. The INSIGHT intervention was associated with slower than average pattern of weight gain during the first 6 months and this effect did not differ by feeding mode. Infants in the INSIGHT group also had lower mean weight-for-length percentiles at 1 year compared with infants in the control group and were less likely to be overweight at age 1 year (5.5% versus 12.7%; p=0.05) (Savage et al, 2016). These results suggest that parental responsive feeding has beneficial effects in the context of obesity prevention.

Baby-led weaning

7.74 Proponents of BLW, where the infant is left to entirely self-feed from the outset, with no spoon-feeding, argue that the pace of complementary feeding can be determined by the infant's acquisition of gross and fine motor skills (Rapley, 2011). It is hypothesised that this approach is less coercive and enables infants to regulate their energy intake more effectively.

7.75 In the only randomised trial of BLW to date, the BLISS Study in New Zealand, Taylor et al tested the hypothesis that compared with conventional feeding BLW would lead to lower BMI and better energy regulation (that is, a higher satiety responsiveness) (Taylor et al, 2017). The trial used a modified form of BLW designed to minimise the risk of choking and iron deficiency and mothers randomised to BLW were also supported by extra contacts with a lactation consultant (Daniels et al, 2015). One hundred and five mothers were randomised to BLW and 101 to standard complementary feeding and followed up at 12 and 24 months of age.

7.76 There was no significant difference in the primary outcome measure of child's BMI-for-age z-score at 12 or 24 months. At 24 months, 10.3% in the BLW group had BMI >95th percentile compared with 6.4% in the control group (RR 1.6; 95% CI 0.5 to 5.3) (Taylor et al, 2017). However, as follow up was only to 24 months of age, an effect on obesity later in childhood cannot be entirely ruled out.

7.77 The infants randomised to the BLW arm of the study were exclusively breastfed for a median of 4.4 weeks longer (p=0.02) and 65% of their parents deferred complementary feeding to 6 months, compared with only 18% in the control arm. BLW infants had significantly lower food fussiness and were less likely to be described as 'picky' at age 12 months. BLW infants also showed higher enjoyment of food at both 12 and 24 months and were more likely to feed themselves most or all of their food than control infants at every age (until 24 months) (Taylor et al, 2017). There were no significant differences in choking risk (Fangupo et al, 2016) or iron intake and status (Daniels et al, 2016) between the two groups.

7.78 Previously, a retrospective observational study had reported that children aged 20 to 78 months of parents who had adopted BLW (n=92) were slightly less likely to be overweight or obese (14% versus 16%) and more likely to be underweight (4.7% versus 0) compared with children of parents who had followed the traditional spoon-feeding approach (n=63) (Townsend & Pitchford, 2012). The retrospective and observational study design makes these findings liable to confounding and reverse causation, that is, parents had resorted to spoon-feeding of already more demanding and heavier infants. Duration of breastfeeding also differed substantially between the groups (BLW group 24 ± 11 months; SF group 10 ± 9 months, $p<0.0001$).

7.79 Two large cross-sectional observational studies reported that BLW was associated with earlier exposure to family foods (Brown & Lee, 2011), but one of these also found an association with low iron-containing foods (Cameron et al, 2013). The authors noted that only around a third of mothers who described themselves as using BLW fully adhered to it, with most also offering some spoon-feeding.

7.80 These results suggest that when compared with spoon-feeding, a BLW approach promotes self-feeding and results in a positive attitude to food (more enjoyment and less fussiness) and earlier exposure to family food. In addition, both experimental and observational studies have reported a longer duration of exclusive breastfeeding and later introduction to solid foods as a consequence of following a BLW approach.

Conclusions

7.81 The existence of a 'critical window' for the acceptance of solid foods between 4 and 6 months is not supported by experimental evidence. Deferring the start of complementary feeding to around 6 months of age is not associated with later difficulty in acceptance of solid foods.

7.82 Observational evidence suggests that breastfed infants may more readily accept new foods than infant formula fed infants.

7.83 Experimental evidence shows that fruit and sweet vegetables are well accepted at every age compared with bitter tasting vegetables. Exposure to fruit does not increase acceptance of vegetables. It is not clear whether pairing sweet with bitter foods increases initial acceptance.

7.84 A range of evidence indicates that repeated exposure to new foods enhances their acceptance, though the number of exposures required varies depending on the age of the child and the flavour in question.

7.85 Some experimental evidence suggests that offering a variety of foods helps to increase acceptance of new flavours, while observational evidence suggests that greater exposure in terms of variety and frequency is associated with enhanced subsequent acceptance.

7.86 Skills such as munching and chewing can only be acquired with experience and exposure to progressively firmer food textures. There is insufficient evidence to give detailed guidance on the speed of progression of solid food textures, but observational evidence suggests that exposure to lumpy foods before 9 months may be beneficial.

7.87 Interventions to promote responsive feeding, a derivative of responsive parenting, have reported beneficial effects on the quality of the infant diet in the context of obesity prevention.

7.88 There is limited evidence on the BLW approach to complementary feeding. However, a single trial reported that a 'BLW approach' did not have a significant effect on the primary outcome of BMI, but did result in earlier self-feeding, less food fussiness and greater enjoyment of food (secondary outcomes self-reported by parents). With appropriate guidance, BLW did not appear to decrease energy or micronutrient intakes.

8 Oral health

Oral health of children in the UK and impact of poor oral health

8.1 Oral health is part of general health and wellbeing and contributes to the development of a healthy child. Dental caries (tooth decay) is the destruction of susceptible dental hard tissues caused by acidic by-products from the bacterial fermentation of dietary carbohydrates by oral bacteria (Marsh & Martin, 1999). This acid causes a drop in pH levels which makes the tooth susceptible to demineralisation. Demineralisation is reversible in the early stages of the process and dental caries in enamel may remineralise. Fluoride aids this remineralisation process by acting as a catalyst for the diffusion of calcium and phosphate (Selwitz et al, 2007).

8.2 Tooth decay in early childhood is known as early childhood caries (ECC) and is defined as one or more decayed, missing or filled (DMF) tooth surface in any primary tooth of children aged under 71 months. In children younger than 3 years of age, any sign of decay on the smooth surface of the teeth is indicative of severe early childhood caries (S-ECC) (American Academy of Pediatric Dentistry, 2008).

8.3 Dental caries is largely preventable; however it is still the most common oral disease affecting children and young people. Poor oral health impacts on children and families' wellbeing and is costly to treat. Children may experience pain, discomfort, acute and chronic infections, eating and sleep disruption as well as a higher risk of hospitalisation. Dental decay may affect nutrition, growth and weight gain as toothache and infection alter eating and sleeping habits, dietary intake and metabolic processes.

8.4 In 2012-2013, dental caries was the most common reason for hospital admission for children aged 5 to 9 years in England (Health and Social Care Information Centre, 2015a). Over 60,000 children aged 0 to 19 years were admitted to hospital to have teeth removed under general anaesthesia in 2015-2016 (PHE, 2016a). This pattern is similar or worse in Scotland, Wales and Northern Ireland.

8.5 Although the oral health of 5 year olds across the UK is improving, in 2015 almost a quarter (24.7%) of 5 year old children in England started school with dental caries, with on average 3 or 4 teeth affected (PHE, 2016b). In the devolved nations, the prevalence of tooth decay at 5 years of age is even higher: 31% of 'Primary 1' children in Scotland had dental caries (NHS National Services Scotland, 2016), 40% in Northern Ireland (Health and Social Care Information Centre, 2015b), and for children in 'Reception' in Wales (2014/15) the prevalence was 35% (Cardiff University, 2016)[7].

[7] Children in Reception and Primary 1 are 4 to 5 years old.

8.6 Poor oral health is associated with material deprivation with children living in deprived communities having poorer oral and general health when compared with their more affluent peers (Marmot & Bell, 2011); these inequalities have been demonstrated in the devolved nations where children from poorer backgrounds experienced the most decay (Morgan & Monaghan, 2015; Scottish Dental Epidemiology Coordinating Committee, 2016; The Northern Ireland Statistics and Research Agency, 2016). Disparity can also be seen across the English regions: 33% of 5 year old children in the North West experienced decay compared with 20% in the South East of England (PHE, 2016b).

8.7 The first survey of the oral health of 3 year old children in England found that 12% had experience of dental caries and those that had dental caries had, on average, 3 teeth affected. The early onset of this disease suggests that infant feeding practices, such as bottle feeding and type of complementary feeding, may be associated with the development of dental caries as might the delayed commencement of toothbrushing and/or lack of fluoride toothpaste (PHE, 2014).

UK guidance for oral health improvement

8.8 Evidence based guidance for oral health improvement in England, including the prevention of dental caries, is covered in 'Delivering better oral health – an evidence based toolkit for prevention' (PHE, 2014). The guidance relating to dental caries prevention in infants and young children (under 3 year olds) reiterates infant feeding advice (see paragraph 1.23) and also recommends that:

- from around 6 months of age infants should be introduced to drinking from a free-flow cup, and from age 1 year feeding from a bottle should be discouraged
- sugars should not be added to foods or drinks
- the frequency and amount of sugary foods and drinks should be reduced
- parents/carers should brush or supervise toothbrushing
- start brushing as soon as the first tooth appears (usually at about 6 months of age), at least twice a day with fluoride toothpaste last thing at night and on at least one other occasion
- see a dentist as soon as the first tooth appears and no later than the first birthday (British Society of Paediatric Dentistry, 2018)
- use fluoridated toothpaste containing no less than 1,000 pm fluoride
- use only a smear of toothpaste.

8.9 Similar advice is provided in the NICE Public Health Guideline which states that parents and carers should be encouraged "to offer drinks in a non-valved, free-flowing cup[8] from age 6 to 12 months", discourage feeding from a bottle from 1 year onwards, provide milk and water to drink between meals, and discourage parents and carers from offering baby juices or sugary drinks at bedtime (NICE, 2014b).

8.10 Free-flow cups (or beakers) are recommended because these enable the child to learn the skill of sipping which is important in the development of the muscles used in talking (American Dental Association, 2004).

8.11 Fluoride in water can reduce the likelihood of experiencing dental decay and minimise its severity. Evidence reviews confirm that it is an effective, safe public health measure suitable for consideration in localities where levels of dental decay are of concern (Iheozor-Ejiofor et al, 2015; PHE, 2018). The 2015 Cochrane review looked at before and after studies that met the reviewers' criteria for inclusion, concluding that the introduction of water fluoridation resulted in children having 35% fewer decayed, missing and filled baby teeth and 26% fewer decayed, missing and filled permanent teeth. They also found that fluoridation led to a 15% increase in children with no decay in their baby teeth and a 14% increase in children with no decay in their permanent teeth (Iheozor-Ejiofor et al, 2015).

Maternal diet and infant feeding practices that may impact on tooth formation and decay experience in the first 12 months of life

8.12 Maternal diet and nutritional status before and during pregnancy can directly influence the formation and structural integrity of both the primary and permanent dentition during fetal growth. Cells in the oral cavity of the fetus start to differentiate to form the primary teeth at around 6 weeks post conception, with tooth mineralisation beginning at around 4 months gestation with the formation of dentine (the foundation for the deposition of enamel) (Jontell & Linde, 1986; Ligh et al, 2011). Exposure to teratogens during pregnancy or severe maternal nutrient deficiencies can impact on the development of the primary teeth and those permanent teeth that start to form during pregnancy (Gardiner et al, 2008).

8.13 There is no evidence that consumption of fluoride supplements (such as tablets, drops, lozenges or chewing gum) by women during pregnancy is effective in preventing dental caries in the primary teeth of their children (Leverett et al, 1997; Takahashi et al, 2017). It is thought that fluoride can cross the placenta (WHO, 2002; US Public Health Service, 2003). However, as the placenta may act as a partial barrier, the pre-eruptive effects of water fluoridation on the primary dentition is unclear (Shimonovitz et al, 1995).

[8] Cups and beakers should be free-flowing vessels. Cups that can be turned upside down and retain the liquid using a non-drip (spill) valve should not be used.

8.14 The oral microbiome of infants is influenced by mode of delivery; infants delivered vaginally are exposed to different microorganisms than those delivered by C-section and this may affect colonisation patterns in the oral cavity (Holgerson et al, 2011). This microbial colonisation initiates maturation of the infant's immune system and alterations to the microbiota may result in illness or increased risk of infection particularly in infancy.

8.15 Mode of feeding (breastfeeding versus infant formula feeding) has also been found to influence the infant oral microbiome and this may have implications for child health and long term human health (Holgerson et al, 2013).

8.16 The nutritional composition of the infant diet can also have a direct effect on tooth development pre-eruption, and both the nutritional composition and the erosive characteristics of the infant diet can affect tooth tissue post-eruption. The literature in this area has not been reviewed as part of the 'Feeding in the first year of life' review and will instead be considered in future risk assessments of the evidence covering young children (aged 12-60 months) and the health of women of reproductive age. The role of illnesses during pregnancy (and maternal health in general), antibiotics and dummy use have not been examined in this report and are considered outside the scope.

8.17 Teeth begin to erupt into the oral environment at around 6 months of age and it would be normal for infants to have both their upper central and lateral incisors erupted before 12 months of age (American Dental Association, 2005). As dental caries take a finite time to develop once the teeth have erupted, any feeding practices that increase the risk of dental caries are likely only to show effects (in terms of dental caries) after the age of 12 months of age (Selwitz et al, 2007).

8.18 The evidence relating to infant feeding and dental decay is inconsistent. Factors that have been explored include: the carbohydrate content of breast milk or infant formula; factors which determine the length of contact between breast milk or infant formula and the erupted dentition (that is, frequency of feeding and feeding practices which result in pooling of breast milk or infant formula around the teeth surfaces); and age of colonisation and levels of cariogenic bacteria (for example, Streptococcus mutans) in an infant's mouth. The growth and adhesion of cariogenic bacteria, particularly oral Streptococci, are inhibited by breast-specific Lactobacilli and substances including human casein and secretory IgA in breast milk which are not found in infant formula (Danielsson et al, 2009; Holgerson et al, 2013).

8.19 The risk of dental caries is also dependent on the presence of teeth and rises with increasing number of teeth. The primary teeth most at risk of early childhood caries (8 upper and lower central and lateral incisors) start to erupt at 6 months and are fully erupted by 12 months of age. The most vulnerable primary teeth (4 upper and lower first molars) erupt between 13 and 19 months, and the remainder are erupted by 33 months of age (Tham et al, 2015). The 'Feeding in the first year of life' review is focused on infant feeding practices up to the age of 12 months however, the risks and effects of infant feeding up to 1 year on the dentition are often observed in children older than 12 months of age. With diversification of the infant diet to include foods and drinks other than breast milk or infant formula, so risk changes depending on the free sugars content of the foods (and drinks) and how frequently such foods (and drinks) are consumed.

8.20 Potential confounding factors need to be taken into account when considering the impact of infant and young child feeding practices on risk of dental caries. For example, formula fed infants may be more likely to be given sugar-sweetened beverages in a bottle than infants who are being breastfed, while some parents/carers are more likely to follow advice on toothbrushing than others.

Breastfeeding practices and dental caries

8.21 In a systematic review, Tham et al identified 63 papers reporting on associations between breastfeeding and ECC and used this evidence to assess the potential impact of breastfeeding when undertaken up to 12 months of age and for over 12 months of age, on risk of dental caries (Tham et al, 2015).

8.22 The quality of the studies within this systematic review was assessed using the Newcastle-Ottawa Scale (NOS) assessment which examined the following categories (which are independently scored a maximum of two per category): representativeness, selection of non-exposed cohort, ascertainment of exposure, outcome of interest not present at start, comparability, assessment of outcome, adequate follow-up time and adequate follow-up of cohorts.

8.23 Tham et al identified two cross-sectional studies that compared breastfeeding 'ever' within the first 12 months versus breastfeeding 'never' within the first 12 months (Tham et al, 2015). These studies were categorised as 'satisfactory' in quality using the NOS Assessment for Cohort Studies. Both studies demonstrated a protective effect of breastfeeding when considering dental caries compared with other feeding (Du et al, 2000; Qadri et al, 2012), however, they were undertaken in China and Syria respectively and the generalisability to UK populations may therefore be limited. Furthermore, data were collected retrospectively; children's feeding practices were assessed by questionnaire when the children were between 2 to 4 years and 2 to 5 years of age, which might result in recall bias and weakened confidence in the strength of the findings.

8.24 Tham et al also identified a prospective cohort study which was designed to assess the association between infant breastfeeding and caries experience in US children (Hong et al, 2014). The study had a sample of 509 subjects recruited from birth for whom the following data were collected: 2 clinical dental exams (at 5 and 9 years old), and demographic and breastfeeding information collected via questionnaires. This study was rated as good using the NOS assessment although Tham et al reported that the study did not have an adequate follow up of their cohort (Tham et al, 2015).

8.25 The study observed that at 5 years of age, 16% of children who were breastfed for less than 6 months had caries (mean decayed filled surface=0.55) while only 9% of children who were breastfed for at least 6 months had caries. From 5 to 9 years old, caries incidence was 32% and 31%, respectively, for children breastfed less than 6 months and for at least 6 months. In multivariable regression analyses, shorter breastfeeding duration was positively associated with caries experience at 5 years old (p=0.005), both before and after controlling for other important factors (Hong et al, 2014). Tham et al concluded that infants who were breastfed in the first 12 months of life had fewer carious teeth compared with formula fed babies (Tham et al, 2015).

8.26 Tham et al also reviewed the evidence relating to dental caries and breastfeeding on demand in urban India (Prakash et al, 2012) and breastfeeding ad libitum during the night in Brazil (Azevedo et al, 2005) and in Sri Lanka (Perera et al, 2014). Three further studies examined the impact of sleeping with the breast in the mouth (Sayegh et al, 2005; Johansson et al, 2010; Retnakumari & Cyriac, 2012). These studies were undertaken in deprived communities in Jordan, Boston (USA) and Kerala (India) and the generalisability to UK-based populations may therefore be limited. Using the NOS, the studies were assessed and scored for quality and were found to be of variable quality, with only one study controlling for confounders (Sayegh et al, 2005).

8.27 Although frequently analysed as separate behaviours, nocturnal breastfeeding, breastfeeding on demand, and an infant falling asleep with the breast in the mouth, are often interrelated. The studies considered by Tham et al found significant correlations between these breastfeeding practices in early childhood and an increased prevalence of dental caries (Tham et al, 2015).

8.28 Tham et al included studies where children were breastfed beyond 12 months. When infants are no longer exclusively breast or formula fed, confounding factors, such as the consumption of potentially cariogenic drinks and foods and toothbrushing practices, need to be taken into account when investigating the impact of infant feeding practices on caries development. Tham et al noted that the studies (Sayegh et al, 2005; Johansson et al, 2010; Retnakumari & Cyriac, 2012) did not control for possible confounders such as the introduction of solid foods and toothbrushing with a fluoride toothpaste (Tham et al, 2015).

8.29 A single prospective cohort study of Brazilian children by Feldens et al investigated the relationship between feeding practices in the first year of life (assessed at 6 and 12 months of age; n=500 at baseline) and the occurrence of S-ECC at 4 years of age (n=340; any sign of smooth-surface caries is indicative of S-ECC) (Feldens et al, 2010). This study was rated 'good' for its quality using the NOS scale overall, however, was scored as poor with regards to comparability of the cohorts within the study (Tham et al, 2015).

8.30 A higher adjusted risk of S-ECC at 4 years was observed when dietary practices at 12 months included: breastfeeding over 7 times daily (RR 1.97; 95% CI 1.45 to 2.68) compared with once or twice daily or not breastfed; intake of foods with a high density of sugar (RR 1.43;

95% CI 1.08 to 1.89); bottle use for liquids other than milk (RR 1.41; 95% CI 1.08 to 1.86); and more than 8 meals and snacks consumed daily (RR 1.42; 95% CI 1.02 to 1.97). The authors acknowledged that the increased risk of S-ECC might be related to other cariogenic factors within the child's diet. They also noted that maternal schooling for more than 8 years was associated with decreased dental caries in the child (Feldens et al, 2010).

8.31 Tham et al concluded that with regard to associations between breastfeeding over 12 months and dental caries "further research with careful control of pertinent confounding factors is needed to elucidate this issue and better inform infant feeding guidelines" (Tham et al, 2015).

Breastfeeding versus bottle feeding and dental caries

8.32 Avila et al systematically reviewed the evidence relating to the association between feeding practice (breastfeeding versus bottle feeding) and risk of dental caries in childhood (Avila et al, 2015). Seven studies were identified: 5 cross-sectional studies, 1 case-control and 1 cohort study. High risk of bias was indicated when the item did not fulfil the NOS assessment criteria. Four items were judged as having a high risk of bias in a number of studies in this review: adjustment for confounding factors, representativeness, feeding habits assessment and dental examination calibration. All of the studies collected data on feeding practices by questionnaire, however, none of the studies reported the content of the bottle during bottle feeding. There was therefore a lack of clarity regarding the impact of bottle versus breastfeeding because bottle fed children may have been consuming infant formula alone and/or other drinks. In addition, all the studies were susceptible to residual confounding as none of them were adjusted for all the confounding factors (Avila et al, 2015).

8.33 The Italian cohort study included in Avila's review recruited 2,395 toddlers aged 24 to 30 months (Majorana et al, 2014). Data on feeding practices, dietary habits, maternal smoking, socio-economic status and fluoride supplementation were collected from mothers via questionnaire at birth, 6, 9 and 12 months. This included a prospective dietary diary to help reduce recall bias. A clinical exam was undertaken when the child was aged 24 to 30 months using the International Caries Detection and Assessment System (ICDAS). The study found significantly lower caries severity and prevalence in toddlers who were exclusively breastfed in infancy when compared with those who were mixed fed (Majorana et al, 2014). Avila et al judged this study as having a high risk of bias for 1 of the 4 criteria: lack of representativeness (Avila et al, 2015).

8.34 Al-Dashti et al undertook a cross sectional study in Kuwait (n=227) to identify the prevalence and extent of caries in early childhood (Al-Dashti et al, 1995). The study found that breastfed children were significantly more likely to be caries free than those who were bottle fed from birth ($p<0.05$), although 'nursing caries' was positively associated with the practice of breastfeeding at night 'at will' after 6 months of age ($p<0.01$). Bottle fed children were more likely to develop caries including nursing caries, particularly when the practice was continued to an older age. Those who were breastfed and mixed-fed (bottle and breast) were less affected by nursing caries than those children who had never been breastfed (p<0.01) (Al-Dashti et al, 1995; Avila et al, 2015). Avila et al judged this study has having a high risk of bias for the 4 criteria: lack of representativeness, adjustment for confounders, dental examination calibration and ascertainment of feeding habits (Avila et al, 2015).

8.35 Du et al randomly selected a convenience sample of children aged 24 to 47 months (n=426; mean age 40 months) attending 6 kindergartens in Hanchuan City (China) and established their decay status by oral examination (Du et al, 2000). Questionnaires were completed by their mothers to establish the child's infant feeding and duration of breastfeeding from birth. The study found that children who were fully bottle fed (8%) had a statistically significant higher prevalence of rampant caries (p<0.01) and incisor caries (p<0.05) compared with children who had been either fully or partly breastfed (92%) (Du et al, 2000). Avila et al assessed Du et al as having a high risk of bias for 2 of the 4 criteria: lack of representativeness and ascertainment of feeding habits (Avila et al, 2015).

8.36 Qadri et al, a third cross sectional study assessed in Avila's review, included 400 children aged 3 to 5 years old randomly selected from 20 kindergartens in Syria (Qadri et al, 2012). Children who had been breastfed were found to be less likely to have ECC (OR 0.27; 95% CI 0.18 to 0.41; p<0.001) and had fewer decayed, missing or filled teeth (OR 0.61; 95% CI 0.39 to 0.97; p=0.038). A higher number of teeth were affected by ECC in bottle fed children (p=0.036) (Qadri et al, 2012). However, Avila et al could not include this study in the meta-analysis as the data could not be extracted. They also rated the study to be at a high risk of bias for 2 of their criteria: lack of calibration of examiners and ascertainment of feeding habits (Avila et al, 2015).

8.37 The four studies described above (Al-Dashti et al, 1995; Du et al, 2000; Qadri et al, 2012; Majorana et al, 2014) found that breastfed children were less frequently affected by dental decay than bottle fed children (p<0.05) while the 3 other studies included by Avila et al found no such association (p>0.05). A meta-analysis of two of the cross-sectional studies (Al-Dashti et al, 1995; Du et al, 2000) showed that breastfed children were less affected by dental caries than bottle fed children (OR 0.43; 95% CI 0.23 to 0.80). The authors concluded that breastfeeding may reduce the risk of dental caries in early childhood (Avila et al, 2015).

Drinking vessel used and caries development

8.38 There is a paucity of research in this area; only one systematic review was identified (but this was not published in English). A single retrospective study by Behrendt et al identified 186 children between the ages of 1 to 6 years with ECC (Behrendt et al, 2001). The most favoured drinks offered in bill-shaped vessels were fruit juices (68%), sweetened teas (32%) and unsweetened teas (26%) while lemonades and cola-drinks were given to the children less often (8%). The authors suggested that the prevailing outcome was that the types of drinks consumed (that is, those with added sugar) coupled with the drinking vessel (bill-shaped) were the contributing factors for these children developing ECC (Behrendt et al, 2001).

8.39 The authors stated that the bill-shaped cups were similar to baby bottles with teats and were used between meals and during the night. They did not state whether the vessel was free-flowing, however the fact children were using these cups whilst sleeping would suggest that the cup had a valve and operated like a baby bottle (Behrendt et al, 2001). It is difficult to draw conclusions from this study as the use of sweetened beverages and the use of fluoride toothpaste were not controlled for.

Alignment of teeth and facial growth

8.40 Malocclusion describes the alignment of teeth which are considered not to be in a normal position in relation to adjacent teeth (that is, the teeth are not correctly aligned) (Nelson, 2014). The term covers a range of disorders relating to development which stem from a variety of causes.

8.41 Malocclusion has been suggested to vary between breast and bottle fed children. The biological plausibility is that children who are breastfed have more facial muscle activity compared with bottle fed children and this promotes craniofacial growth and jaw bone development. The growth of the face is affected by the infant's use of their facial muscles during feeding and suckling.

8.42 Peres et al undertook a systematic review with meta-analysis of 48 studies looking at the association between breastfeeding and facial growth and the development of malocclusion (Peres et al, 2015). Of the 48 studies, 13 were considered of high quality, 20 of medium quality and 15 of low quality. The meta-analysis included data for 27,023 children.

8.43 Meta-analysis comparing those children who were 'ever breastfed' with those 'never breastfed' found that participants ever exposed to any type of breastfeeding were less likely to develop malocclusions than those 'never breastfed' up to 12 years of age (Peres et al, 2015). Those who were breastfed were less likely to develop anterior open bites and the quality of the studies did not influence the effect size. The effect on posterior cross bites was not significant.

8.44 When considering children who were exclusively breastfed, they had a lower risk of nonspecific malocclusions compared with those who were not exclusively breastfed. This difference was not apparent for gaps between the upper and lower front teeth (anterior open bite) or a reversal of the normal relationship between the upper and lower back teeth (posterior cross-bite). Children who were breastfed for longer were less likely to have malocclusions than those breastfed for shorter periods. The authors concluded that breastfeeding decreased the risk of malocclusions (Peres et al, 2015), however, the lifetime effects of breastfeeding reducing malocclusions were not included in this review. There are no conclusions linking historic breastfeeding with orthodontic treatment need in the permanent dentition.

Conclusions

8.45 Breastfeeding during the first year of life has oral health benefits. The available evidence indicates that breastfeeding up to 12 months of age is associated with a decreased risk of dental caries and may offer some protection when compared with infant formula.

8.46 The consideration of children breastfed beyond 12 months was not within the remit of the evidence review. However, observational evidence suggests that once the primary teeth erupt, there may be an increased risk of dental caries associated with factors such as breastfeeding ad libitum, nocturnal feeding and sleeping with the breast in the mouth. However, the quality of the available evidence is generally low. With the exception of a single study in Brazil, confounders such as complementary feeding with cariogenic foods/drinks, or inadequate oral hygiene practices (for example, not brushing with a fluoride toothpaste) were not controlled for. Further research is required with careful control for confounding factors to inform infant feeding guidelines.

8.47 The data presented in this review reflect the evidence considered by the one available systematic review with meta-analysis which found that 'ever breastfed' children may be less likely to develop malocclusions compared with 'never breastfed' children up to 12 years of age.

9 Risks of allergic and autoimmune diseases

Background

9.1 Atopic conditions, including asthma, eczema, rhinitis and food allergy, appear to have increased in prevalence in recent decades in many countries, and are some of the commonest causes of chronic illness in children and young adults living in the UK (Gupta et al, 2004; Gupta et al, 2007; Venter et al, 2010; de Silva et al, 2014; Nwaru et al, 2014). Food allergy is estimated to affect 3 to 6% of children in HIC (Rona et al, 2007; NICE, 2011). Increases in the prevalence of food allergy are reflected by a documented increase in hospital admission rates for very severe reactions (anaphylaxis). Between 1998 and 2012, food anaphylaxis admission rates in the UK rose from 1.2 to 2.4 per 100,000 population (Turner et al, 2015). Other immunologically mediated reactions to food occur; the main one in the UK being coeliac disease, which is induced by a reaction to gluten (COT, 2000). Between 1990 and 2011, there was a 4-fold increase in the incidence of coeliac disease in the UK (West et al, 2014).

9.2 The mechanisms for the development of atopic or autoimmune conditions are multiple and complex in nature, likely to vary between individuals, and may be condition-specific. The apparent increase in disease prevalence, combined with data from migration studies, suggests that early-life environmental factors may be important modulators of allergic sensitisation and atopic disease risk. The relationship between maternal and infant dietary exposures and a child's risk of developing any of the common atopic or autoimmune diseases has been an area of considerable scientific uncertainty and debate in recent years.

Development of UK advice

9.3 UK advice on the introduction of allergenic foods into the infant diet has largely been based on recommendations from the 1994 COMA report on 'Weaning and the weaning diet' (DH, 1994), which stated that:

> "Where there is a family history of atopy or gluten enteropathy, mothers should be encouraged to breastfeed for 6 months or longer. Weaning before 4 months should particularly be discouraged and the introduction of foods traditionally regarded as allergenic should be delayed until 6 months at the earliest."

9.4 Advice to the public regarding the avoidance of peanuts has changed over time as new evidence has become available. In 1998, COT recommended that pregnant women who were atopic, or for whom the father or siblings of the unborn child had an atopic disease, might want to avoid eating peanuts and peanut products during pregnancy and lactation. It was further advised that when these infants were introduced to solid foods during complementary feeding, all peanuts and peanut products should be avoided and that this should continue until the child is at least 3 years of age (COT, 1998).

9.5 The COT report on 'Adverse reactions to foods and food Ingredients' (2000) identified knowledge gaps relating to the prevalence and pathogenesis of atopic reactions to foods (COT, 2000). These included the effect of early exposure in utero and in infancy on the development of oral tolerance or sensitisation to food antigens.

9.6 In 2007, COT commissioned a review to examine whether the dietary recommendations made by COT in its 1998 report remained appropriate, taking into account developments in the scientific evidence base. The subsequent COT review on peanut allergy also highlighted uncertainty about the determinants of peanut sensitisation and allergy. It stated the need to gauge the importance of skin and respiratory, as well as oral, routes of exposure to peanut and other food allergens when determining the importance of timing and dose of exposure when exploring the development of tolerance or allergy to food antigens (COT, 2008).

9.7 COT also considered that the evidence that had become available since 1998 "does not indicate whether maternal dietary consumption of peanut during pregnancy or lactation is more likely to increase or decrease the risk of sensitisation and allergy to peanut in the child" (COT, 2008). COT therefore concluded that their previous precautionary advice (to avoid peanut consumption during pregnancy, breastfeeding and infancy, where there is atopy or atopic disease in family members) was no longer appropriate (COT, 2008). They considered that the basis for more general recommendations remained justified and therefore recommended that "in common with advice given for all children, infants with a parent or sibling with atopic disease should be breastfed exclusively for around 6 months; and infants and children who are allergic to peanuts or peanut products, should not consume them or foods that contain them" (COT, 2008).

9.8 In 2010, a joint SACN/COT working group was convened to assess the evidence on the timing of introduction of gluten into the infant diet and the subsequent risk of developing coeliac disease or type 1 diabetes. The request was made in response to the publication of an EFSA Panel on Dietetic Products, Nutrition and Allergies scientific opinion proposing that gluten should be introduced into the infant diet no later than 6 completed months of age. The aim of this advice was to reduce the risk of subsequent development of coeliac disease and type 1 diabetes. The joint SACN/COT working group concluded that there was insufficient evidence to support recommendations about the appropriate timing of introduction of gluten into the infant diet beyond 3 completed months of age, for either the general population or high-risk sub-populations (SACN/COT, 2011).

9.9 Consumer-facing guidance recommends that allergenic foods, such as peanuts, nuts, seeds, egg, cows' milk, soya, wheat (and other cereals that contain gluten, for example, rye and barley), fish and shellfish "should be introduced into the infant's diet in very small amounts and one at a time, watching carefully for any symptom of an allergic reaction". Where parents offer solid foods before 6 months of age, it is advised that these commonly allergenic foods are avoided until the infant is 6 months old (PHE et al, 2018).

Commissioned systematic reviews and COT consideration of infant diet and development of allergic and autoimmune disease

9.10 To inform SACN's review of feeding in the first year of life, the Department of Health asked COT to examine the evidence relating to the influence of infant diet on the development of atopic and non-allergic immunologically mediated conditions including autoimmune disease.

9.11 To support COT's considerations, the FSA commissioned a series of systematic reviews of the published scientific literature (up to March 2016). The systematic reviews considered various aspects of infant feeding and allergic sensitisation, atopic disease, or autoimmune disease. Evidence included in the systematic reviews was evaluated using the GRADE system which provides a systematic approach to assess the certainty for each finding (Guyatt et al, 2011). The interpretation of GRADE evidence assessments is as follows: where the quality of the evidence is rated as 'high', there is considerable confidence that the true effect lies close to that of the estimate of the effect; when rated as 'moderate', there is moderate confidence in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; when rated as 'low', confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Where the quality of evidence is rated as 'very low', there is very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

9.12 More information about the review methodology is available in Boyle et al (2016a). The commissioned systematic reviews were evaluated by COT (COT, 2016a; COT, 2016b; COT, 2017) and published in the peer-reviewed literature (Boyle et al, 2016b; Ierodiakonou et al, 2016; Garcia-Larsen et al, 2018).

9.13 The scope of these reviews is described below.

- Duration of total and exclusive breastfeeding and timing of solid food introduction and the child's future risk of developing allergic sensitisation, atopic disease, or autoimmune disease.
- This review included the timing of transition from exclusive/predominant breastfeeding to partial or no breastfeeding in the first year of life, the total duration of breastfeeding up to 2 years of life and the timings of transition from liquid infant milk feed to complementary feeding (other than infant formula) in the first year of life (Garcia-Larsen et al, 2018).

- The potential role of dietary exposures during pregnancy/lactation and infancy to influence children's future risk of developing allergic or autoimmune disease (Garcia-Larsen et al, 2018).
- Infant formula containing hydrolysed cows' milk protein and its potential role in reducing the risk of infants and young children developing allergic or autoimmune disease (Boyle et al, 2016b; Ierodiakonou et al, 2016).
- The timing of introduction of specific allergenic foods (cows' milk, hen's egg, peanut, tree nuts, fish, wheat, soya) into the infant diet during the first year of life and whether this influences the child's future risk of developing allergic sensitisation, atopic disease or autoimmune disease. This review also explored whether the observed effect varies according to exclusive/predominant and continued breastfeeding (Ierodiakonou et al, 2016).

COT conclusions on breastfeeding and solid food introduction and risk of allergic or autoimmune disease

9.14 Based on the findings of the systematic review (Garcia-Larsen et al, 2018), COT concluded that overall there was very little evidence to suggest an association between breastfeeding or the timing of introduction of non-milk foods and the development of atopic outcomes or allergic disease (COT, 2017). The data were largely derived from observational studies in normal risk populations and were heterogeneous.

COT conclusions on maternal and other infant dietary exposures and risk of allergic or autoimmune disease

9.15 COT concluded that from the available studies included in the systematic review (Garcia-Larsen et al, 2018) there was little evidence that the maternal and other infant dietary exposures examined (other than the timing of introduction of allergenic foods described below in 9.18 to 9.20) increased children's future risk of developing allergic or autoimmune diseases (COT, 2017).

9.16 COT agreed with the conclusions reported in the systematic review (Garcia-Larsen et al, 2018) as detailed below.

- There was moderate quality evidence to suggest a relationship between the use of probiotics in pregnancy and infancy, and particularly during lactation, and a reduced risk of eczema and eczema associated with allergic sensitisation in high-risk children aged under 4 years of age. There was low quality evidence that the use of probiotics during pregnancy, lactation and infancy reduces the risk of allergic sensitisation.
- There was moderate quality evidence that the use of polyunsaturated fatty acid (PUFA) supplements reduces the risk of allergic sensitisation to hen's eggs in high risk infants

and that prenatal administration may be important. There was no evidence that PUFA supplementation affects the risk of development of other immune-related outcomes.

- There was no indication that avoidance or consumption of allergenic foods by mothers during pregnancy or lactation would reduce atopic outcomes or autoimmune disease in their children. There was also no clear or consistent evidence that maternal or infant consumption of mineral and vitamin supplements, fruit and vegetables, fish, fats, fatty acids or particular diets would influence the outcomes studied; however, the evidence available was limited for these exposures.
- There was low quality evidence to suggest a relationship between multifaceted interventions and a reduced risk of wheeze or recurrent wheeze at age 5 to 14 years, and allergic rhinitis at age ≤4 years.

COT conclusions on infant formula containing hydrolysed cows' milk protein and risk of allergic and autoimmune diseases

9.17 COT agreed with the findings reported in the systematic review (Boyle et al, 2016b) that the available evidence did not support the use of partially hydrolysed formula or extensively hydrolysed formula to influence the risk of developing allergic or autoimmune outcomes. There was also no association with the milk fraction used to produce the hydrolysed cows' milk formula (casein versus whey). COT further noted that although the majority of data were derived from high risk groups, the conclusions are likely to be applicable to a lower risk population (COT, 2016a).

Findings from the systematic review and COT conclusions on the timing of introduction of allergenic foods and risk of allergic and autoimmune diseases

9.18 The findings of the systematic review on the timing of introduction of a number of the major food allergens (milk, hen's egg, fish, shellfish, tree nuts, wheat, peanuts and soya) and later risk of allergic and autoimmune disease (Ierodiakonou et al, 2016) are described below.

- There was moderate quality evidence that early introduction of peanut (between 4 to 11 months) was associated with reduced risk of developing peanut allergy.
- There was moderate quality evidence that early introduction of hen's egg (between 4 to 6 months) was associated with reduced risk of developing hen's egg allergy.
- There was low quality evidence that early introduction of fish (before 6 to 12 months of age) was associated with reduced allergic rhinitis and very low quality evidence that fish introduction before 6 to 9 months was associated with reduced allergic sensitisation.
- There was high quality evidence that the timing of introduction of gluten was not associated with coeliac disease risk.
- There was no association between the timing of introduction of other allergenic foods and risk of food allergy or allergic sensitization.

9.19 Following consideration of the full systematic review and accompanying publication (Ierodiakonou et al, 2016), COT concluded that:

> "The meta-analyses performed indicate that for hen's egg and peanut allergy early introduction (at 4-6 months for hen's egg and 4-11 months for peanut) of allergenic food reduces subsequent development of an allergy to that food, based on 6 studies for hen's egg and 2 studies for peanut. […] To date, there is insufficient evidence for conclusions to be drawn on the effect of timing of introduction of common allergenic foods other than peanut and hen's egg in relation to developing an allergy to that food" (COT, 2016b).

9.20 COT further concluded from the evidence available that early introduction of allergenic foods does not increase the risk of allergy or autoimmune disease. Indeed, the deliberate exclusion or delayed introduction of specific allergenic foods may increase the risk of allergy to the same foods. However, the review indicated that further consideration should be given to advice on the timing of the introduction of peanut and hen's egg into the infant diet.

Joint SACN/COT statement: 'Assessing the health benefits and risks of the introduction of peanut and hen's egg into the infant diet before 6 months of age in the UK'

9.21 Following consideration by COT, a joint SACN/COT working group was convened with an independent chair to undertake a benefit-risk assessment on the timing of the introduction of peanut and hen's egg into the infant diet, and the risk of developing allergy to these foods. The working group agreed with COT's conclusions but noted that the previous assessment had considered early compared with later introduction of either peanut or hen's egg, without stipulating the specific timing. Therefore, the SACN/COT working group considered the available evidence for the introduction of peanut and hen's egg before 6 months of age versus after 6 months, taking account of the quality of evidence, change in effect, population group and health impact.

9.22 The joint SACN/COT working group used benefit:risk analysis for foods (BRAFO) methodology (Hoekstra et al, 2012) to explore issues related to the introduction of peanut and hen's egg before 6 months of age and this process, together with the existing evaluations of the relevant evidence by SACN and COT, allowed clear conclusions for both peanut and hen's egg to be reached. The joint working group noted that the systematic reviews identified limited evidence on the timing of introduction: 2 RCTs on peanut and 7 RCTs for hen's egg. BRAFO provided a framework to systematically explore the full range of benefits and risks, though the nature of the evidence limited the detailed application of the second stage of the methodology (SACN/COT, 2017).

9.23 The joint SACN/COT working group conclusions are stated below.

- There was insufficient data to support the existence of a 'window of opportunity' for the introduction of peanut before 6 months of age. Evidence that the introduction of hen's egg before 6 months might be beneficial was limited and derived from RCTs where participants were not representative of the general population.
- The benefit-risk assessment indicated that there were insufficient data to demonstrate that the introduction of peanut or hen's egg into the infant diet before 6 months of age reduced the risk of developing food allergy to any greater extent than introduction from around 6 months.
- There was reasonable evidence to demonstrate that the deliberate exclusion or delayed introduction of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods. Importantly, once introduced, these foods should continue to be consumed as part of the infant's usual diet in order to minimise the risk of allergy to peanut or hen's egg developing after initial exposure. Families of infants with a history of early-onset eczema or suspected food allergy may wish to seek medical advice before introducing these foods.
- There were differences in the evidence base for peanut and hen's egg: there were more RCTs investigating earlier introduction of hen's egg in a number of geographically-diverse areas; earlier age at presentation of clinical allergy (which might be related to hen's egg being introduced earlier during complementary feeding); greater heterogeneity in the food matrix in which the hen's egg was consumed. Despite differences in the available evidence, there is a need to maintain simple and consistent public health advice; at the present time peanut and hen's egg should be treated in the same way.

9.24 The joint SACN/COT working group recommendations are stated below.

- The government should continue to recommend exclusive breastfeeding for around the first 6 months of life.
- Advice on complementary feeding should state that foods containing peanut and hen's egg need not be differentiated from other solid foods. Complementary feeding should be introduced in age-appropriate form from around 6 months of age, alongside continued breastfeeding, at a time and in a manner to suit both the family and individual child.
- The deliberate exclusion of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods. Once introduced, and where tolerated, these foods should be part of the infant's usual diet, to suit both the individual child and family. If initial exposure is not continued as part of the infant's usual diet, then this may increase the risk of sensitisation and subsequent food allergy.
- Families of infants with a history of early-onset eczema or suspected food allergy may wish to seek medical advice before introducing these foods.

- These recommendations build on the conclusions from the COT statement that “from the evidence available, early introduction of allergenic foods does not increase the risk of allergy or autoimmune disease. Indeed, the deliberate exclusion or delayed introduction of specific allergenic foods may increase the risk of allergy to the same foods.”

Conclusions

9.25 There was insufficient evidence to indicate that breastfeeding influences the development of allergic or autoimmune diseases.

9.26 The available evidence indicates that the deliberate exclusion or delayed introduction of peanut or hen’s egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods.

9.27 The available evidence indicates that allergenic foods such as peanut, hen’s egg, gluten or fish can be introduced from around 6 months of age and need not be differentiated from other solid foods:

- there is insufficient evidence to demonstrate that the introduction of peanut or hen’s egg into the infant diet before 6 months of age reduces the risk of developing food allergy to any greater extent than introduction from around 6 months
- there is high quality evidence that the timing of introduction of gluten is not associated with the risk of developing coeliac disease
- there is low to very low quality evidence that early fish introduction (before 6 to 12 months of age) was associated with reduced allergic rhinitis and sensitisation
- there is insufficient evidence for conclusions to be drawn on the effect of the timing of introduction of other allergenic foods in relation to developing an allergy to that food.

9.28 There was no indication that avoidance or consumption of allergenic foods by mothers during pregnancy or lactation would reduce the risk of allergic or autoimmune disease in their children.

9.29 The available evidence does not support the use of extensively hydrolysed or partially hydrolysed protein formula to influence the risk of developing allergic or autoimmune disease.

9.30 There was little evidence that maternal and other infant dietary exposures increased children’s future risk of developing allergic or autoimmune diseases.

10 Risks of chemical toxicity

10.1 To complement the SACN review of the scientific evidence underpinning current dietary recommendations for infants and young children in the UK, COT was asked to examine the risks of toxicity from chemicals in the diet of infants and to consider whether current government advice should be revised.

10.2 COT reviewed the toxicity of a number of chemicals which were selected on the basis of their known or suspected adverse effects and the potential for dietary exposure for infants via breast milk, infant formula and solid foods.

10.3 Consequently, COT published an overarching statement on risks of chemical toxicity and allergic disease in relation to the infant diet (COT, 2012). This included evaluations for caffeine, alcohol, methylmercury, dioxins and dioxin-like compounds, vitamin A, soy phytoestrogens, phthalates, bisphenol A, aluminium, lead, legacy pesticides, brominated flame retardants, and persistent organic pollutants. These are summarised in Table 10.1.

10.4 In addition, COT decided that a more detailed review was required for a number of substances (vitamin A, aluminium, lead, soya phytoestrogens, brominated flame retardants, and environmental pollutants) and that these would be individually assessed and published as separate COT statements. These evaluations are summarised in Table 10.2 along with the links to these statements.

Table 10.1 Summary of the substance evaluations included in the 2012 COT overarching statement on potential chemical risks from the infant diet

Chemical considered	Summary of COT conclusions on substances and contaminants (COT, 2012)
Caffeine	Available information did not provide a basis for refining the advice that breastfeeding women should have no more than 200mg caffeine over the course of a day (which roughly equates to two mugs of instant coffee, or two mugs of tea, or one mug of filter coffee).
Alcohol	Evidence supported the recommendations that breastfeeding mothers should consume no more than 1 or 2 units of alcohol once or twice a week.
Methylmercury	The exposure of infants to methylmercury from breast milk, infant formula and solid foods did not exceed the safety guideline.
Dioxins and dioxin-like compounds	Dietary exposures of infants may exceed the safety guideline, but because this would only be for a short time, it would not be expected to produce a build-up in the body to levels that would be harmful. Furthermore, there was clear evidence from multiple studies that exposures were decreasing over time.
Phthalates	Exposures of infants to phthalates from breast milk, infant formula and solid foods were found to be unlikely to exceed the safety guidelines.
Bisphenol A (BPA)	The exposures of infants to bisphenol A from breast milk, infant formula and solid foods were well below the safety guideline. Moreover, exposures were likely to be even lower in the future as a result of decreased use of the chemical in plastic bottles used for infant feeding. COT stated it would review its conclusions following the completion of the ongoing EFSA re-evaluation of BPA. In 2015 EFSA published a new opinion on BPA, concluding that exposure estimates for infants and prenatally exposed children did not indicate a health concern (EFSA, 2015b).
Legacy pesticides (including aldrin, dieldrin,endrin, chlordane, heptachlor, hexachlorobenzene, mirex, toxaphene, DDT)	These are a group of pesticides that were banned during the 1980s and 1990s, but which, because of their persistence in the environment, can still be detected in the food chain. The few studies that were available indicated that levels in breast milk were declining, and did not point to a concern for the health of UK infants.

Table 10.2 Summary of COT evaluations requiring more detailed assessment and the individual statement references

Chemical considered	COT conclusion	Reference / web link
Soya phytoestrogens	There was some uncertainty about the safety of soya-based formula. COT concluded that there was no scientific basis for a change in the government advice: • there is no substantive medical need for, nor health benefit arising from the use of, soya-based infant formula • soya-based infant formula should only be used in exceptional circumstances to ensure adequate nutrition.	COT Statement on the potential risks from high levels of soya phytoestrogens in the infant diet (2013) https://cot.food.gov.uk/sites/default/files/cot/cotstaphytos.pdf
Aluminium	Estimated exposures to aluminium from dietary sources were considered not to indicate a toxicological concern or a need for modified government advice.	COT Statement on the potential risks from aluminium in the infant diet (2013) http://cot.food.gov.uk/sites/default/files/cot/statealuminium.pdf
Lead	Total exposures to lead were unlikely to pose a material risk to health in the large majority of UK infants. However, there was a concern that adverse effects could occur where concentrations of lead in water or soil were unusually high.	COT Statement on the potential risks from lead in the infant diet (2013) http://cot.food.gov.uk/sites/default/files/cot/cotstatlead.pdf
Vitamin A	Overall COT concluded that there was potential for some infants to exceed the TUL under the following circumstances: • if exclusively breastfed by mothers taking dietary supplements containing high levels of vitamin A • if fed with infant formula at the upper limit of the retinol content allowed by regulation • if given high dose vitamin A supplements • if consuming liver more than once per week.	COT Statement on the potential risks from high levels of vitamin A in the infant diet (2014) http://cot.food.gov.uk/sites/default/files/cot/cotstavita.pdf

Chemical considered	COT conclusion	Reference / web link
	The possibility of adverse effects from such exceedances could not be excluded, but should they occur, it was considered likely to be in only a very small proportion of infants.	
Endosulfan isomers, pentachlorobenzene and chlordecone	Available information did not indicate a toxicological concern regarding dietary exposures to any of the 3 chemicals, since exposures were below the relevant safety guideline, or if none had been set, were low and decreasing.	COT Statement on endosulfan isomers, pentachlorobenzene and chlordecone in relation to infant diet (2014) https://www.food.gov.uk/sites/default/files/cotstaonpops.pdf
α-, β- and γ-hexachloro-cyclohexanes (HCHs)	Overall COT concluded that its evaluation did not provide a basis for recommendations on the infant diet relating to HCHs, particularly as levels in food appeared to be decreasing over time. However continued monitoring of HCHs in breast milk, infant formula and food, with appropriately sensitive methods, was considered useful to confirm that there are unlikely to be any risks.	COT Statement on α-, β- and γ-hexachloro-cyclohexanes in the infant diet (2014) http://cot.food.gov.uk/sites/default/files/cot/cotstatmhchs.pdf
Polybrominated biphenyls (PBBs)	Reliable estimation of infants' exposure to PBBs was not possible, and thus no meaningful risk assessment could be performed.	COT Statement on polybrominated biphenyls (PBBs) in the infant diet (2015) http://cot.food.gov.uk/sites/default/files/pbbstatementfinal.pdf
Polybrominated diphenyl ethers (PBDEs)	Analysis indicated possible concerns regarding the exposures of infants to commercial mixtures of PBDEs: • BDE-99 and -209 via ingestion of dust • BDE-47, -99 and -153 via breast milk • BDE-99 and -153 from food. Given that the main dietary sources of exposure to residual environmental PBDEs are breast milk and dairy products, COT considered the options	COT Statement on the potential risks from polybrominated diphenyl ethers (PBDEs) in the infant diet (2015) http://cot.food.gov.uk/sites/default/files/PBDEstatementfinal.pdf

Chemical considered	COT conclusion	Reference / web link
	for risk management were limited.	
Hexabromocyclo-dodecanes (HBCDDs)	Estimated exposures via breast milk and food were not a cause for concern, but high levels found in some samples of domestic dust were. Further dust sampling should be carried out to obtain a more reliable assessment of the distribution of potential exposures through ingestion of dust, and especially to establish whether levels begin to fall since production and new usage of HBCDDs has largely ceased. New studies on the levels of HBCDDs in infant formula and commercially produced infant food were also considered to be useful, but of lower priority.	COT Statement on the potential risks from hexabromocyclo-dodecanes (HBCDDs) in the infant diet (2015) http://cot.food.gov.uk/sites/default/files/HBCDDsstatementfinal.pdf
Tetrabromo-bisphenol A (TBBPA)	COT concluded it was not possible to perform a meaningful risk assessment due to the lack of an appropriate reference point and limited exposure data.	No statement issued
Perfluorooctane sulfonate (PFOS)	Exposure estimates were found to be below the safety guideline, and even when allowance was made for any additional exposures to PFOS precursors, they did not indicate a need for formulation of dietary recommendations to protect the health of infants.	COT statement on the potential risks from perfluorooctane sulfonate (PFOS) in the infant diet (2014) http://cot.food.gov.uk/sites/default/files/cot/cotstatmpfos.pdf
Acrylamide	COT concluded that the low margins of exposure (MoEs) from infants and young children's exposure to acrylamide from infant formula and food were a potential concern for genotoxicity and carcinogenicity. For other health effects such as neurotoxicity, exposures do not suggest any concern.	COT Statement on potential risks from acrylamide in the diet of infants and young children (2016) https://cot.food.gov.uk/sites/default/files/finalacrylamidestatement.pdf
Arsenic	Overall, the inorganic arsenic exposures for exclusively breastfed or formula fed	Statement on potential risks from arsenic in the

Chemical considered	COT conclusion	Reference / web link
	UK infants aged 0 to 4 months generated MOEs that were generally greater than 10 and would therefore be considered of low concern. There could be a small risk to high level consumers of infant formula that has been reconstituted with water containing a high level of inorganic arsenic as this scenario generated MOEs that were marginally less than 10. Total exposure to inorganic arsenic, from dietary and non-dietary sources, in infants and young children aged 4 to 12 months and 1 to 5 years generally generated MOEs of less than 10 and could therefore pose a risk to health. When comparing the estimated exposures from different sources, it becomes apparent that in these age groups, dietary sources generally contribute more significantly to exposure than non-dietary sources such as soil and dust. It is therefore reiterated that efforts to reduce the levels of inorganic arsenic in food and water should continue.	diet of infants aged 0 to 12 months and children aged 1 to 5 years (2016) https://cot.food.gov.uk/sites/default/files/finalstatementonarsenic_0.pdf

Conclusions

10.5 COT assessed toxicity issues from the infant diet for a number of nutrients, substances and contaminants in breast milk, infant formulae and solid foods. They concluded there were unlikely to be concerns over toxicity in the diet of infants for substances considered at current levels of exposure. Issues where there is potential concern are described in the paragraphs below.

10.6 In relation to vitamin A, COT concluded that there is potential for some infants to exceed the TUL under the following circumstances:

- exclusively breastfed by mothers taking dietary supplements containing high levels of vitamin A
- fed with infant formula at the upper limit of the retinol content allowed by regulation
- given high dose vitamin A supplements

- consuming liver more than once per week.

10.7 COT's conclusions in relation to caffeine, alcohol, soya and acrylamide are described below.

- Caffeine - Breastfed infants can be exposed to caffeine as a result of maternal consumption of caffeine-containing foods and beverages, but the available scientific evidence does not demonstrate a consequent health risk in infants. The available information does not provide a basis for refining the current government advice that breastfeeding mothers should have no more than 200mg caffeine over the course of a day (which roughly equates to two mugs of instant coffee, or two mugs of tea, or one mug of filter coffee).
- Alcohol - Reported effects in breastfed babies from maternal consumption of alcohol support the government's current advice that breastfeeding mothers should consume no more than 1 or 2 units of alcohol once or twice a week.
- Soya - There is some uncertainty about the safety of soya-based formula and there is no scientific basis for a change in the current government advice: there is neither substantive medical need for, nor health benefit arising from the use of soya-based infant formula and it should only be used in exceptional circumstances to ensure adequate nutrition.
- Acrylamide - There was a potential concern about exposure to acrylamide from infant formula and solid foods. Efforts to reduce acrylamide exposure should be continued, with respect to both commercially-produced and home-cooked food.

10.8 COT's conclusions on the contaminants lead, arsenic and PBDEs are provided below.

- Lead - Where soil and water concentrations of lead are unusually high there is concern that adverse effects could occur but that this is unlikely to pose a risk in the large majority of the UK.
- Arsenic - Exposure for exclusively breastfed or formula fed UK infants aged 0 to 4 months was considered of low concern. There could be a small risk to high level consumers of infant formula that has been reconstituted with water containing a high level of inorganic arsenic.
- PBDEs - No data were available on levels of PBDEs in infant formula and commercially produced infant foods in the UK. There are possible concerns in relation to PBDEs but dietary sources are residual environmental PBDEs in breast milk and dairy products with limited options for risk management.

11 UK infant feeding practice

The UK Infant Feeding Survey

11.1 The IFS, a national survey of infant feeding practices, was conducted every 5 years from 1975 to 2010. The survey provided national estimates of the incidence, prevalence and duration of breastfeeding (including exclusive breastfeeding) and other feeding practices adopted by mothers in the first 8 to 10 months after their infant was born. In the more recent surveys these estimates were provided separately for England, Wales, Scotland and Northern Ireland, as well as for the UK as a whole.

11.2 The design of the study, questions and sampling procedure changed little since inception. This enabled the surveys to capture overall trends in infant feeding practices since 1975 and to adjust these for demographic change, notably the trend towards increasing maternal age at delivery.

11.3 The 2010 survey was based on an initial representative sample of mothers who were selected from all births registered between August and October 2010 in the UK. Three stages of data collection were conducted, with Stage 1 being carried out when infants were around 4 to 10 weeks old, Stage 2 when they were around 4 to 6 months old, and Stage 3 when they were around 8 to 10 months old. A total of 10,768 mothers completed and returned all 3 questionnaires.

11.4 Full details of the methodology employed and findings from the IFS 2010 can be found elsewhere (McAndrew et al, 2012); a summary of the key findings pertinent to this review is given below.

11.5 The findings of the 2005 IFS were reviewed by SACN in 2008. Fourteen recommendations for policy and practice were made and 6 recommendations for the conduct of future surveys.

Key findings on incidence, prevalence and duration of breastfeeding

11.6 IFS used the term 'incidence' to denote the proportion of infants put to the breast, even if only once. This figure included those given expressed breast milk. 'Prevalence' denoted the proportion of infants still receiving any breast milk at subsequent sampling stages, whether or not they were receiving other milks and liquids as well.

11.7 From 2005 IFS distinguished between exclusive and any breastfeeding. The prevalence of 'exclusive breastfeeding' was defined as the proportion of infants who were receiving only breast milk and had never been given other milks, liquids or solid foods.

11.8 Across the UK, the initial breastfeeding rate increased from 76% in 2005 to 81% in 2010 (83% in England, 74% in Scotland, 71% in Wales, and 64% in Northern Ireland). Since 1990, there was a 31% increase in the incidence of breastfeeding in the UK, with proportionate increases being greatest in Scotland (48% increase) and Northern Ireland (78% increase) (Table D.1). The mother's age at birth of the infant and her age on completion of full-time education remained strong predictors of breastfeeding in the 2010 survey. Table D.2 shows a standardised incidence for each 5-yearly sample adjusted for the secular change in these demographic characteristics.

11.9 The highest incidence of breastfeeding was observed among mothers aged 30 or over (87%), those from minority ethnic groups (97% for 'Chinese or other', 96% for 'Black or Black British' and 95% for 'Asian or Asian British' ethnic groups), those who left education aged over 18 (91%), those in managerial and professional occupations (90%) and those living in the least deprived areas (89%).

11.10 Table D.3 shows changes between 1995 and 2010 in the prevalence of breastfeeding between birth and 9 months of age. In 2010, across the UK as a whole, the prevalence of breastfeeding fell from 81% at birth to 55% at 6 weeks. At 6 months, 34% of mothers were still breastfeeding. It is apparent that the most rapid decline in breastfeeding prevalence occurs in the first 2 weeks of the infant's life; by 6 weeks of infant age 32% of mothers who initiated breastfeeding had stopped.

11.11 The proportion of mothers initiating breastfeeding who stopped by 6 weeks of age changed very little between 1995 (36%) and 2010 (32%), with a maximum of 39% in 2000 (Table D.3). The reasons mothers stop breastfeeding in the early weeks have been consistently described in IFS since 1980. Table D.4 shows data for 2005 and 2010; the principal reasons were difficulties with attachment at the breast, breast or nipple pain, and a perception that breast milk was insufficient or the infant was hungry. The 5-yearly IFS also showed consistently that mothers who stopped in the early weeks would have preferred to continue had they felt able to do so. Table D.5 shows data for 2010.

11.12 Table D.6 shows the prevalence of exclusive breastfeeding in 2005 and 2010. In 2010, fewer than half of all mothers (46%) were exclusively breastfeeding by one week of infant age, while this had fallen to around a quarter (23%) by 6 weeks. By 6 months, prevalence of exclusive breastfeeding had decreased to only 1%. Thus, very few mothers followed the UK recommendation that infants should be exclusively breastfed until around the age of 6 months.

11.13 Table D.7 shows that formula or other liquids rather than solid foods principally accounted for early (prior to 4 months of age) loss of exclusive breastfeeding. Only after 17 weeks did introduction of solid foods account for more than 2% of cases.

11.14 The proportion of UK women who continue to breastfeed after 6 months of infant age is very low compared with international statistics. In 2010, only 1 in 3 UK women were breastfeeding at all at 6 months of infant age, and only 1 in 4 at 9 months of infant age (see Table D.3). Even though mothers in the UK continued to breastfeed for longer in 2010 than in 2005 (McAndrew et al, 2012), this is substantially lower than the rates observed in other HIC where prevalence of 50% to 70% was observed at 6 months (Victora et al, 2016).

Use of milk other than breast milk

11.15 Almost three-quarters of mothers (73%) had given milk other than breast milk by the age of 6 weeks and 88% had done so by 6 months. Mothers from managerial and professional occupations and older mothers were likely to introduce other milks later (Table D.8).

11.16 At Stage 2 of the 2010 survey (when infants were 4 to 6 months of age), most mothers who had given their infant milk other than breast milk in the last 7 days were mainly giving infant formula (88%). Use of follow-on formula or liquid cows' milk was low at this stage (9% and 1%, respectively). By Stage 3 of the survey (when infants were 8 to 10 months of age), mothers were more likely to be using follow-on formula (57%) as their infant's main source of milk other than breast milk, rather than infant formula (35%).

11.17 Most mothers followed the recommendation not to give follow-on formula before the age of 6 months. Mothers from routine and manual occupations and those who had never worked were more likely to say they had given their infant follow-on formula at an earlier age (18% and 27%, respectively, at 4 months).

11.18 By 8 to 10 months of age, 42% of mothers had given their infant liquid cows' milk. Twenty-nine per cent had mixed it with food while 24% had used it as an occasional drink. Only 4% of mothers had introduced liquid cows' milk as their infant's main milk (Table D.9).

Liquids other than milk

11.19 In 2010, 27% of mothers were giving drinks in addition to breast milk or formula by 4 weeks of infant age. This had risen to 55% by 4 months and 81% by 6 months. 'Drinks' could have included water, fruit juice, squash or herbal liquids but these were not differentiated in the survey.

11.20 The most common reasons for giving drinks at Stage 1 (4 to 10 weeks of age) were to help with constipation (48%) or to help colic, wind or indigestion (42%). By Stages 2 and 3 (when infants were 4 to 6 months and 8 to 10 months, respectively) the main reason for giving drinks was because the infant was thirsty (56% at Stage 2 and 86% at Stage 3).

11.21 At all ages up to 6 months fewer mothers gave drinks than in 2005. This was most evident at 4 months, when the proportion fell from 64% in 2005 to 55% in 2010.

11.22 Mothers who breastfed initially were less likely to give additional drinks before 6 months than those who formula fed from birth (78% compared with 92%).

11.23 Mothers aged under 20 were more likely than those aged 35 or over to give their infant drinks at an early age (64% and 24%, respectively, at 6 weeks old). Those from routine and manual occupation groups or who had never worked were more likely than mothers from managerial and professional groups to give drinks at an early age (48%, 44% and 25%, respectively, at 6 week old).

Use of cups and beakers

11.24 On average, mothers introduced cups and beakers a little earlier in 2010 than in 2005. By 6 months 54% of all mothers had introduced a cup or beaker compared with 48% in 2005.

Age at introduction of complementary feeding

11.25 Successive 5-yearly IFS have documented a trend towards later introduction of solid foods in keeping with changes in national feeding recommendations. In 2003, the UK health departments recommended that solid foods should be introduced when infants are around 6 months old (DH, 2003; SACN/SMCN, 2003). While in 2000 85% of mothers were introducing solid foods before 4 months (McAndrew et al, 2012), Table D.10 shows that this figure had decreased to 51% in 2005, and to 30% in 2010. These data indicate that there has been an increase of nearly 5-fold in the proportion of mothers introducing solid foods after 4 months since the change in policy.

11.26 Younger mothers and those from lower socio-economic groups tended to introduce solid foods at earlier ages. In 2010, 57% of mothers aged under 20 years and 38% of mothers in the routine and manual category or those who had never worked introduced solid foods by the time their infant was 4 months old.

11.27 Table D.11 indicates mothers' reasons for introducing solid foods at various ages. The most commonly cited reason for introducing solid foods before 4 months was an unsatisfied infant (64% of mothers). Mothers who introduced solid foods after 5 months were more likely to cite written information, advice from a health professional or the infant's acquisition of motor skills as their reason.

Types of solid foods introduced

11.28 Baby rice was the most common type of solid food first given to infants (57%). The majority of mothers said the food they first gave to their infant was mashed or pureed (94%), while only a small proportion gave finger food (4%).

11.29 When infants were 4 to 6 months old, mothers were most likely to have given them fruit or vegetables on the previous day (46%), ready-made baby foods (38%), baby rice (31%) or homemade foods (28%).

11.30 Table D.12 shows the foods most frequently given when infants were 8 to 10 months old. Fruit and vegetables, fresh food, breakfast cereals, cheese, yoghurt and fromage frais were the most popular items. Chicken was the most frequently offered meat. Red meats (beef, pork or lamb) were given less frequently, with 46% or more of mothers offering them less than weekly or never.

Types of solid foods avoided

11.31 Nearly half of mothers reported that they had consumed peanuts or peanut products during pregnancy (49%) and 2 in 5 mothers who breastfed at least initially (40%) said that they had done so while breastfeeding. At Stage 3, only a small minority of infants had been given peanuts or peanut products (8%).

11.32 Ninety per cent of mothers completely avoided the use of salt in the diets of their 8 to 10 month old infants, but mothers from ethnic minority backgrounds were less likely to do so. Thirty-seven per cent of mothers of 'Chinese or other' ethnic origin, 37% of 'Asian or British Asian' mothers, 26% of 'Black and Black British' mothers and 16% of mothers of 'Mixed' ethnic origin added salt to their infants' diets, compared with only 5% of 'White' mothers.

11.33 Nearly half of mothers mentioned that they avoided giving their infant particular ingredients at Stage 3 (45%). Other than salt, the principal ingredients omitted were nuts (41%), sugar (38%), honey (19%), eggs (12%) and dairy produce (11%).

Supplementary vitamins

11.34 The UK health departments have recommended for some time that children from 6 months to 5 years old should be given a supplement containing vitamins A, C and D, unless they are receiving more than 500ml of infant formula per day (DHSS, 1988; DH, 1994). The advice at the time of the 2010 survey was that if there was any doubt about the mother's vitamin D status (for example, if she did not take a vitamin D supplement during her pregnancy or falls into other at-risk groups), breastfed infants were to be administered vitamin supplements from 1 month (DH, 1998).

11.35 Seven per cent of infants at Stage 1 were being given vitamin drops, rising to 14% at Stage 3 (Table D.13). As expected, breastfeeding mothers were more likely to be giving vitamin drops than those feeding with formula, particularly at Stage 3 (22% and 11%, respectively).

The UK Diet and Nutrition Survey of Infants and Young Children

11.36 The UK DNSIYC (Lennox et al, 2013) was commissioned by the Department of Health and the FSA to provide detailed information on the food consumption, nutrient intakes and nutritional status of infants and young children aged 4 months up to 18 months living in private households in the UK. Fieldwork was carried out between January and August 2011.

11.37 DNSIYC provides the only source of high quality nationally representative data on the types and quantities of foods consumed by the 4 to 18 month age group. The survey was conducted in all 4 countries of the UK and was designed to be representative of the UK population. Additional recruitment was undertaken in Scotland and among those in receipt of Healthy Start vouchers in order to provide more detailed analysis of these populations. These additional samples were referred to as ‘boosts’.

11.38 The survey involved a face-to-face interview to obtain background information, such as socio-economic status, a 4-day food diary, and child and maternal anthropometric measurements. Information was obtained from 2,683 individuals (2,283 excluding the ‘Scottish boost’). Nine hundred and seventy three infants attended a clinic at which 98% provided a measure of skinfold thickness, 87% completed a stable isotope assessment of fluid intake, breast milk intake and body composition, and 55% provided a blood sample for the analysis of iron and vitamin D status.

Feeding patterns

11.39 Overall, feeding patterns observed in DNSIYC were very similar to those recorded by IFS 2010.

11.40 Seventy eight per cent of the infants recruited had been breastfed at some point since birth, of which 57% were not breastfed beyond 3 months. Only 2 children (both aged 4 to 6 months) were exclusively breastfed at the time of the survey.

11.41 Ten per cent of the infants in DNSIYC were introduced to complementary feeding before the age of 3 months. Seventy-five per cent of infants consumed solid foods before the age of 5 months and 22% were introduced at the age of 6 months. Baby rice and pureed fruit or vegetables were the most common first foods consumed by infants (65% and 21%, respectively).

11.42 Children aged less than 1 year generally consumed no more than 146g of whole cows’ milk per day.

11.43 Mean total fruit and vegetable consumption (which includes the fruit and vegetable component of composite dishes) ranged from 100g per day for children aged 4 to 6 months to 170g per day for children aged 12 to 18 months. This equates to 2 adult (80g) portions per day. Mean fruit consumption of 7 to 18 month olds was 73-96g per day which was higher than that observed in the NDNS 11 to 18 year old age group (60g per day) (PHE & FSA, 2014).

11.44 There is only limited data on liver consumption by infants in DNSIYC however the available data indicated that some infants may be consuming large amounts of liver and liver-containing products (for example, liver sausage) once a week or more and these infants could exceed the TUL for vitamin A. In these data the vitamin A intake, primarily from a single eating occasion, was based on a small number of consumers and was averaged over the 4 reporting days of DNSIYC. It is uncertain whether the TUL would be exceeded if the intakes were averaged over a longer period of time.

11.45 The proportion of children given a micronutrient supplement during the 4-day food diary period ranged from 5% (aged 4 to 6 months) to 10% (aged 12 to 18 months). Those most likely to receive at least one supplement were children aged 4 to 18 months of South Asian and 'other' ethnicities.

Nutrient intakes

11.46 Seventy-five per cent of boys and 76% of girls exceeded the EAR for energy. Infant formula was the largest contributor to energy intake for children under 12 months of age.

11.47 Table D.14 shows the percentage contribution of each food group to average daily energy intake by infant age. Between 4 and 6 months of age infant formula and breast milk accounted for 69% of average daily energy intake, declining to 12% at 12 to 18 months of age. Cereals/cereal products and milk/milk products were the greatest contributors to energy intake after 12 months, together accounting for about half of daily energy intake.

11.48 Non-milk extrinsic sugars (NMES) intake[9] increased with age, providing 4.3% of total energy for children aged 4 to 6 months and 6.2% for children aged 7 to 11 months (Table D.15a). The largest contributor to NMES for children aged 4 to 6 months and 7 to 9 months was the food group 'commercial infant foods' (44% and 34%, respectively), particularly 'fruit based foods and dishes' and 'cereal based foods and dishes' (Table D.15b).

11.49 Table D.16a shows average daily intakes of sodium and salt between 4 and 18 months of age. These exceeded the SACN recommendation of a maximum of 1g of salt a day for infants between 7 and 12 months (SACN, 2003), particularly after 10 months of age; the average daily salt intake was 1.5g for children aged 10 to 11 months and 2.3g for those aged 12 to 18 months. Table D.16b shows the percentage contribution of food groups to daily sodium intake in children aged between 4 to 18 months. The largest contributor to salt intakes after 10 months of age was the food group 'cereals and cereal products'.

11.50 Average daily intake of minerals from all sources generally exceeded the RNI (Table D.17) though intake of iron fell below the lower reference nutrient intake (LRNI) in 10 to 14% of children at all ages (Table D.18). Infant formula was the major contributor to iron intake for children aged 4 to 6 months (56%), 7 to 9 months (48%) and 10 to 11 months (42%).

11.51 The proportion of children in all age groups with daily intakes of vitamins below the LRNI was less than 1% for most vitamins. For vitamin A, 2% of children aged 12 to 18 months were below the LRNI. No children were below the LRNI for vitamin C (Table D.19). Average daily intakes of all vitamins other than vitamin D exceeded RNIs (Table D.20).

[9] In 2015, SACN recommended that a definition of 'free sugars' should be adopted in the UK for public health nutrition purposes to replace the concept of non-milk extrinsic sugars (NMES) on which sugar intake recommendations had been based since 1991 (SACN, 2015). DNSIYC (2013) measured sugar intakes using the NMES definition and in this context it is therefore appropriate to report sugar intakes as intakes of NMES rather than 'free sugars'.

11.52 The mean vitamin D intakes of breastfed children from food and supplements ranged between 37 and 54% of RNI at various ages, excluding any contribution from breast milk. The mean daily vitamin D intake of non-breastfed children exceeded RNI at all ages under 12 months (Table D.20).

11.53 Average daily intakes of vitamin A were at least double the RNI for the 3 youngest age groups (4 to 6 months, 7 to 9 months, 10 to 11 months), with infant formula being the largest contributor to vitamin A intake for each group (39%, 33% and 30%, respectively).

Body size

11.54 More than 75% of the sample (aged 4 to18 months) exceeded the WHO growth standard 50th percentile for weight and more than 70% for length (Table D.21).

Blood analytes

11.55 Iron status measures are shown in Table D.22. Five children (3%) aged 5 to 11 months had haemoglobin and serum ferritin concentrations below the level at which iron deficiency anaemia is indicated.

11.56 Ninety four per cent of children (aged 5 to 11 months) had serum 25-hydroxyvitamin D (25-OHD) concentrations compatible with the SACN recommendation for good health (≥25nmol/l) (SACN, 2016).

Conclusions

11.57 The 5-yearly IFS have provided a unique perspective on infant feeding practices in the UK over the period 1975 to 2010. By using consistent methodology to survey a nationally representative sample they have documented the geographical, demographic, social and educational inequalities that underlie variations in infant nutrition and health.

11.58 In the period up to 2010, the surveys have shown increases in the proportion of women initiating breastfeeding, particularly since 2000, but the proportion of women who discontinued breastfeeding before their infant was 6 weeks old remained between 32% and 39% since 1995.

11.59 The proportion of women in the UK who breastfeed exclusively to 6 months of age or who continue to breastfeed beyond the first 6 months is very low compared with other HIC.

11.60 There has been a reduction in the proportion of infants receiving solid foods before 4 months of age between 2000 and 2010. This followed a change in advice from the UK health departments during 2003.

11.61 Both IFS and DNSIYC have shown that the proportion of infants receiving vitamin supplements was low (less than 14%).

11.62 Despite this, there was a low prevalence of suboptimal serum vitamin D levels (6%) and only 2% of children aged 12 to 18 months had intakes of vitamin A below the LRNI, while no children were below the LRNI at age 4 to 11 months

11.63 The main source of iron was infant formula and follow-on formula in the second 6 months of life. Low prevalence of iron deficiency anaemia (3% in children aged 5 to 11 months) was found in DNSIYC.

11.64 The low reliance on cows' milk as a main drink in the first year of life reported by DNSIYC (2013) offers reassurance that the risks associated with consumption of unmodified cows' milk are well recognised.

11.65 Contrary to popular perception fruit and vegetable consumption in this age group is substantial and relatively higher than intake later in childhood.

11.66 Intakes of NMES in DNSIYC (2013) increased with age, from an average contribution of 4% to total energy intakes in infants aged 4 to 6 months, to 8% in children aged 12 to 18 months.

11.67 Salt intakes in DNSIYC exceeded SACN recommendations by 50 to 100% after 10 months of age.

11.68 In DNSIYC (2013), around 75% of the children surveyed had parent-reported intakes that exceeded the UK EAR for energy. The same proportion exceeded the WHO growth standard median for weight. These findings suggest that UK infants are exceeding their energy requirements. This is of concern in relation to wider evidence on the prevalence and risk of overweight and obesity in childhood.

12 Conclusions and recommendations

Conclusions

Infant and complementary feeding practice in the UK

The conclusions in this section are based on the findings of Chapter 11 (UK infant feeding practice).

12.1 Successive UK IFS up to 2010 have shown increases in the proportion of women initiating breastfeeding, particularly since 2000. However, successive surveys have also shown that the proportion of women who discontinued breastfeeding before their infant was 6 weeks old had remained between 32% and 39% since 1995.

12.2 The proportion of women in the UK who breastfed exclusively to 6 months of age or who were still breastfeeding at 1 year remained very low in 2010 compared with other HIC.

12.3 Surveillance data from the IFS indicate that there was a reduction in the proportion of infants receiving solid foods before 4 months of age between 2000 and 2010. This followed a change in advice from the UK health departments in 2003 to recommend exclusive breastfeeding for around the first 6 months of life. The previous policy recommendation was to exclusively breastfeed for the first 4 to 6 months of life.

12.4 In the UK, breastfeeding and age of introduction of solid foods are patterned by parental social and educational status, which may lead to confounding in their associations. This is also the case for the quality of the complementary diet. Parents of breastfed infants are more likely to follow complementary feeding guidance and other health and lifestyle guidance.

Breastfeeding

The conclusions in this section are based on the finding of Chapters 3 (Infant feeding, growth and health).

12.5 Breastfeeding makes an important contribution to infant and lifelong health and represents the physiological norm for early infant feeding.

12.6 Breastfeeding has an important role in the development of the infant immune system through the provision of passive specific and non-specific immune factors. There is evidence that not breastfeeding is associated with a higher risk of infant hospital admission as a consequence of gastrointestinal or respiratory infections even in HIC such as the UK.

12.7 There is evidence that not breastfeeding may also be associated with disadvantages for certain neurodevelopmental outcomes during childhood, as shown in one RCT and a range of observational studies, but residual confounding cannot be ruled out.

12.8 The available evidence indicates that breastfeeding is also associated with improved maternal health. Women who breastfeed for longer are at lower risk of breast cancer and endometriosis. Breastfeeding is also associated with greater postpartum weight loss and lower BMI in the longer term. Furthermore, breastfeeding is not associated with an increased risk of low bone mineral density or osteoporosis in later life.

12.9 Once solid foods have been introduced at around 6 months, continued breastfeeding alongside solid foods for at least the first year of life is associated with improved infant and maternal health.

Acceptance of solid foods

The conclusions in this section are based on the findings of Chapters 3 (Infant feeding, growth and health), 4 (Energy requirements), 7 (Eating and feeding of solid foods) and 11 (UK infant feeding practice).

12.10 By around 6 months of age, infants are usually developmentally ready to actively accept foods other than breast milk (or infant formula).

12.11 The available evidence indicates that the introduction of solid foods or infant formula to breastfed infants before 6 months of age reduces the amount of breast milk consumed without increasing total energy intake or altering growth or weight gain. The introduction of solid foods or infant formula before 6 months of age is also associated with greater risk of gastrointestinal infections and lower and upper respiratory infections in infants.

12.12 The existence of a 'critical window' for the acceptance of solid foods between 4 and 6 months is not supported by experimental evidence. Deferring the start of complementary feeding to around 6 months of age is not associated with later difficulty in accepting solid foods.

12.13 A range of evidence indicates that repeated exposure to new foods enhances their acceptance. Offering a variety of foods also helps to increase acceptance of new flavours by infants.

12.14 There is limited evidence on the BLW approach to complementary feeding. A single trial reported that a 'BLW approach' resulted in earlier self-feeding, less food fussiness and greater enjoyment of food (secondary outcomes self-reported by parents).

12.15 Data from DNSIYC (2013) indicate that infants' consumption of fruit and vegetables is substantial and relatively higher than intakes later in childhood. Intakes of NMES increased with age, from an average contribution of 4% to total energy intakes in infants aged 4 to 6 months, to 8% in children aged 12 to 18 months. Salt (sodium chloride) intakes after 10 months of age exceeded SACN guidance by 50 to 100%.

Growth and energy requirements

The conclusions in this section are based on the findings of Chapters 3 (Infant feeding, growth and health), 4 (Energy requirements), 5 (Infant feeding, body composition and health) and 11 (UK infant feeding practice).

12.16 The WHO growth standards describe the linear and ponderal growth pattern of infants who were exclusively or predominantly breastfed for at least the first 4 months of life (with a mean age of 5.4 months at introduction of complementary feeding) and breastfed for at least the first 12 months of life. They describe a pattern of growth to be attained by all infants whether or not breastfed. The EARs for dietary energy for UK infants were derived using the WHO growth standards.

12.17 The best estimates to date indicate that breast milk production increases between 4 and 6 months of age and that this meets the increasing energy demands of the growing infant. The available evidence indicates that breastfeeding exclusively for the first 6 months of life does not constrain infant energy intakes or weight gain.

12.18 There is a body of observational evidence indicating that rapid weight gain in infancy predicts later obesity but also predicts tall stature.

12.19 There is evidence from observational studies regarding an association between the age of first solid foods and later adiposity. However, most prospective studies that have examined infant weight or weight gain before commencement of complementary feeding have identified rapid early weight gain as a predictor rather than a consequence of the early introduction of solid foods. This indicates a likelihood of reverse causality in any relationship between early complementary feeding and subsequent overweight. There are too few data to draw conclusions about relationships between age at introduction of complementary feeding and cardio-metabolic outcomes in later life.

12.20 In DNSIYC (2013), around 75% of the children (aged 4 to 18 months) surveyed had parent-reported intakes that exceeded the UK EAR for energy. The same proportion exceeded the WHO growth standard median for weight. These findings suggest that UK infants are exceeding their energy requirements. This is of concern in relation to wider evidence on the prevalence and risk of overweight and obesity in childhood.

Micronutrients

Iron

The conclusions in this section are based on the findings of Chapters 6 (Micronutrients) and 11 (UK infant feeding practice).

12.21 Iron status at birth is the most important determinant of iron status throughout infancy. Factors associated with lower iron status at birth include low infant birthweight, and maternal iron deficiency anaemia, obesity, smoking status and gestational hypertension. Delaying clamping of the umbilical cord until it has stopped pulsating is an effective intervention to increase iron status at birth.

12.22 Healthy term infants are born with sufficient body iron stores, which along with iron in breast milk, are sufficient to meet their needs for growth and development for the first 6 months of life.

12.23 From around 6 months of age, a diverse complementary diet is needed to meet the increasing iron requirements of older infants.

12.24 Breast milk (or infant formula) should be the main drink throughout the first year of life. The consumption of unmodified cows' milk as a main drink by infants younger than 12 months is associated with lower iron status. The low reliance on cows' milk as a main drink in the first year of life reported by DNSIYC (2013) offers reassurance that this risk is now well recognised.

12.25 Experimental evidence on the effect of iron supplements on infant growth is mixed, with only some studies reporting a positive effect. There is evidence in infants who are iron replete that iron supplements in infancy are not protective against future deficiency and may have a detrimental effect on linear growth.

12.26 DNSIYC (2013) reported that 3% of UK children aged 5 to 11 months had haemoglobin and serum ferritin concentrations below the level which iron deficiency anaemia is indicated.

Vitamins D and A

The conclusions in this section are based on the findings of Chapters 6 (Micronutrients), 10 (Risks of chemical toxicity) and 11 (UK infant feeding practice).

12.27 Other than the prevention of nutritional rickets, data are not available to clearly relate serum 25(OH)D concentration in infants to current or long term health outcomes. Data from DNSIYC (2013) indicate that 6% of infants were at risk of vitamin D deficiency. SACN recommends a 'safe intake' of vitamin D (8.5-10µg/d) for all infants from birth (except for those consuming more than 500ml of infant formula a day), however data from both IFS (2010) and DNSIYC (2013) indicate that the proportion of infants receiving vitamin supplements was low (less than 14%).

12.28 Regarding vitamin A, data from DNSIYC (2013) indicated that no child was below the LRNI at age 4 to 11 months. However, COT concluded that there is potential for some infants to exceed the TUL for vitamin A if "exclusively breastfed by mothers taking dietary supplements containing high levels of vitamin A" or if infants are "fed infant formula at the upper limit of the retinol content allowed by regulation, given high dose vitamin A supplements, or consume liver more than once per week".

Oral health

The conclusions in this section are based on the findings of Chapter 8 (Oral health).

12.29 Breastfeeding during the first year of life has oral health benefits. The available evidence indicates that breastfeeding up to 12 months of age is associated with a decreased risk of dental caries and may offer protection when compared with infant formula feeding.

12.30 Observational evidence suggests that once the primary teeth erupt, there may be an increased risk of dental caries associated with factors such as breastfeeding ad libitum, nocturnal feeding and sleeping with the breast in the mouth. However, the quality of the available evidence is generally low and, in most of the studies, important confounders (such as complementary feeding with cariogenic foods/drinks, or inadequate oral hygiene practices) were not controlled for.

12.31 The one available systematic review with meta-analysis found that 'ever breastfed' children may be less likely to develop malocclusions compared with 'never breastfed' children up to 12 years of age.

Risks of allergic and autoimmune diseases

The conclusions in this section are based on the findings of Chapter 9 (Risks of allergic and autoimmune diseases).

12.32 There was insufficient evidence to indicate that breastfeeding influences the development of allergic or autoimmune diseases.

12.33 The available evidence indicates that the deliberate exclusion or delayed introduction of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods.

12.34 The available evidence indicates that allergenic foods such as peanut, hen's egg, gluten or fish can be introduced from around 6 months of age and need not be differentiated from other solid foods:

- there is insufficient evidence to demonstrate that the introduction of peanut or hen's egg into the infant diet before 6 months of age reduces the risk of developing food allergy to any greater extent than introduction from around 6 months

- there is high quality evidence that the timing of introduction of gluten is not associated with the risk of developing coeliac disease
- there is low to very low quality evidence that early fish introduction (before 6 to 12 months of age) was associated with reduced allergic rhinitis and sensitisation
- there is insufficient evidence for conclusions to be drawn on the effect of the timing of introduction of other allergenic foods in relation to developing an allergy to that food.

12.35 There was no indication that the avoidance or consumption of allergenic foods by mothers during pregnancy or lactation would reduce allergic or autoimmune diseases in their children.

12.36 The available evidence does not support the use of extensively hydrolysed or partially hydrolysed protein formula to influence the risk of developing allergic or autoimmune disease.

12.37 There was little evidence that maternal and other infant dietary exposures increased children's future risk of developing allergic or autoimmune diseases.

Risks of chemical toxicity

The conclusions in this section are based on the findings of Chapter 10 (Risks of chemical toxicity).

12.38 COT assessed toxicity issues from the infant diet for a number of nutrients, substances and contaminants in breast milk, infant formula and solid foods. They concluded there were unlikely to be concerns over toxicity in the diet of infants for substances considered at current levels of exposure. Issues where COT has flagged that there is potential concern are described in chapter 10.

Recommendations

Breastfeeding

12.39 The totality of the evidence reviewed for this report supports current guidance to breastfeed exclusively for around the first 6 months of an infant's life and to continue breastfeeding for at least the first year of life. Each makes an important contribution to infant and maternal health.

12.40 Given the rapid decline in the proportion of women breastfeeding over the first few weeks of an infant's life in the UK, greater focus should be given to:

- reducing attrition rates
- supporting women who make the informed choice to breastfeed.

12.41 Increasing the proportion of women who continue to breastfeed or express breast milk beyond 6 months of age would yield additional health benefits.

12.42 Infant formula (based on either cows' or goats' milk) is the only suitable alternative to breast milk for babies who are under 12 months old. The use of soya-based formula should only be on medical advice and the possible health effects of soya-based formula should be kept under review.

Introduction of complementary feeding

12.43 Current advice on the age of introduction of complementary feeding should remain unchanged. That is, most infants should not start solid foods until around the age of 6 months, having achieved developmental readiness.

12.44 Breast milk, infant formula and water should be the only drinks offered after 6 months of age. Unmodified cows' milk should not be given as a main drink to infants under 12 months of age. This is because cows' milk consumption in infancy is associated with lower iron status as a result of gastrointestinal blood loss and because the iron content and bioavailability of cow's milk is low.

12.45 A wide range of solid foods, including iron-containing foods, should be introduced in an age-appropriate form[10] from around 6 months of age, alongside continued breastfeeding, at a time and in a manner to suit both the family and individual child.

12.46 Dietary, flavour and texture diversification should proceed incrementally throughout the complementary feeding period, taking into account the variability between infants in developmental attainment and the need to satisfy nutritional requirements. When introducing new foods it should be recognised that they may need to be presented to infants on many occasions before they are accepted, particularly as infants get older.

12.47 In view of the high intakes of salt (sodium chloride) and free sugars in this age group, there is a need to re-emphasise the risks associated with added salt and free sugars in foods given to infants during the complementary feeding period and to keep reported intakes under review.

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[10] Infants and young children should never be left alone while they are eating. Children under 5 years old must not be given whole nuts, as they can choke on them.
Infants, children, pregnant women and elderly people can safely eat raw or lightly cooked eggs that are produced under the British Lion Code of Practice. The revised advice (updated in October 2017), based on the latest scientific evidence, means that people vulnerable to infection or who are likely to suffer serious symptoms from food poisoning (such as infants, children, pregnant women and elderly people) can now safely eat raw or lightly cooked hen eggs or foods containing them.
The existing advice on UK non-Lion eggs has not changed; non-hen eggs and eggs from outside the UK, should always be cooked thoroughly for vulnerable groups.
Eggs from other birds, such as duck, goose and quail eggs, should always be cooked thoroughly.

12.48 Healthy infants do not require iron supplements. To optimise iron status throughout the first year of life, SACN and NICE recommendations on delayed cord clamping should be implemented and monitored.

12.49 All infants from birth to 1 year of age who are being exclusively or partially breastfed should be given a daily supplement containing 8.5 to 10µg of vitamin D (340-400IU/d). Infants who are fed infant formula should not be given a vitamin D supplement unless they are consuming less than 500ml (about one pint) of infant formula a day, as infant formula is fortified with vitamin D.

12.50 The low prevalence of vitamin A deficiency in the healthy infant population, despite the current low uptake of supplements, suggests the need to review recommendations on routine vitamin A supplementation, particularly in light of the COT conclusion that there is the potential for some infants to exceed the TUL for vitamin A. It is recommended that government consider opportunities to review advice on supplements and foods containing vitamin A during infancy.

12.51 Advice on complementary feeding should state that foods containing peanut and hen's egg can be introduced from around 6 months of age and need not be differentiated from other solid foods. The deliberate exclusion of peanut or hen's egg beyond 6 to 12 months of age may increase the risk of allergy to the same foods. Once introduced, and where tolerated, these foods should be part of an infant's usual diet, to suit both the individual child and family. If initial exposure is not continued as part of an infant's usual diet, then this may increase the risk of sensitisation and subsequent food allergy. Families of infants with a history of early-onset eczema or suspected food allergy may wish to seek medical advice before introducing these foods.

12.52 Government should keep the risk from lead, acrylamide and arsenic under review. Efforts to reduce the levels of inorganic arsenic in food and water, and levels of acrylamide in commercially-produced and home-cooked foods should continue.

12.53 Government should consider public health messages to help ensure that infants are fed an appropriate and diverse complementary feeding diet.

12.54 Government should consider ways to monitor the prevalence of overweight and overfeeding in infants, and ways to address high energy intakes in this age group.

12.55 Government should consider how to address gaps in the evidence on infant feeding practices, in the absence of national monitoring of current practice. This includes evidence gaps on the prevalence and duration of breastfeeding, use of nutritional supplements, and use of foods other than breast milk in infancy. The questions and definitions previously adopted in the 5-yearly IFS would allow tracking of secular trends and changes in practice consequent to new recommendations and guidance.

13 Research Recommendations

Approach

13.1 Throughout the development of this report, a number of limitations in study design have been identified for some of the available research. Recommendations for all future research are given below.

- Measure the exclusivity, intensity and duration of breastfeeding as precisely as possible, preferably by application of standard WHO definitions of breast milk exposure and a prospective study design. Definitions adopted should be fully explained in publications.
- Include a reference group with breastfeeding infants in studies considering alternatives to breast milk or other infant dietary interventions (DH, 1996).
- Minimise the risk of reverse causation by employing prospective data collection for observational research. Data should be collected with sufficient frequency to capture accurately and precisely the timing of events of interest, given the rapid pace of change in the infant diet.
- Control for potential confounding factors to accurately identify the impact of the diet and feeding practices at this crucial stage of development. Prospective cohort study designs reduce the likelihood of recall bias.
- Collect detailed information on study populations and exercise considerable care when making statistical adjustment, to ensure that the strength and complexity of socio-demographic confounding of infant feeding practices are fully accounted for.
- Relate growth outcomes in infant feeding studies to the WHO multicentre growth study standards (2006) and those set by SACN/RCPCH (2007).
- Distinguish between exposure to fruit or vegetables, characterise the dominant sensory attributes of the foods (taste, texture) and how they were processed.
- Describe the mode of delivery of feeds and drinks, for example, breastfed compared with expressed breast milk taken from a bottle, and the use of free flow cups.

Topics

13.2 A number of gaps in the evidence were identified during the development of this report. Further research should be considered in the areas outlined below.

Breastfeeding in the UK

- Establish valid measures of the successful establishment of breastfeeding that go beyond simple initiation at birth.

- Explore the factors influencing caregiver choices on infant feeding and investigate effective behaviour change interventions to promote and support breastfeeding initiation and longer breastfeeding durations.
- Examine the effect of timing of introduction of solid foods on the duration of breastfeeding.

Feeding in the first year of life and health outcomes

- Examine the quality of growth during infancy to distinguish between weight and length gain and accruals of lean versus fat mass in relation to risk factors and intermediate markers for chronic non-communicable diseases.
- Explore the relationships between infant nutrient intake and (i) infant body composition and (ii) health outcomes in later life.
- Examine the effect of timing of introduction of solid foods, as opposed to introduction of infant formula, on health outcomes in exclusively breastfed, exclusively infant formula fed, and mixed fed infants.
- Examine the use of expressed breast milk on health outcomes, including oral health.
- Determine whether the constituents of breast milk inhibit the growth and adhesion of cariogenic bacteria to the teeth.
- Identify any association between breast and infant formula feeding and dental caries when the consumption of other drinks, mixed feeding and toothbrushing habits are established.
- Determine the later potential effects of infant food exposures during the start of complementary feeding (for example vegetables or food variety) on food preferences and food intakes.
- Examine the potential impact of different dietary patterns (such as vegetarian or vegan diets) on infant immediate and long term health outcomes.
- Describe the extent of variations in infant feeding practices and examine the potential impact on the infant's immediate and long term health outcomes.

Micronutrients

- Explore the benefit-risk of universal multivitamin supplementation, including vitamin A, in infancy in addition to the many foods and drinks that are already voluntarily fortified and widely consumed in infancy.
- Examine the potential role of micronutrients not considered in this report due to the lack of evidence relevant to the UK. Review status of these micronutrients and implications for health in infants in the UK to support the development of DRVs in infancy.

Annexes

Annex A Policy Background

Table A.1 UK recommendations for breastfeeding and the introduction of complementary feeding

Category of Recommendations	Present day practice in infant feeding. Report of a working party of the panel on child nutrition, Committee on Medical Aspects of Food Policy. (DHSS, 1974)	Present day practice in infant feeding. Report of a working party of the panel on child nutrition, Committee on Medical Aspects of Food Policy. (DHSS, 1980)	Present day practice in infant feeding: third report. Report on Health and Social Subjects 32. (DHSS, 1988)	Weaning and the weaning diet. Report on Health and Social Subjects 45. (DH, 1994)
Breastfeeding	Breastfeeding for a minimum of 2 weeks and preferably for the first four to six months of life.	The Working Party endorses the recommendation published in the 1974 report, that breastfeeding should be encouraged for the first months of life.	Reaffirms what the 1980 report stated, that the Government Health Departments should encourage all healthy mothers to breastfeed their babies.	Mothers should be encouraged and supported in breastfeeding for at least four months and may choose to continue to breastfeed as the weaning diet becomes increasingly varied.
Introduction of complementary feeding	Early introduction of cereals or other solid foods to the diet before about four months of age should be strongly discouraged. Cereal foods in any form should not be added to the milk in bottle feeds.	The age at which the infant should be offered solid foods varies. The majority of infants should be offered a mixed diet no later than six months, while very few will require solid foods before the age of three months.	The majority of infants should be offered a mixed diet not later than the age of six months . Breastfeeding or feeding with infant formula can, with advantage, be continued to at least the end of the first year as part of a mixed diet.	The majority of infants should not be given solid foods before the age of four months and a mixed diet should be offered by the age of six months.
Recommended/ common first complementary foods to be introduced to the infant's diet	Cereal powders and rusks made from wheat flour are the most common first solid foods introduced to the infant's diet. These are often sweetened and may be fortified with vitamins and minerals.	The most common first solid foods introduced to the infant's diet are wheat based cereal foods.	The Office of Population Censuses and Surveys reported that the first foods used during weaning were rusks, cereals and commercial baby foods.	An adequate intake of protein with a proper balance of essential amino acids should be ensured during weaning. Infants being weaned on diets restricted in animal protein (e.g. a vegetarian diet) should particularly be offered a variety of foods at each meal. The working group recommends non-wheat cereals, fruit, vegetables and potatoes as suitable first weaning foods.
Mode of feeding	—	—	—	Semi-solid foods should be given from a spoon and should not be mixed with milk or other drink in a bottle. From six months of ages, infants should be introduced to drinking from a cup and from age one year onwards, drinking from a bottle should be discouraged.

Category of Recommendations	Present day practice in infant feeding. Report of a working party of the panel on child nutrition, Committee on Medical Aspects of Food Policy. (DHSS, 1974)	Present day practice in infant feeding. Report of a working party of the panel on child nutrition, Committee on Medical Aspects of Food Policy. (DHSS, 1980)	Present day practice in infant feeding: third report. Report on Health and Social Subjects 32. (DHSS, 1988)	Weaning and the weaning diet. Report on Health and Social Subjects 45. (DH, 1994)
Progression of complementary feeding	—	—	—	Food consistency should progress from pureed through minced/mashed to finely chopped. By the age of one year the diet should be mixed and varied.
Allergens	The use of wheat cereal at an early age (before four to six months) is to be discouraged.	In relation to developing gluten enteropathy, for the majority of infants there is no evidence that wheat-based cereals are a food hazard.	For the majority of infants wheat-based cereal foods present no hazard of inducing coeliac disease. Those at risk of developing coeliac disease cannot be identified in advance.	Where there is a family history of atrophy or gluten enteropathy, mothers should be encouraged to breast feed for six months or longer. Weaning before six months should be discouraged. The introduction of foods traditionally regarded as allergenic should be delayed until six months at the earliest.
Vitamin supplementation	Vitamin supplementation should be made available to children during at least the first year of life. A single dose of the vitamin supplement, made available by the UK government, contains the recommended daily intake of three vitamins (vitamin A, C & D). Breastfed babies should receive three drops daily from the first month, increasing slowly to serval drops daily at four months. Bottle fed babies should receive two drops daily from the first month and increase to four drops daily at four months. When breast or bottle feeding stops, all infants should receive seven drops daily.	Vitamin supplements should be advised for all expectant and lactating mothers and to infants and young children up to the age of five years. The working party recommends altering the dosage of the vitamins for infants to a standard dose of five drops from the age of one month until at least two years and preferably five years.	Vitamin supplementation should be given to infants and young children aged from six months up to at least two years and preferably five years. The Working Party endorses the dosage recommended in the 1980 report.	Breastfed infants under six months do not need vitamin supplementation provided the mother had an adequate vitamin status during pregnancy. From age six months, infants receiving breast milk as their main drink should be given supplements of vitamins A and D. Infants fed on manufactured milks do not need vitamin supplements provided their consumption of infant formula/follow on milk is more than 500ml per day. If they are consuming these milks in smaller amounts or are being given cows' milk, vitamins A & D should be given.
Addition of sugar/salt to complementary foods	Sugar or salt should not be added to the solid foods in an infant's diet.	Sugar or salt should not be added to the solid foods in an infant's diet.	—	Salt should not be added and additional sugars should be limited to that needed for palatability of sour fruits.

An infant is a child who has not attained the age of one year and a young child is a child aged from one to three years.

Historically the terms 'weaning foods' or 'solids' were commonly used to describe the foods introduced to infants alongside breast milk (or infant formula). 'Weaning' can be interpreted as the cessation of breastfeeding (or milk feeding), therefore, the term 'complementary feeding' has been used throughout this report.

Table A.2 World Health Organization (WHO) recommendations for breastfeeding and the introduction of complementary feeding

Category of Recommendations	WHO/UNICEF meeting on infant and young child feeding. (WHO/UNICEF, 1980)	Feeding and nutrition of infants and young children. Guidelines for the WHO European Region, with emphasis on the former Soviet countries. (WHO Europe, 2003)	Guiding principles for complementary feeding of the breastfed child. (PAHO, 2003)	Guiding principles for feeding non-breastfed children 6-24 months of age 2005. (WHO, 2005)	Essential nutrition actions: improving maternal, newborn, infant and young child health and nutrition. (WHO, 2013)
Breastfeeding	For optimal breastfeeding the use of supplementary bottle feeding (water and formula) should be avoided. Fully breastfed babies should not need to be introduced to complementary foods before four to six months of age.	All infants should be exclusively breastfed from birth to about six months (26 weeks) of age and at least for the first four months of life. Breastfeeding should preferably continue beyond the first year of life.	Exclusive breastfeeding from birth to six months of age.	Exclusive breastfeeding for the first six months of life. However it is recognised that this may not be possible for all infants.	Exclusive breastfeeding for the first six months of life.
Introduction of complementary feeding	Complementary foods will need to be introduced between four and six months of age.	Complementary foods should be introduced at about six months of age. Some infants may need complementary foods before this time, but they should not be before four months of age.	Introduction of complementary foods at six months of age, with small amounts of food, while maintaining frequent breastfeeding.	Introduction of complementary foods at six months of age with continued breastfeeding up to two years or beyond.	After six months of age infants should receive nutritionally adequate and safe complementary foods while breastfeeding for up to two years of age or beyond.
Recommended/ common first complementary foods to be introduced to the infant's diet	Foods that are locally available in the home can be made suitable for weaning.	Infants should be fed a wide variety of foods of high nutritional value. First foods offered should be single-ingredient, pureed foods with a smooth consistency. Examples include pureed home-cooked rice, mashed potato and pureed fruit or vegetables.	Feed a variety of foods to ensure nutrient needs are met. Meat, poultry, fish or eggs should be eaten daily or as often as possible.	Infants can eat pureed, mashed and semi-solid foods beginning at six months of age.	Small amounts of a variety of foods to ensure nutrients needs are met and increase quantity as the child gets older.
Mode of feeding	During weaning, infants should be fed by cup and spoon or other suitable utensils.	Infant should become accustomed to eating from a spoon.	—	—	—
Progression of complementary feeding	—	As infants continue to develop, foods of a thicker consistency and lumpier texture may be introduced.	Infants can eat pureed, mashed and semi-solid foods beginning at six months. By eight months, most infants can also eat ‘finger foods’.	By age eight months most infants can also eat finger foods. By 12 months of age, most children can eat the same types of foods as consumed by the rest of the family.	—
Allergens	—	—	No restrictions advised.	—	—

Category of Recommendations	WHO/UNICEF meeting on infant and young child feeding. (WHO/UNICEF, 1980)	Feeding and nutrition of infants and young children. Guidelines for the WHO European Region, with emphasis on the former Soviet countries. (WHO Europe, 2003)	Guiding principles for complementary feeding of the breastfed child. (PAHO, 2003)	Guiding principles for feeding non-breastfed children 6-24 months of age 2005. (WHO, 2005)	Essential nutrition actions: improving maternal, newborn, infant and young child health and nutrition. (WHO, 2013)
Vitamin supplementation	—	Vitamin supplementation can differ between countries.	Use fortified complementary foods or vitamin-mineral supplements for the infant, as needed.	Vitamin supplements that contain iron and the use of fortified foods should be taken as needed. If adequate amounts of animal-source foods are not consumed, fortified foods or supplements should contain other nutrients, such as zinc, calcium and vitamin B12.	Use fortified complementary foods or vitamin-mineral supplements as required.
Addition of sugar/salt to complementary foods	—	Complementary foods should have no added sugar, salt or strong seasoning such as curry powder or chilli pepper.	Avoid giving sugary drinks such as soda.	—	—

Annex B Energy requirements

Table B.1 Energy content of tissue deposition of infant

Age interval (months)	Protein gain (g/d)	Fat mass gain (g/d)	Energy deposited in growing tissues (kJ/g)
Boys			
0-3	2.6	19.6	25.1
3-6	2.3	3.9	11.6
6-9	2.3	0.5	6.2
9-12	1.6	1.7	11.4
Girls			
0-3	2.2	19.7	26.2
3-6	1.9	5.8	15.6
6-9	2.0	0.8	7.4
9-12	1.8	1.1	9.8

Gross energy equivalents: 1g protein = 23.6kJ (5.65 kcal); 1g fat = 38.7kJ (9.25kcal)

Source: (Butte, 2005)

Table B.2 Estimated average requirement (EAR) for infants 0–12 months of age

Age (months)	Total energy expenditure (TEE) (kJ/day)			EAR[a]					
	Breastfed TEE = 388 Weight (kg) – 635	**Breast milk substitute-fed** TEE = 346 Weight (kg) – 122	**Feeding mixed or unknown** TEE = 371 Weight (kg) – 416	**Breastfed**		**Breast milk substitute-fed**		**Feeding mixed or unknown**	
				kJ/day	**kJ/kg per day**	**kJ/day**	**kJ/kg per day**	**kJ/day**	**kJ/kg per day**
Boys									
1	1099	1425	1242	2030	454	2356	527	2173	486
2	1522	1802	1647	2421	435	2701	486	2546	458
3	1837	2082	1947	2505	393	2750	432	2615	411
4	2081	2300	2181	2321	332	2540	363	2421	346
5	2279	2476	2370	2474	329	2671	356	2565	342
6	2442	2622	2526	2602	328	2782	351	2686	339
7	2585	2750	2663	2661	321	2826	340	2739	330
8	2706	2857	2778	2769	322	2920	339	2841	330
9	2818	2957	2886	2877	323	3016	339	2945	331
10	2919	3047	2982	3016	329	3144	343	3079	336
11	3016	3134	3075	3109	330	3227	343	3168	337
12	3109	3217	3164	3199	332	3307	343	3254	337
Girls									
1	991	1328	1138	1819	434	2156	514	1966	469
2	1355	1653	1487	2165	422	2463	480	2297	448
3	1631	1899	1751	2241	384	2509	430	2361	404
4	1856	2099	1966	2154	336	2397	373	2264	353
5	2042	2265	2144	2288	332	2511	364	2390	346
6	2197	2404	2292	2401	329	2608	357	2496	342
7	2329	2521	2418	2412	316	2604	341	2501	327
8	2450	2629	2533	2525	318	2704	340	2608	328
9	2554	2722	2634	2620	319	2788	339	2700	328
10	2655	2812	2730	2738	323	2895	341	2813	332
11	2748	2895	2819	2825	324	2972	341	2896	332
12	2838	2975	2904	2912	325	3049	341	2978	333

[a] Calculated as TEE + energy deposition (kJ/day) as in Table B.3

Source: (SACN, 2011a)

Table B.3 Weights, growth and energy deposition rates for infants 1–12 months of age

Age (months)	Weight (kg)[a]	Weight velocity (g/day)[b]	Energy deposition (kJ/g)	Energy deposition (kJ/day)
Boys				
1	4.47	37.1	25.1	931
2	5.56	35.8	25.1	899
3	6.37	26.6	25.1	668
4	7	20.7	11.6	240
5	7.51	16.8	11.6	195
6	7.93	13.8	11.6	160
7	8.3	12.2	6.2	76
8	8.61	10.2	6.2	63
9	8.9	9.5	6.2	59
10	9.16	8.5	11.4	97
11	9.41	8.2	11.4	93
12	9.65	7.9	11.4	90
Girls				
1	4.19	31.6	26.2	828
2	5.13	30.9	26.2	810
3	5.84	23.3	26.2	610
4	6.42	19.1	15.6	298
5	6.9	15.8	15.6	246
6	7.3	13.1	15.6	204
7	7.64	11.2	7.4	83
8	7.95	10.2	7.4	75
9	8.22	8.9	7.4	66
10	8.48	8.5	9.8	83
11	8.72	7.9	9.8	77
12	8.95	7.6	9.8	74

[a] 50th percentile weight for age of the WHO Child Growth Standards (WHO MGRS, 2006b)

[b] 50th percentile weight increment of the WHO Child Growth Standards (WHO MGRS, 2006b)

Source: (SACN, 2011a)

Annex C Key studies considered in relation to infant feeding in the first year of life

Table C.1 Infant feeding, growth and health: systematic reviews and meta-analyses

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Bachrach et al (2003) Funding Not specified. Declaration of interest (DOI) Not specified.	Meta-analysis to examine breastfeeding and the risk of hospitalisation for LRTD in healthy term infants with access to modern medical care. 9 studies included: - 7 cohort studies, allowing summary relative RR to be reported - 1 cross-sectional analysis (OR) - 1 ecological design (OR).	Studies included characterised breastfeeding as exclusive (little or no formula offered) and provided a duration of exclusive breastfeeding (EBF) for 2, 4 or 6 months, or total (any) breastfeeding for longer durations. The breastfeeding inclusion criterion was an EBF of 2 months minimum or 9 months of total (any) breastfeeding compared with its absence.	Healthy term infants in HIC (that is, high living standards in terms of access to modern medication and sanitation). The meta-analysis evaluated the risk of hospitalisation in 3,201 breastfed subjects and 1,324 non-breastfed subjects. Countries US, Canada, New Zealand, Australia, Scotland, Norway	LRTD hospitalisation rates LRTD included: bronchiolitis, asthma, bronchitis, pneumonia, empyema, infections due to specific agents (such as respiratory syncytial virus).	Comments by the authors The effects of smoking and SES as possible confounders of the relationship between breastfeeding and hospitalisation for LRTD were investigated.	The summary RR of respiratory disease hospitalisation for 4 months of EBF compared to no breastfeeding was 0.28 (95% CI 0.14 to 0.54), using a random-effects model. This effect remained stable and statistically significant after adjusting for the effects of smoking or SES. EBF for 4 months or more appears to decrease the risk of respiratory hospitalisation in infancy to one-third or less the risk observed for formula fed infants, even in HIC with high standards of living.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Bowatte et al (2015) <u>Funding</u> The Bill and Melinda Gates Foundation; the WHO. <u>DOI</u> None to declare.	Systematic review with meta-analysis to synthesis the evidence on the association between duration and exclusivity of breastfeeding and risk of AOM. <u>24 studies included:</u> - 18 cohort studies - 6 cross-sectional studies.	Definitions, durations and methods of feeding practices (exclusive, partial, formula, solid or combinations coupled with duration of feeding) were highly variable between studies. 4 categories identified for the meta-analyse: 1) EBF vs not EBF or not breastfed during first 6 months 2) ever vs never breastfed 3) any breastfeeding $\geq$3-4 months vs $\leq$3-4 months 4) more or less breastfeeding.	Numbers of participants in the studies included ranged from 281 to 11,349. The cohort studies followed subjects from birth to a mean of 6 to 24 months (2 reported outcomes at 5 and 6 years). The cross-sectional studies reported outcomes from 12 months up to 8 years. <u>Countries</u> Europe and North America	Development of AOM defined as: - doctor diagnosed AOM - parent or self-reported AOM - AOM recorded on health-related databases. Studies reported either current or past disease or recorded healthcare utilisation for AOM.	<u>Comments by the authors</u> Potential confounders on AOM and breastfeeding: - parental history of allergy - number of siblings - day care attendance - maternal smoking/ second-hand smoke exposure - gender - ethnicity - SES. The authors noted that while some studies adjusted for these covariates, some were not adjusted for any confounders and some were adjusted for only a few. This may have caused some bias in the meta-analysis results but there were too few studies in each stratum to perform analysis stratified by good vs poor adjustment for confounders.	In the pooled analysis, any form of breastfeeding was found to be protective for AOM in the first 2 years of life. EBF for the first 6 months was associated with the greatest protection (OR 0.57; 95% CI 0.44 to 0.75; 5 studies), followed by 'more vs less' breastfeeding (OR 0.67; 95% CI 0.59 to 0.76; 12 studies) and 'ever vs never' breastfeeding (OR 0.67; 95% CI 0.56 to 0.80; 5 studies). The authors concluded that this systematic review found good evidence that breastfeeding is associated with a reduced risk of AOM during the first two years of life, with an average reduced risk of 30% to 40% in all categories of breastfeeding.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Horta & Victora (2013) Funding Not specified. DOI Not specified.	Systematic review with meta-analysis to address the long-term effects of breastfeeding. This review being an update of the 2007 review by the same authors on the long-term effects of breastfeeding, only articles published from 2006 (to allow late inclusion in databases) to September 2011 were searched. Number of studies included, by outcome: - Overweight and obesity: 33 new studies identified; 71 studies (75 estimates) included in meta-analysis. - Blood pressure: 8 new studies identified; 36 studies (37 estimates) included in meta-analysis. - Serum cholesterol: 8 new studies identified; 35 studies (42 estimates) included in meta-analysis. - Type-2 diabetes: 3 new studies identified; 10 studies included in meta-analysis. - Intellectual performance: 8 new studies identified; 13 studies (14 estimates) included in meta-analysis.	The definitions and classifications varied across studies. The authors did not apply any restrictions on the type of categorisation of breastfeeding (never vs breastfed, breastfed for more or less than a given number of months, exclusively breastfed for more or less than a given number of months). Studies that did not use an internal comparison group were excluded.	Studies in infants were excluded as the aim of this review as to assess the long-term effects of breastfeeding. Countries Most studies were derived from HIC.	- Overweight and obesity - Blood pressure - Serum cholesterol - Type-2 diabetes - Intellectual performance	Comments by the authors The authors highlighted that confounding is one of the challenges in interpreting the evidence of observational studies and that even large studies that measures the possible confounders may still be affected by residual confoundings. In HIC, breastfeeding mothers are more likely to be health-conscious and, therefore, to promote healthy habits to their infants, including prevention of obesity, promotion of physical activity and intellectual stimulation. This self-selection bias should therefore be treated as a confounding factor. The authors noted that as their meta-analyses are almost exclusively based on observational studies, the possibility of self-selection and residual confounding must be considered.	Overweight/obesity In the pooled analyses of all studies, breastfeeding was associated with a 24% reduction in overweight and/or obesity, but the reduction was only 12% in the high-quality studies. The authors concluded that breastfeeding may provide some protection against overweight or obesity, but residual confounding cannot be ruled out. Blood pressure The pooled estimate from the high-quality studies indicates a small reduction of less than 1 mmHg in systolic pressure among breastfed subjects, and no significant protection in terms of diastolic pressure. The authors concluded that the protective effect of breastfeeding, if any, is too small to be of public health significance. Total cholesterol Breastfeeding does not seem to protect against total cholesterol levels. Type 2 diabetes There was substantial protection in the pooled analyses, with a 34% reduction, but few studies are available and their results were considerably heterogeneous. The authors concluded that further studies were needed on this outcome. Intelligence tests Breastfeeding was associated with an increase in 3.5 points in normalised test scores in the pooled analyses of all studies, and 2.2 points when only the high-quality studies are included. The authors concluded that there is strong evidence of a causal effect of breastfeeding on IQ, although the magnitude of this effect seems to be modest. The meta-analyses of overweight/ obesity, blood pressure, diabetes and intelligence suggest that benefits are larger for children and adolescents, and smallest among adults, suggesting a gradual dilution of the effect with time.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Horta et al (2015) Funding Bill and Melinda Gates Foundation. DOI None to declare.	Systematic review with meta-analyses to study the association between breastfeeding and performance in intelligence tests. Update of (Horta & Victora, 2013), focusing only on the intellectual performance as an outcome. Only articles published from September 2011 to December 2014 were searched and 4 new studies were identified. In total, 17 studies with 18 estimates of the relationship between breastfeeding and performance in intelligence tests were included in the meta-analyses.	The type of comparison group (never breastfed, breastfed for less than x months, etc) and exposed group (ever breastfed, breastfed for more than x months, exclusively breastfed for x months) was not considered as eligibility criteria. However, studies that did not use an internal comparison group were excluded.	Only studies carried out among subjects older than 1 year of age were included.	Cognition, measured using standard tests.	Comments by the authors Selection criteria of the studies: estimates had to be adjusted for stimulation or interaction with the child. The authors highlighted that maternal IQ is an important confounder that account for part of the association between breastfeeding and performance in intelligence tests. Therefore, estimates were adjusted for maternal IQ.	In a random-effects model, breastfed subjects achieved a higher IQ (mean difference 3.44 points; 95% CI 2.30 to 4.58 points). No evidence of publication bias was found. Studies that controlled for maternal IQ showed a smaller benefit from breastfeeding (mean difference 2.62 points; 95% CI 1.25 to 3.98 points). Studies that evaluated subjects aged between 10 and 19 years also reported a smaller benefit from breastfeeding (mean difference 1.92 points; 95% CI 0.43 to 3.40 points) than studies involving younger subjects (mean difference 4.12 points; 95% CI 2.50 to 5.73 points). In the meta-regression, none of the study characteristics explained the heterogeneity among the studies. A positive effect of breastfeeding on cognition was observed in a randomised trial, suggesting a causal association. The authors concluded that breastfeeding is related to improved performance in intelligence tests.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Ip et al (2007) Funding The Agency for Healthcare Research and Quality (AHRQ) and its Evidence-Based Practice Centres (EPCs); the Office on Women's Health of the Department of Health and Human Services (DHHS). DOI None to declare. To note This report was requested by the DHHS Office on Women's Health and was conducted through EPC program at the AHRQ.	Systematic review and evidence report to summarise the literature concerning the relationship of breastfeeding and various infant and maternal health outcomes. Studies included: - 29 systematic reviews or meta-analyses (covering about 400 individual studies) - 43 primary studies on infant health outcomes - 43 primary studies on maternal health outcomes.	The majority of the studies did not distinguish between exclusive and partially breastfed infants. For this review, all definitions of EBF were accepted as provided by the different study authors.	Participants: - healthy term infants - preterm infants - healthy mothers. Countries HIC	Full term infant outcomes: - AOM - atopic dermatitis - gastrointestinal infections - hospitalisation for LRTI - asthma - cognitive development - obesity - risk of cardiovascular disease - type 1and 2 diabetes - childhood cancer (including leukemia) - infant mortality - sudden infant death syndrome. Preterm infant outcomes: - necrotizing enterocolitis - cognitive development. Maternal outcomes: - maternal weight change - maternal type 2 diabetes - osteoporosis - postpartum depression - breast cancer - ovarian cancer.	Comments by the authors One of the well-known confounders in breastfeeding research is the demographic difference between mothers who breastfeed and those who chose not to: mothers who breastfeed tend to be white, older, more educated and in a higher SES. While it is possible to control for some of these factors, it is not possible to control for behavioural or attitudinal factors intrinsic in the desire to breastfeed. The confounding factors identified by the authors are listed below for the outcomes of interest in this report. Full term infant outcomes AOM: parental history of allergy, number of siblings, use of day care, maternal smoking, gender, ethnicity, SES. Atopic dermatitis: gender, SES, family history of atopy, parental smoking, presence of furry animals in the home. Gastrointestinal infection: SES, child care variables (home vs day care, degree of crowding at home, etc). LRTI: smoking, SES. Asthma: age, SES, family history of atopy, parental smoking.	Key findings for this report: Full term infant outcomes AOM 23% (95% CI 9 to 36%) reduction when comparing ever breastfeeding with exclusive formula feeding 50% (95% CI 30 to 64%) reduction when comparing EBF with exclusive formula feeding either for >3 or >6 months. Atopic dermatitis 42% (95% CI 8 to 59%) reduction for EBF ≥3 months compared with <3 months in children with a family history of atopy. Gastrointestinal infection A reduction in the risk of non-specific gastrointestinal infections during the first year of life was identified in breastfed infants from HIC. LRTI 72% (95% CI 46 to 86%) reduction in the risk of hospitalisation due to LRTI in infants <1 year of age who were EBF ≥4 months. Asthma 27% (95% CI 8 to 41%) risk reduction in those without a family history of asthma for breastfeeding ≥3 months compared with no breastfeeding. 40% (95% CI 18 to 57%) risk reduction in children <10 years of age with a family history of asthma who were breastfed ≥3 months compared with no breastfeeding. Cognitive development Little or no evidence was found for an association between breastfeeding and cognitive performance in childhood. Obesity/overweight There is an association between breastfeeding and a reduction in the risk of being overweight or

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
					Cognitive development: SES, maternal education, birthweight, gestational age, birth order, gender. Obesity/overweight: birth weight, parental overweight, parental smoking, dietary factors, physical activity, SES, age, sex, birth order, number of siblings. Cholesterol: BMI, height, SES. Blood pressure: age, gender, race, height, BMI. Risk of CVD mortality: age, birth weight, infant health, SES, birth order. Maternal outcomes Maternal weight change: pre-pregnancy weight or BMI, age, educational level, physical activity, parity, smoking status, dieting practice, ethnicity Osteoporosis: age, hormone replacement therapy, parity, BMI Breast cancer: parity, number of children breastfed, lifetime duration of breastfeeding, menopausal status, ethnic origin, education, family history of breast cancer, age at menarche, height, weight, BMI, use of hormonal contraceptives, alcohol, tobacco	obese in adolescence and adult life: 24% (95% CI 14 to 33%) reduction in one meta-analyse; 7% (95% CI 1 to 12%) in another one and a 3rd one found a 4% risk reduction for each additional month of breastfeeding. Risk of CVD The relationship between breastfeeding in infancy and the risk of CVD could not be confidently characterised and need further investigation. Maternal outcomes Maternal weight change The effects of breastfeeding on postpartum weight loss were unclear. Osteoporosis There is little or no evidence for an association between lifetime breastfeeding duration and the risk of fractures due to osteoporosis. Breast cancer Consistent evidence suggests that there is an association between breastfeeding and a reduced risk of breast cancer: 4.3% reduction was found for each year of breastfeeding in one meta-analysis and 28% reduction for ≥12 months of breastfeeding in another.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Kramer & Kakuma (2002) Funding McGill University (Canada); Canadian Institutes of Health Research; Canadian Cochrane Network; Department of Nutrition for Health and Development (WHO, Switzerland). DOI MSK is the principal investigator of some of the studies included in this review.	Systematic review to assess the effects on child health, growth and development, and on maternal health, of EBF for 6 months vs EBF for 3 to 4 months with mixed breastfeeding thereafter through 6 months. 16 independent studies (32 articles) included: - 2 RCTs - 14 observational studies. Only the studies with an internal comparison group were included in the review. Therefore, studies based on external comparisons (with reference data) were excluded.	Definition of EBF varied considerably across studies and few studies strictly adhered to the WHO definition. In some studies, EBF included water, teas or juices or even small amount of infant formula. Mixed breastfeeding: introduction of complementary liquid (juices, formula, other milks, other liquids) or solid foods with continued breastfeeding. The selection criteria was an EBF ≥6 months compared with an EBF of at least 3 to 4 months with continued mixed breastfeeding for at least 6 months.	Healthy term infants and their mothers from both LMIC and HIC. Studies of or including low-birth weight (<2,500g) infants were not excluded provided that they were born at terms (≥37 completed weeks). Countries Of the 16 studies, 7 were carried out in LMIC (2 of which were the RCTs) and 9 in HIC (all observational studies).	Infant outcomes: - growth (weight, length, head circumference, z-scores for weight-for-age, length-for-age, weight-for-length) - infections, morbidity, mortality - micronutrient status - neuromotor and cognitive development - asthma, atopic eczema, other allergic diseases - type 1 diabetes - blood pressure and subsequent adult chronic diseases such as hypertension, coronary heart disease, type 2 diabetes, inflammatory and autoimmune diseases. Maternal outcomes: - postpartum weight loss - duration of lactational amenorrhea - chronic diseases such as breast and ovarian cancer - osteoporosis.	Comments by the authors For growth and morbidity outcomes, the pertinent confounding factors were defined by the authors as being: - SES - water supply - sanitation facilities - parental height and weight - birth weight - weight and length at 3 months (or age at which complementary feeding was introduced in the mixed breastfeeding group).	Neither the trials nor the observational studies suggest that infants EBF for 6 months show deficits in weight or length gain, although larger sample sizes would be required to rule out small increases in the risk of undernutrition. The data are scarce with respect to iron status, but at least in LMIC where new-born iron stores may be suboptimal, they suggest that EBF without iron supplementation through 6 months may compromise hematologic status. Based primarily on one observational study of a large randomised trial in HIC, infants EBF for 6 months or more appear to have a significantly reduced risk of one or more episodes of gastrointestinal infection. No significant reduction in risk of atopic eczema, asthma, or other atopic outcomes was demonstrated. Data from the 2 RCT suggest that EBF through 6 months is associated with delayed resumption of menses and more rapid postpartum weight loss in the mother. The authors concluded that the available evidence demonstrates no apparent risks in recommending EBF for the first 6 months of life in both LMIC and HIC.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Kramer & Kakuma (2012) Funding McGill University (Canada); Canadian Institutes of Health Research; Canadian Cochrane Network; Department of Nutrition for Health and Development (WHO, Switzerland). DOI MSK is the principal investigator of some of the studies included in this review.	Update to the systematic review (Kramer & Kakuma, 2002) to assess the effects on child health, growth and development, and on maternal health, of EBF for 6 months vs EBF for 3-4 months with mixed breastfeeding thereafter through 6 months. This updated review included 7 new independent studies and data from 2 studies included in the original review were updated (both from HIC). In total, 23 independent studies were included: - 2 RCTs - 21 observational studies. Only those studies with an internal comparison group were included in the review. Therefore, studies based on external comparisons (with reference data) were excluded.	See (Kramer & Kakuma, 2002).	See (Kramer & Kakuma, 2002). Countries Of the 23 studies, 11 were carried out in LMIC (2 of which were the RCT) and 12 in HIC (all observational studies).	See (Kramer & Kakuma, 2002).	See (Kramer & Kakuma, 2002).	Neither the trials nor the observational studies suggest that infants who continue EBF for 6 months show deficits in weight or length gain, although larger sample sizes would be required to rule out modest differences in risk of undernutrition. In LMIC settings where new-born iron stores may be suboptimal, the evidence suggests that EBF without iron supplementation through 6 months may compromise hematologic status. Based on 1 study in HIC, 6 months of EBF confers no benefit (vs 3 months of EBF followed by continued partial breastfeeding through 6 months) on height, weight, BMI, dental caries, cognitive ability, or behaviour at 6.5 years of age. However, infants who continue EBF for 6 months or more appear to have a significantly reduced risk of gastrointestinal and respiratory infection. No significant reduction in risk of atopic eczema, asthma, or other atopic outcomes was demonstrated. Data from the 2 RCTs and from 2 observational studies in LMIC suggest that EBF through 6 months is associated with delayed resumption of menses and more rapid postpartum weight loss in the mother. The author's conclusions remained unchanged, that is, that the available evidence demonstrates no apparent risks in recommending EBF for the first 6 months of life in both LMIC and HIC.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Sankar et al (2015) Funding None to declare. DOI None to declare.	Systematic review with meta-analysis to compare the effect of predominant, partial or non-breastfeeding vs EBF on all-cause and infection-related mortality rates from 0 to 6 months of life, and effect of no BF on mortality rates between 6 to 23 months of age. 13 studies included: - 9 prospective cohort studies - 2 case-control studies - 2 secondary analyses from RCTs.	WHO definitions used for classifying breastfeeding exposure categories (exclusive, predominant, partial, or non-breastfeeding).	n=46,499 infants aged <2 years. Countries 6 studies from Africa; 2 studies from Latin America; 5 studies from South-East Asia; 1 study from Eastern Mediterranean; 1 study from Western Pacific. To note One study reported data from 3 different regions.	All-cause mortality and infection-related mortality at: 0 to 5 months; 6 to 11 months; 12 to 23 months of age. Infection-related mortality included deaths due to any infection including sepsis, meningitis, pneumonia, diarrhoea, measles, malaria, etc.	Comments by SACN No discussion on confounding factors was included in the review. The authors opted for a more inclusive approach to enable more studies to be included. As a result, most of the data used in the meta-analysis were unadjusted.	Risk of all-cause mortality was higher in predominantly (RR 1.48; 95% CI 1.14 to 1.92; 3 studies), partially (RR 2.84; 95% CI 1.63 to 4.97; 3 studies) and non-breastfed (RR 14.4; 95% CI 6.13 to 33.9; 2 studies) infants compared with infants EBF from 0 to 5 months of age. Children aged 6 to 11 months and 12 to 23 months of age who were not breastfed had 1.8 (RR 1.76; 95% CI 1.28 to 2.41; 4 studies) and 2.0 (RR 1.97; 95% CI 1.45 to 2.67; 6 studies) fold higher risk of mortality, respectively, compared with EBF infants. Risk of infection-related mortality from 0 to 5 months was higher in predominantly (RR 1.7; 95% CI 1.18 to 2.45; 3 studies), partially (RR 4.56; 95% CI 2.93 to 7.11; 3 studies) and non-breastfed (RR 8.66; 95% CI 3.19 to 23.5; 2 studies) infants compared with EBF infants. The risk was 2-fold higher in non-breastfed children aged 6 to 23 months.

Table C.2 Infant feeding, growth and health: experimental evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Cohen et al (1994) Funding The Thrasher Research Fund; the WHO; UNICEF Honduras; the Institute for Reproductive Health. DOI Not specified. To note Complementary foods were provided at reduced costs by Gerber Products Company.	RCT to investigate the effects of age of introduction of complementary foods on infant breast milk intake, total energy intake, and growth. Participants randomly assigned to 1 of 3 groups: - group EBF: continued EBF to 6 months (control) - group SF: introduction of complementary foods at 4 months with ad libitum nursing - group SF-M: introduction of complementary foods at 4 months, with maintenance of baseline nursing frequency. Follow-up - Weekly between 16 and 26 weeks to assess growth and morbidity (home visit). - 3 three-day stays at the La Leche League unit at 16 weeks (4 months), 21 weeks (5 months), and 26 weeks (6 months) for measurement of breast milk intake, breast milk sampling, and maternal and infant anthropometry.	EBF: breastfeeding with no other liquids or solids until 6 months. Complementary feeding (CF): introduction of complementary solid food at 4 months with either ad libitum nursing (SF) or maintenance of baseline nursing frequency (SF-M).	n=141 infants born to low income primiparous mothers and EBF for 4 months (152 randomised but 11 dropped out). EBF: n=50 SF: n=47 SF-M: n=44 Country Honduras	- Infants' weight and length gain, weight-for-age and length-for-age - Infant morbidity (maternal recall of illness symptoms such as fever, cough, nasal discharge, diarrhoea, upper respiratory illness) - Timing and duration of each breastfed - Breast milk intake (measured by test weighting) - Solid food intake (measured by weighting baby food jars before and after) - Total energy intake - Maternal postpartum weight loss	Comments by the authors Commercially baby foods were used to avoid potential confounding factors linked to home-prepared foods.	At 4 months, there was no significant difference in breast milk intake between the groups (average 797g/d). Between 4 to 6 months, breast milk intake was unchanged in the EBF group (+6 g/d) but decreased significantly in the SF (-103 g/d) and SF-M (-62 g/d) groups (p<0.001). Change in total energy intake (including solid foods) and infant weight and length did not differ significantly between groups. Weight and length gain from 4 to 6 months were comparable to those of breastfed infants in an affluent US population. The results indicate that breastfed infants self-regulate their total energy intake when other foods are introduced. As a result, the authors concluded that there is no advantage in introducing CF before 6 months of age in this population, whereas there may be disadvantages if there is increased exposure to contaminated foods.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Kramer et al (2001) Funding The Thrasher Research Fund, the National Health Research and Development Program (Health Canada); UNICEF; the European Regional Office of WHO. DOI Not specified.	Cluster RCT to assess the effects of breastfeeding promotion intervention (PROBIT) on breastfeeding duration and exclusivity as well as on gastrointestinal and respiratory infection and atopic eczema among infants. The PROBIT intervention was modelled on the WHO/UNICEF baby-friendly hospital initiative (BFHI). 31 hospitals (and affiliated polyclinics) randomised to 1 of the 2 groups: - intervention group: BFHI training of medical, midwifery and nursing staff to emphasise breastfeeding support (intervention group) - control group: to continue their routine practices. Follow-up at 1, 2, 3, 6, 9, and 12 months of age.	EBF: no solids or liquids other than breast milk. Predominantly breastfed: no solids and no milk other than breast milk; juices, water, teas and other liquids permitted.	n=16,491 mother-infant pairs consisting of singleton infants, born at >37 weeks gestation, weighing ≥2500g at birth and their healthy mothers who intended to breastfeed (17,046 initially recruited). Country Republic of Belarus	- Duration of any breastfeeding - Prevalence of predominant and EBF at 3 and 6 months - Occurrence during the first 12 months of life of: 1 or more episodes of gastrointestinal tract infection; 2 or more episodes of respiratory tract; atopic eczema and recurrent wheezing.	Comments by the authors At the group level, a dichotomous stratification for region was used: - west vs east - urban vs rural. At individual level, for breastfeeding outcomes: - birth weight - maternal age - history of having breastfed a previous infant for 3 months or longer. At individual level, for gastrointestinal and respiratory tract infection: - birth weight - number of other children living in the household - maternal smoking during pregnancy (only for respiratory tract infection). At individual level, for atopic eczema: - family atopic history (asthma, allergic rhinitis, atopic eczema).	When compared to control infant, infants from the intervention sites were : - significantly more likely to be breastfed to any degree at 12 months (19.7% vs 11.4%; adjusted odd ratio [AOR] 0.47; 95% CI 0.32 to 0.69) - were more likely to be EBF at 3 months (43.3% vs 6.4%; p<0.001) and at 6 months (7.9% vs 0.6%; p=0.01) - had a significant reduction in the risk of one or more gastrointestinal infection (9.1% vs 13.2%; AOR 0.60; 95% CI 0.40 to 0.91) and of atopic eczema (3.3% vs 6.3%; AOR 0.54; 95% CI 0.31 to 0.95) - no significant reduction in respiratory infection was observed (intervention group, 39.2%; control group, 39.4%; AOR 0.87; 95% CI 0.59 to 1.28). The authors concluded that this experimental intervention increased the duration and degree (exclusivity) of breastfeeding and decreased the risk of gastrointestinal tract infection and atopic eczema in the first year of life.

Table C.3 Infant feeding, growth and health: observational evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Collaborative Group on Hormonal Factors in Breast Cancer (2002) Funding Cancer Research UK, and the UNDP/UNFPA/WHO /World Bank special programme of research, development and research training in human reproduction. DOI None to declare.	Meta-analysis to examine the relation between breastfeeding and breast cancer, taking careful account of the effects of other related aspects of childbearing. 47 epidemiological studies included: - 5 cohort studies - 27 case-control studies (population controls) - 15 case-control studies (hospital controls).	Breastfeeding Definitions varied across studies. Most did not differentiate between EBF and the use of supplementary feeds. There was also some variation between studies in the definition of whether or not a woman had ever breastfed. Breastfeeding duration was categorised into: 1) 0 months 2) ≤6 months 3) 7-18 months 4) 19-30 months 5) 31-54 months 6) >54 months. Parity Defined as the total number of births, be they livebirths or stillbirths. If no information on stillbirths, parity was the total number of livebirths.	n=50,302 women with invasive breast cancer; n=96,973 control. Case control and cohort studies were eligible if they had data for at least 100 women with incident invasive breast cancer and had recorded information on each woman with respect to reproductive factors and use of hormonal preparations. Countries studies from 30 countries from HIC and LMIC.	Breast cancer incidence.	Comments by the authors Relative risks for breast cancer associated with breastfeeding were stratified by age, parity and women's ages when their first child was born, as well as by study and menopausal status. When studying the effect of each birth, potential confounding by breastfeeding can be eliminated by looking at the relation between parity and the relative risk of breast cancer in women who never breastfed. When studying the effect of breastfeeding, there is potentially extensive confounding by parity and, to a lesser extent, by age at first birth. Therefore, all analyses that examine the risk of breast cancer in relation to lifetime duration of breastfeeding were stratified according to the number of births and to the age at first birth. The trends according to duration of breastfeeding do not vary significantly by parity or age at first birth, indicating no strong interaction with these factors.	Women with breast cancer had, on average, fewer births than did controls (2.2 vs 2.6) and a greater proportion were nulliparous (16% vs 14%). Fewer parous women with cancer than parous controls had ever breastfed (71% vs 79%), and their average lifetime duration of breastfeeding was shorter (9.8 vs 15.6 months). The relative risk of breast cancer decreased by 4.3% (95% CI 2.9 to 5·8%; p<0.0001) for every 12 months of breastfeeding in addition to a decrease of 7.0% (95% CI 5.0 to 9.0%; p<0.0001) for each birth. The size of the decline in the relative risk of breast cancer associated with breastfeeding did not differ significantly for women in HIC and LMIC, and did not vary significantly by age, menopausal status, ethnic origin, the number of births a woman had, her age when her first child was born, or any of nine other personal characteristics examined. It is estimated that the cumulative incidence of breast cancer in HIC would be reduced by more than half, from 6.3 to 2.7 per 100 women by age 70, if women had the average number of births and lifetime duration of breastfeeding that had been prevalent in LMIC until recently. Breastfeeding could account for almost two-thirds of this estimated reduction in breast cancer incidence. The authors concluded that the lack of or short lifetime duration of breastfeeding typical of women in HIC makes a major contribution to the high incidence of breast cancer in these countries.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Farland et al (2017) <u>Funding</u> National Institutes of Health; National Cancer Institute; National Institute of Child Health and Human Development; the Dana Farber and Harvard Cancer Center Mazzone Award. <u>DOI</u> Support from the Harvard T H Chan School of Public Health, the Eunice Kennedy Shriver National Institute of Child Health and Human Development and the National Cancer Institute was declared for the submitted work. No others financial relationships, relationships or activities to declare.	Prospective cohort study (embedded in the Nurses' Health study II, 1989-2011) to investigate the association between lifetime breastfeeding, postpartum amenorrhea and incidence of endometriosis among parous women. Lifetime history of breasting data was collected in 1993 and detailed information on history of breastfeeding and duration for each of their first 4 children in 1997. <u>Follow-up</u> questionnaires every 2 years (health and lifestyle).	<u>Total duration of breastfeeding</u> was assessed by the question "If you breastfed, at what month did you stop breastfeeding altogether?". <u>Duration of EBF</u> was assessed by the question "At what month did you start giving formula or purchased milk at least daily?" and "At what month did you start giving solid food at least once daily (baby food, cereal, table food, etc)?". <u>EBF</u> was defined as the earlier of the two time points.	n=72,394 women aged 25 to 42 years in 1989, who had a at least one pregnancy lasting at least 6 months; 3,296 of whom had laparoscopically confirmed endometriosis. <u>Country</u> US	Self-reported laparoscopically confirmed endometriosis (via questionnaires).	<u>Comments by the authors</u> Results were stratified by calendar time with age (months) and adjusted for (time varying covariates updated at every questionnaire cycle): - current BMI - BMI at age 18 years - history of smoking - use of oral contraceptives - pregnancies lasting at least 6 months - age at menarche - history of infertility - time since last birth.	Duration of total and EBF was significantly associated with decreased risk of endometriosis. Among women who reported a lifetime total length of breastfeeding <1 month, there were 453 endometriosis cases/100 000 person years compared with 184 cases/100 000 person years in women who reported a lifetime total of ≥36 months of breastfeeding. Every additional 3 months of total breastfeeding per pregnancy was associated with an 8% lower risk of endometriosis (HR 0.92; 95% CI 0.90 to 0.94; p<0.001 trend). Every additional 3 months of EBF per pregnancy was associated with a 14% lower risk (HR 0.86; 95% CI 0.81to 0.90; p< 0.001 trend). Women who breastfed for ≥36 months in total across their reproductive lifetime had a 40% reduced risk of endometriosis compared with women who never breastfed (HR 0.60; 95% CI 0.50 to 0.72). The protective association with breastfeeding was strongest among women who gave birth within the past 5 years (p=0.04 for interaction). The association with total breastfeeding and EBF on endometriosis was partially influenced by postpartum amenorrhea (% mediated was 34% [95% CI 15% to 59%] for total breast feeding and 57% [95% CI 27% to 82%] for EBF).

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Fisk et al (2011) Funding Medical Research Council; University of Southampton; British Heart Foundation; Food Standards Agency; University of Southampton Research Policy Committee. DOI None to declare.	Prospective birth cohort study (embedded in the SWS) to assess the relationship between the duration of breastfeeding (including mixed feeding) and the prevalence of LRTI, ear infections and gastrointestinal morbidity during the first year of life. Follow-up at 6 and 12 months of age.	Breastfeeding duration was defined according to the date of last breastfeed and included all types of breastfeeding, including mixed feeding (breast milk alongside infant formula and other foods and drinks). A detailed history of milk feeding (human milk, formulas and other milks) was obtained at 6 and 12 months. Information on age at which solids were first regularly introduced was collected at 6 months.	n=1,764 singleton infants born at >37 weeks gestation to SWS participants (1,981 initially recruited). Country UK	Questions were asked at 6 and 12 months regarding whether the infant had suffered from any of the following over the previous 6 months: - diarrhoea lasting 2 or more days - 1 or more bouts of vomiting lasting 2 or more days - 1 or more episodes of chest wheezing/whistling or woken at night coughing 3 or more nights in a row (prolonged cough) - diagnosis by a doctor of chest infection, bronchitis, bronchiolitis, pneumonia or an ear infection.	Comments by the authors Statistical analysis to determinate associations between breastfeeding duration, outcomes measures and 13 maternal and infant factors. Maternal factors: - maternal age - BMI - smoking in pregnancy - months that mother had been back at work - whether the mother lived with a partner - index of multiple deprivation - educational attainment - social class. Infant factors: - birth order - age when solids were first regularly introduced - gestational age - birthweight (adjusted for gestational age and sex) - sex.	81% infants were breastfed initially, and 25% were breastfed up to 6 months. There were graded decreases in the prevalence of respiratory and gastrointestinal symptoms between 0 to 6 months as breastfeeding duration increased; these were robust to adjustment for confounding factors. The adjusted RR for infants breastfed for 6 or more months compared with infants who were never breastfed were 0.72 (95% CI 0.58 to 0.89), 0.43 (95% CI 0.30 to 0.61) and 0.60 (95% CI 0.39 to 0.92) for general respiratory morbidity, diarrhoea and vomiting, respectively. Duration of breastfeeding in the 2nd half of infancy was less strongly related to diagnose respiratory tract infections and gastrointestinal morbidity, although important benefits of breastfeeding were still seen. The adjusted RR for diagnosed ear infections in the first 6 months of infancy was 0.40 (95% CI 0.21 to 0.76), but the trend in the decreased risk of ear infections with increasing breastfeeding duration was not robust to adjustment for confounders.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Paricio-Talayero et al (2006) Funding Not specified. DOI None to declare.	Prospective cohort study to assess the effect of breastfeeding on the probability of hospitalisation as a result of infectious processes during the first year of life. Recruitment and data collection were done at 6 months. Data about hospitalisations as a result of an infection were obtained by cross-referencing hospital records.	Full breastfeeding (FB): exclusive (no other liquid or solid is given to the infant) or almost exclusive (vitamins, mineral water, juice, or ritualistic feeds are given infrequently in addition to breast feeds). Duration of breastfeeding was measured in months, with precision of 1 week. Data were grouped into 3 categories: 1) FB for 0 months 2) FB for <4 months 3) FB for ≥4 months.	n=1,385 infants recruited between 1996 and 1999 and followed from birth to 1 year old. Infants were recruited from an area with middle to upper-middle SES and with an unemployment rate almost half the national average. Country Spain	Hospitalisation as a result of an episode of infection in the first year of life, excluding infections of perinatal cause but no other infections that occurred within 2 weeks after birth.	Comments by the authors Statistical analyses were performed to identify relationship between the outcome measures and a number of variables. The following variables were identified as confounding factors (p<0.1). Maternal variable: - number of children (>1 child – yes or no) - smoking status (yes or no; number of cigarettes per day). Delivery-related variables: - public or private hospital. Infant-related variables: - gender - premature - birth weight.	EBF at discharge after delivery and at 3, 4 and 6 months of age were 85%, 52%, 41% and 15%, respectively. 78 hospital admissions as a result of infections were recorded (38 respiratory tract, 16 gastrointestinal). Mean age at admission was 4.1 months. When compared with infants FB for 4 months or more, the risk for hospital admission for infection in the first year of life was 4.91 higher (95% CI 2.41 to 9.99) among never breastfed infants and 2.45 times higher (95% CI 1.28 to 4.66) among those FB up to 4 months. After estimating the attributable risk, it was found that 30% of hospital admissions would have been avoided for each additional month of full breastfeeding. The authors estimated that EBF at 4 months would avoid 56% hospital admissions in infants who are younger than 1 year.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Quigley et al (2007) Funding Department of Health (England). DOI None to declare.	Prospective cohort study (sweep 1 of the UK Millennium Cohort Study) to measure the effect of breastfeeding on hospitalisation for diarrheal and LRTI in the first 8m after birth in contemporary UK. Data were collected at 9 months and analysed per month of age.	EBF: received only breast milk and no other milk, solids, or fluids other than water. Partially breastfed: received some breast milk but also received other milk and/or solids. Infant feeding was categorised per month into the following groups: 1) not breastfed 2) partially breastfed 3) EBF.	n=15,980 singleton, healthy term infants born in 2000-2002. Country UK	Parental report of hospitalisation for diarrhoea (gastroenteritis) and LRTI (chest infection or pneumonia) in the first 8 months after birth.	Comments by the authors The odd ratios were adjusted for the following variables: - birth weight - gestation - mode of delivery - infant's age in months - infant's gender - maternal age in years - whether the infant was first born - maternal (current) smoking - maternal occupation - maternal education - maternal marital status - whether the infant lives in rented accommodation. In the final model, adjustment was made for variables significantly ($p<0.05$) associated with the outcomes.	71% infants were ever breastfed, 34% received breast milk for at least 4 months and 1.2% were EBF for at least 6 months. By 8 months of age, 12% infants had been hospitalised (1.1% for diarrhoea and 3.2% for LRTI). Data analysed by month of age (after adjustment for confounders) found that EBF vs not breastfeeding protects against hospitalisation for diarrhoea (AOR 0.37; 95% CI 0.18 to 0.78) and LRTI (adjusted AOR 0.66; 95% CI 0.47 to 0.92). The effect of partial breastfeeding was weaker (not statistically significant). Population-attributable fractions suggest that an estimated 53% of diarrhoea hospitalisations could have been prevented each month by EBF and 31% by partial breastfeeding. Similarly, 27% of LRTI hospitalisations could have been prevented each month by EBF and 25% by partial breastfeeding. The protective effect of breastfeeding for these outcomes wears off soon after breastfeeding ceases. The authors concluded that breastfeeding, particularly when exclusive and prolonged, protects against severe morbidity in contemporary UK and that a population-level increase in exclusive, prolonged breastfeeding would be of considerable potential benefit for public health.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Quigley et al (2009) Funding Department of Health (England). DOI None to declare.	Prospective cohort study (sweep 1 of the UK Millennium Cohort Study) to assess the independent effect of solids and breastfeeding on the risk of hospitalisation for infection in the first 8 months after birth in contemporary UK. Data were collected at 9 months and analysed per month of age.	Breastfeeding duration and introduction of other milk and solids were estimated from interview responses about the age of the infant when last given breast milk, and when first given formula, other types of milk and solids. Infants were categorised separately according to whether they were on solids (yes, no) and the type of milk they were receiving (formula only, breast milk and formula, breast milk only).	n=15,980 singleton, healthy term infants born in 2000-2002. Country UK	Hospitalised morbidity was assessed by the reported age and diagnosis at the time of any hospital admissions since birth. Diarrhoea was defined as 'gastroenteritis' (n=201) and LRTI as 'chest infection or pneumonia' (n=552).	Comments by the authors For diarrhoea, the odd ratios were adjusted for the following confounders ($p<0.05$): - milk group - solids - baby's age - mother's age at delivery - mode of delivery - mother's education. For LRTI, the odd ratios were adjusted for the following confounders ($p<0.05$): - milk group - solids - baby's age and sex - mother's age at delivery - mode of delivery - household income - whether the baby was first born - mother's (current) smoking status - family history of asthma.	At 6 months, 25% of the infants were still breastfed. The mean age of introduction of solids was 3.8 months. For both diarrhoea and LRTI, the monthly risk of hospitalisation was significantly lower in those receiving breastmilk compared with those receiving formula (for diarrhoea, AOR 0.39; 95% CI 0.20 to 0.77; for LRTI AOR 0.65; 95% CI 0.47 to 0.89). The monthly risk of hospitalisation was not significantly higher in those who had received solids compared with those not on solids (for diarrhoea, AOR 1.39; 95% CI 0.75 to 2.59; for LRTI AOR 1.14; 95% CI 0.76 to 1.70), and the risk did not vary significantly according to the age of starting solids. The authors concluded that in their study, the strongest risk factor for hospitalisation for infection was formula milk.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Wright et al (2004) Funding Grant support: Henry Smith Charity (SPARKS). DOI Not specified.	Prospective cohort study (the Millennium Baby Study) to examine what predicts the age of introduction to CF and how this relates to weight gain and morbidity. Questionnaires sent at 6 weeks, and 4, 8 and 12 months, which all included questions to be completed once CF had been commenced. Families were also issued with a food diary to complete when the first five solid feeds were given.	No definition of EBF provided and no distinction made between partial and exclusive breastfeeding. Duration of breastfeeding assessed by questionnaire and categorised as: 1) never 2) <6 weeks 3) 6 weeks to 4 months 4) >4 months 5) no feeding information. Age of introduction to CF assessed by questionnaire and categorised as: 1) <3 months (13 weeks) 2) 3 to 4 months 3) >4 months (17.3 weeks).	n=923 term infants born in a defined geographical area and recruited shortly after birth between June 1999 and May 2000. Data on complementary feeding was obtained for 707 (77%) of them. Country UK (Gateshead)	Assessed through questionnaires: - age when solid foods were first given as well as 5 questions exploring why and whether breastmilk was given at that age - whether the child has seen their family doctor, suffered a cold, diarrhoea, a rash or a chest infection, or been admitted to hospital. - child weight. Assessed through food diary for the first 5 feeds: - date - type of food - how the child responded.	Comments by the authors Socioeconomic information (collected at recruitment) was used to dichotomise families into affluent and deprived. The risks of parentally reported morbidity were adjusted for feeding mode and deprivation level.	The median age of first solid food was 3.5 months, with 21% commencing before 3 months and only 6% after 4 months. Infants progressed quickly to regular solids with few reported difficulties, even when introduced to CF early. Babies introduced to CF before 3 months, compared to after 4 months, had an increased risk of diarrhoea (AOR 1.65; 95% CI 1.09 to 2.5; p=0.02) but not of GP consultations (AOR 1.32; 95% CI 0.94 to 1.89; p=0.1). Most parents did not perceive professional advice or written materials to be a major influence. The strongest independent predictors of earlier introduction to CF were rapid weight gain to age 6 weeks, lower socioeconomic status, the parents' perception that their baby was hungry and feeding mode (not breast feeding at age 4 months was a significant predictor of early start of CF while continued breastfeeding at 4 months was associated with late start of CF). Weight gain after 6 weeks was unrelated to age of introduction to CF.

Table C.4 Energy requirements: systematic reviews and meta-analyses

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Redsell et al (2016) Funding Burdett Trust for Nursing. DOI None to declare.	Systematic review of RCTs of interventions designed to reduce the risk of overweight/obesity delivered antenatally or during the first 2 years of life with outcomes reported from birth to 7 years of age. 27 unique trials (35 studies) included: - 3 non-behavioural trials (RCTs manipulating milk formula milk composition) - 24 behavioural trials, categorised by type of intervention: 1) nutritional and/or responsive feeding interventions (n=12) 2) breastfeeding promotion and lactation support (n=5) 3) parenting and family lifestyle (n=4) 4) maternal health (n=3). Studies with any type of comparison group were eligible for inclusion.	Not specified.	Participants: - pregnant women - parents/carers/ guardians of infants <2 years old - healthy infants <2 years old. Countries No restriction on geographical settings of the intervention program.	Primary outcomes: - infant/child BMI - weight - weight gain velocity - weight-for-length - weight-for-age. Secondary outcomes were related to feeding practices (such as breastfeeding uptake or timing of introduction of solid foods) and physical activity from birth to 7 years old.	Comments by SACN The authors did not comment on confounding factors, but, as the studies included were all RCTs, the risk of confounding is lower than for observational studies. However, the authors did highlight that many studies failed to adequately describe their randomisation methods, increasing the risk of selection bias and unbalanced confounding factors between groups.	Nutritional and/or responsive feeding interventions 12 trials (16 studies) identified, of which 3 had a significant impact on weight outcomes in the desired direction. - The Healthy Beginnings intervention, that focused on parent education around diet and feeding practices, was successful at improving the breastfeeding duration and at delaying the introduction to solid foods. - The NOURISH intervention, that included components to help parents understand about responsiveness to infant cues as well as teaching them about diet and feeding, resulted in a slower weight gain from birth to 9 months and a lower BMI-for-age z-score. However, effect was no longer present at a 2-year follow-up. -The SLIMTIME intervention focused on responsive feeding rather than diet. It resulted in a significant slower weight gain, suggesting that educating parents about responsive feeding may be more beneficial than dietary advice alone. Breastfeeding promotion and lactation support interventions 5 trials (7 studies) identified. The majority of interventions demonstrated highly significant improvements in the outcome assessed, including uptake, duration and exclusivity of breastfeeding. However, none of the studies reported a positive effect on infant weight in the first 2 years of life. Parenting and family lifestyle interventions 4 trials (4 studies) identified. These interventions had significant impact on feeding behaviours but overall this type of intervention reported fewer improvements than those focusing exclusively on diet feeding.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
						Maternal health interventions 3 trials (3 studies) identified. None of these interventions led to significant improvements in the infant's weight. Non-behavioural interventions 3 trials (5 studies) identified. Two trials reported slower infant weight gain in infants fed hydrolysed formula while the third study reported that infants given higher protein cow's milk formula feed grew more rapidly when compared with infants fed lower protein formula. The authors concluded that the interventions that aim to improve parental feeding practices, including infant diet and parental responsiveness to infant cues, showed most promise in relation to behaviour change but not weight.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Reilly et al (2005) Funding Caledonian Research Foundation. DOI Not specified.	Systematic review to evaluate evidence on metabolisable energy consumption and pattern of consumption with age in infants in the developed world who were exclusively breastfed, at around the time of introduction of complementary feeding. The authors aimed to extract and summarise evidence on the following 3 questions. 1) How much milk is transferred from mother to infant? 2) Does milk transfer increase to match the increasing energy needs of the infant in longitudinal studies? 3) What is the metabolisable energy content of the breast milk transferred? 44 observational studies were included, 9 of which were longitudinal studies.	EBF: mothers providing breast milk as the sole source of nutrients and energy.	Singleton, healthy term infants, EBF and aged 3 to 6 months. Transfer at 3-4 months: n=1,041 mother-infant pairs (33 studies). Transfer at 5 months: n=99 mother- infant pairs (6 studies). Transfer at 6 months: n=72 mother- infant pairs (5 studies). Breast milk energy content: n=777 mother-infant pairs (25 studies). Countries Europe, North America, Australia, New Zealand.	Breast milk output, measured by isotopic techniques or by test-weighing the infant. Breast milk energy content estimated by sampling breast milk or by conducting a study of infant energy balance.	Comments by SACN The authors did not report on confounding factors and only specified that they "considered impact of bias in individual studies to be negligible in view of the nature of the questions addressed and the lack of bias in the methodology used".	The weighted mean transfer of breast milk was: 779 (SD 40)g/d at 3-4 months 827 (SD39)g/d at 5 months 894 (SD 87)g/d at 6 months. Cross-sectional studies suggested an increase in milk transfer while longitudinal studies reported no significant increase in milk transfer over time over the period 3-6 months. The weighted mean metabolisable energy content was 2.6 (SD 0.2) kJ/g.

Table C.5 Energy requirements: experimental evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Cohen et al (1994)	See Table C.2					
Mehta et al (1998)	See Table C.8					
Savage et al (2016) Funding National Institute of Diabetes and Digestive and Kidney Diseases; the Children's Miracle Network (Penn State Children's Hospital); US Department of Agriculture. DOI None to declare.	Randomised clinical trial (controlled) to examine the effect of a responsive parenting (RP) intervention on infant weight gain between birth and 28 weeks and overweight status at age 1 year. Participants were randomised at 2 weeks postpartum to either: - control group - RP group: INSIGHT intervention. All participants received a home visit at 3, 16, 28 and 40 weeks (research nurse) and a research centre visit at 1year. The RP group received information about infant feeding, sleep hygiene, active social play, emotion regulation, and growth record education. The control group received a developmentally appropriate home safety intervention.	Predominantly breastfed: 80%or more of milk feedings were breastmilk, either at the breast or by bottle. Not predominantly breastfed otherwise. Responsive feeding: the feeding component of the RP intervention taught parents to recognise hunger, satiety cues, and age-appropriate portion sizes and to use food for hunger only and not as a reward, punishment, or to soothe a distressed but not hungry child.	n=291 singleton term infants (>2500g) from primiparous mother (min age 20 years, mean 28.7years). n=269 (96.4%) at 28 weeks. n=253 (90.7%) at 1 year. RP group: n=145 (125 at 1 year). Control group: n=146 (125 at 1 year). Enrolment initiated in January 2012, and analyses for this study conducted between April 2015 and November 2015. Country US (Pennsylvania)	Main outcome: - conditional weight gain from birth to 28 weeks (a score of zero represents the population mean; positive scores indicate more rapid or faster than average weight gain; negative scores indicate slower weight gain). Measures and secondary outcomes: - infant weight and length (measured at each visit) - infant weight for age, length for age and weight for length at birth, 28weeks, and 1 year (converted to percentiles and z scores using WHO data).	Comments by the authors The randomisation process was stratified by gestational age and intended feeding mode. The conditional weight gain was adjusted for feeding method, maternal pre-pregnancy BMI, income, marital status, and maternal age at recruitment. Apart from the feeding method, the other covariates were non-significant.	Mean conditional weight gain score was lower among infants in the RP group compared with the control (-0.18; 95% CI -0.36 to -0.001; and 0.18; 95% CI 0.02 to 0.34, respectively), reflecting that the RP infants gained weight more slowly than control infants. This effect did not differ by feeding mode (predominantly breastfed or not). Infants in the RP group had lower mean weight-for-length percentiles at 1 year than infants in the control group (57.5%; 95% CI 52.56 to 62.37% vs 64.4%; 95% CI 59.94 to 69.26%; p =0.04) and were less likely to be overweight at age 1 year (5.5%vs 12.7%; p=0.05).

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Wells et al (2012) Funding Mead Johnson; the Eimskip Fund (University of Iceland). DOI None to declare.	RCT to determine whether EBF infants would consume more breast milk at 6 months than infants receiving breast milk and complementary foods. At 4 months, infants were randomly assigned to either: - EBF group: continue EBF to 6 months - CF group: continue breastfeeding alongside the introduction of solid foods. Follow-up at 4 and 6 months.	EBF: breastfeeding with no additional liquid or solid foods other than vitamins and medications, although up to a maximum of 10 feedings of formula or water during the first 6 months were allowed because of practicalities of breastfeeding.	n=100 singleton infants (50 per group), gestational age ≥37 weeks, healthy, and EBF at time of assessment (119 randomised but 19 dropped out). Country Iceland (Reykjavik)	- Mean breast milk intake (g/d, measured using stable isotopes) - Average daily intake of solid foods in the CF group (weighted over 3 days) - Anthropometric outcomes (infant body weight, length and head circumference at 4 and 6 months, corresponding BMI and *z*-scores) - Maternal weight at 6 months	Comments by SACN The authors collected background information (such as maternal age and education, parity and mode of delivery) and did perform statistical analyses, including a regression analysis adjusted for confounding variables to test group differences in breast milk. However, they did not specify what these confounding variables were.	Mean breast milk intake in the EBF group was 901±158g/d, which was significantly higher than the WHO reference values of 854±24g/d (p=0.04). The CF group consumed 818±166g breast milk/d (mean), which was not significantly different from the WHO reference values. The EBF group therefore consumed 83g/d more breast milk than did the CF group (p=0.012) and this was equivalent to 56kcal/d. Infants in the CF group obtained 63±52 kcal/d form complementary foods. Estimated total energy intakes were similar (EBF: 560±98kcal/d; CF: 571±97kcal/d). Secondary outcomes (anthropometric measures and body composition) did not differ significantly between groups.

Table C.6 Energy requirements: observational evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Nielsen et al (2011) Funding Scottish Government Health Department; Yorkhill Children's Foundation; Scottish Government Chief Scientist Office. DOI No financial relationships to disclose.	Longitudinal, observational field study to test whether and how human lactation and breastfeeding practices can adapt to fulfil infant energy requirements during exclusive breastfeeding for 6 months. Follow-up at 15 and 25 weeks.	WHO definition of EBF: only breast milk, with allowance for oral rehydration, and vitamins, minerals, and/or medicines.	n=50 healthy, EBF infants. Participants were recruited from breastfeeding support groups from May 2007 to October 2008. Country Scotland (Glasgow)	Primary outcome: - breast milk intake (g/day) and changes between time. Secondary outcome: - breastfeeding practice - infant growth expressed as z-scores relative to WHO Child Growth Standards - infant length - energy intake - milk energy content measured by DLW method.	Comments by SACN The authors specified that changes in milk intake between time points were assessed with a paired *t* test and gender differences using independent *t* tests. The other outcomes were tested for change over time. The participants were characterised for sociodemographic factors (Scottish Index of Multiple Deprivation), maternal age, height and BMI but the authors did not specify if the results were adjusted for these variables.	Mean breast milk intake was 923(SD 122)g/day at 15 weeks (n=36 EBF) and 999 (SD 146)g/day at 25 weeks (n =33 EBF). Both values were significantly higher (p<0.0001) than reported literature values (779g/day at 3 to 4 months and 894g/day at 6 months). Breast milk intake increased significantly between the two time points (mean increase 61g/day; 95% CI 23 to 99g/day; p=0.003). Infant growth was normal compared with WHO Child Growth Standards, and energy intakes were adequate compared with references for energy requirements. Behavioural data on breastfeeding practices and infant behaviour suggested very small and insignificant changes in feeding frequency from the 1st to the 2nd time point. The authors concluded that when mothers are well supported and follow the WHO recommendation on breastfeeding, milk intakes are high and increase over time, and that there is adequate energy intake, normal infant growth, and no marked changes in breastfeeding practices.

Table C.7 Infant feeding, body composition and health: systematic reviews and meta-analyses

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Moorcroft et al (2011) Funding None to declare. DOI None to declare.	Systematic review to investigate current evidence to determine whether the timing of introducing solid foods is associated with obesity in infancy and childhood. 24 studies included: - 1 RCT - 1 re-analysis of 2 RCTs - 1 case-control study - 21 cohort studies. To note - Some studies analysed data from the same cohorts (e.g. UK Millenium Cohort Study). - Meta-analysis was not possible due to the heterogeneity of the studies.	Only studies which specifically investigated and included within their measures of exposures the timing or age at which solid foods were introduced were included. To note - There was inconsistency in categorising introduction of solid foods across studies. - Some studies collected data retrospectively, relying on recall.	Over 34,000 healthy term infants. Countries From HIC	Only studies that tracked and measured obesity in infancy (0-12 months) and/or childhood (1-18 years) were included. Anthropometric measures ranged between studies (weight, length, BMI, ponderal index, skin-fold measures, fat mass, lean mass and DEXA) and were measured and reported at different ages.	Comments by the authors Confounders varied considerably across studies and some potentially important were not always identified and measured. The most common confounding factors were: - SES - maternal weight or BMI - method of milk feeding. The authors also noted that that the strong relationship between milk feeding and consumption of solid foods had been frequently identified but not consistently reported.	No clear association between the age of introduction of solid foods and obesity in infancy and childhood was found. Solid foods and obesity in infancy (≤12 months) (8 studies) - 4 studies observed that infants introduced to solids earlier were heavier or showed a higher weight gain. - 1 study found that those fed solids earlier were longer and lighter and had lower mean z-scores for BMI at 12 months. - Overall, in the majority of these studies, no clear association was found between time of introduction of solid food and measures of obesity. Solid foods and obesity in childhood (> 1 to 18 years) (19 studies) - 4 studies observed that earlier introduction of solid foods was associated with being heavier in childhood. - 1 study found a positive correlation between early solid foods and length gain between 1 and 24 months but not with change in BMI at 2 or 3 years old. - 14 studies found no association between the age at which solid foods were introduced and obesity risk. Two studies, including one prospective cohort study and a case-control study, reported on obesity in adolescence (12 to 18 years) and neither found an association. The authors concluded that no clear association between the age of introduction of solid foods and obesity was found.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Pearce et al (2013) Funding Feeding For Life Foundation. DOI None to declare.	Systematic review to investigate the relationship between the timing of the introduction of complementary feeding and overweight or obesity during childhood. 23 studied included: - 14 cohort studies - 8 cross-sectional studies - 1 case-control study. Follow-up - Up to 4 to 7 years old (19 studies). - Up to 10/11 years old (3 studies). - Up to 19 years old (1 study). To note Meta-analysis was not possible due to the considerable heterogeneity of methodologies and analysis in the different studies.	Most studies referred to complementary food as 'solid foods'. Introduction of CF: age at which food other than breast milk, water, tea or formula milk was first introduced.	Over 42,700 term infants. Studies were excluded if involving infants at risk of abnormal growth patterns, of serious disease or suffered from condition associated with obesity. Data were collected between 1959 and 2009. Countries Australia, Brazil, Canada, China, Denmark, India, Palestine, UK, US, Europe	Childhood measures of BMI or percentage body fat at one or more point between 4-12 years. All measurements used to calculate BMI were taken by health professionals or trained investigators (inclusion criteria).	Comments by the authors Confounders listed for each study included in the review. The 4 main confounding variables identified were: - breastfeeding - maternal education - SES - birth weight.	21 studies considered the relationship between the timing of introduction of CF and childhood BMI. 5 studies found that introducing complementary foods <3 months (2 studies), 4 months (2 studies) or 20 weeks (1 study) was associated with a higher BMI in childhood. 7 studies considered the association between CF and body composition. Only one study reported an increase in percentage body fat among children given complementary foods before 15 weeks of age. The authors concluded that no clear association was found between the timing of introduction of CF and childhood overweight and obesity, although some evidence to suggest that introduction ≤4 months, rather than 4 to 6 months or ≥6 months, may increase the risk of childhood obesity.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Pearce & Langley-Evans (2013) Funding Feeding For Life Foundation. DOI None to declare.	Systematic review of to investigate the relationship between the types of food consumed by infants during the CF period and overweight or obesity during childhood. 10 studies included: - 8 cohort studies - 2 retrospective studies. Follow-up from 4 to 11 years old, expect 1 study which followed up until 42 years old. Studies were categorised into 3 groups: - macronutrient intake (5 studies: 4 on protein intake and 1 on energy intake) - food type/group (4 studies) - adherence to dietary guidelines (1 study). To note Meta-analysis was not possible due to the considerable heterogeneity of methodologies and analysis in the different studies.	Introduction of CF: age at which food other than breast milk, water, tea or formula milk was first introduced.	Over 4,200 term infants. Studies were excluded if involving infants part of a selected group such as childhood cancer survivors or diabetes sufferers. Data were collected between 1959 and 2009. Countries Brazil, Denmark, Germany, Iceland, Palestine, UK	Childhood measures of BMI or percentage body fat at one or more point between 4-12 years. All measurements used to calculate BMI were taken by health professionals or trained investigators (inclusion criteria).	Comments by the authors Confounders listed for each study included in the review.	Some association was found between high protein intakes at 2-12 months of age and higher BMI or body fatness in childhood, but this was not the case in all studies. Higher energy intake during CF was associated with higher BMI in childhood. Adherence to dietary guidelines during the complementary feeding period was associated with a higher lean mass, however, intakes of specific foods or food groups made no difference to children's BMI. The authors concluded that high intakes of energy and protein, particularly dairy protein, in infancy could be associated with an increase in BMI and body fatness.

Table C.8 Infant feeding, body composition and health: experimental evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Koletzko et al (2009) Funding The Commission of the European Community (5th and 6th Framework Programme); the Child Health Foundation (Munich, Germany); LMU innovative research priority project MC-Health; the Competence Network Obesity (funded by the German Federal Ministry of Education and Research); the International Danone Institutes. BK is the recipient of a Freedom to Discover Award of the Bristol-Myers-Squibb Foundation (New York, NY). DOI None to declare. To note The infant formulas were manufactured and provided free of charge by Bledina, France.	Double-blind, randomised, controlled multicentre European intervention to test the hypothesis that higher protein intake in infancy leads to more rapid length and weight gain in the first 2 years of life. Formula fed infants randomised into: - lower protein group: infant formula: 1.77 g protein/100kcal; follow-on formula: 2.2 g protein/100kcal - higher protein group: infant formula: 2.9 g protein/100kcal; follow-on formula: 4.4 g protein/100kcal. The formulas were all cow milk based formula. They differed in the amount of cow milk protein but had identical energy densities by compensatory adaptation of the fat content. A group of EBF infants was also followed as control group. Follow-up at 3, 6, 12 and 24 months (anthropometric measurements plus 3-days weighted food records).	Formula fed infants had to be exclusively formula fed at the end of the 8th week of life. Noncompliance was defined as feeding of non study formula or breastfeeding for >10% of feedings (or >3 bottles/week) over ≥1 week in the first 9 months of life. Breastfed infants had to be breastfed since birth and exclusively breastfed (<10% of feedings or <3 bottles of formula/week) for the first 3 months of life.	n=1,090 formula fed, singleton, healthy term infants born between 1 October 2002 and 31 July 2004 and enrolled during the first 8 weeks of life (1,138 initially randomised). Low protein group: n=540 (n=313 at 24 months). High protein group: n=550 (n=322 at 24 months). Control (EBF): n=619 (n=304 at 24 months). Countries Belgium, Germany, Italy, Poland and Spain	At inclusion, 3, 6, 12 and 24 months: - weight - length - weight-for-length - BMI. Primary endpoints: length and weight-for-length z scores based on the 2006 WHO growth standards.	Comments by the authors The results were adjusted for potential confounders: - sex - mother's education status - smoking in pregnancy - country. Randomisation was stratified by sex.	Length was not different between randomised groups at any time. At 24 months, children in the low-protein group had lower weight-for-length and BMI z-scores than those in the higher protein group (0.23; 95% CI 0.089 to 0.36 and 0.20; 95% CI 0.06 to 0.34, respectively). Furthermore, the low-protein group did not differ significantly in these outcomes from a breastfed reference group. The authors concluded that a higher protein content of infant formula is associated with higher weight in the first 2 years of life but had no effect on length. Lower protein intake in infancy might diminish the later risk of overweight and obesity.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mehta et al (1998) Funding Gerber Products Inc.; USDHD Grant from General Clinical Research, National Center for Research Resources; National Institutes of Health. DOI Not specified. To note 1 of the authors is associated to Gerber Products Company.	Randomised trial to determine whether early vs late introduction of solid foods and commercially vs parent's choice of solid food affects growth or body composition in the first year. Infants recruited before 3 months of age and randomised to receive: - group 1: commercially prepared solid foods from 3 to 12 months - group 2: commercially prepared solid foods from 6 to 12 months - group 3: parent's choice of solid foods from 3 to 12 months - group 4: parent's choice of solid foods from 6 to 12 months. Groups 1 & 2 (commercial food): infants introduced first to single cereals, followed by multiple grain cereals, and then fruits and vegetables. Group 3 & 4 (parent's choice): infants introduced first to cereals followed by other foods as directed by parents/paediatrician. Follow-up at 3, 6, 9 and 12 months, including 3-day food diaries.	'Early' group: introduced to solids at 3 to 4 months . 'Late' group: introduced to solids at 6 months. Infants in all groups were formula fed, but were permitted to consume breast milk before randomisation at 3 months.	n=147 healthy term white infants of appropriate birth weight for gestational age (165 randomised but 18 withdrawn before end of study). Group 1: n=36 Group 2: n=40 Group 3: n=35 Group 4: n=36 Country US	- Weight, length, head circumference measured at 3, 6, 9 and 12 months. - Body composition (DXA) measured at 3, 6 and 12 months.	Comments by the authors Only white infants were included to eliminate race as a confounder. There were no differences in maternal educational level, maternal and paternal BMI, or ethnicity between groups. Differences between groups for diet data were determined by multiple regression analysis using baseline data at 3 months as a covariate to minimise the influence of baseline differences between groups.	There were no differences in growth or body composition between infants in early vs late introduction groups or commercial vs parent's choice at any age. No differences between early vs late introduction groups for total energy intake at any age. Infants consuming commercially prepared foods have a decreased caloric intake from protein and fat but despite this difference there is no effect on growth or body composition. The authors concluded that the early introduction of solid foods to an infant's diet does not alter growth or body composition during the first year of life and results in displacement of energy intake from formula.

Table C.9 Infant feeding, body composition and health: observational evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Abraham et al (2012) Funding None to declare. DOI None to declare.	Longitudinal birth cohort study (Growing Up in Scotland) to investigate the interrelationships between early feeding experiences (breastfeeding and CF) and 1) eating patterns in the second year of life, and 2) weight status in the fourth year of life. Follow-up to 45-48 months.	Breastfeeding defined using the question 'Was the child ever breastfed?'. Age of starting CF assessed using the question 'How many months old when the child started solid foods?'.	n=5,217 Scottish children born between June 2004 and May 2005. First sweep of data was collected at aged 9-12 months. Country Scotland	Eating pattern defined by using SPSS two-step cluster analysis technique. Variables included: variety of fruit intake, variety of vegetable intake, snacking behaviour, intake of energy-dense or low-nutrient foods, meal or snack pattern.	Comments by the authors Results were adjusted for the following potential confounders: - birth weight - parent's education level - Scottish Index of Multiple Deprivation.	Children who were ever breastfed compared with never breastfed were significantly more likely (AOR 1.48; 95% CI 1.27 to 1.73; n=3,825) to have a positive eating pattern in the 2nd year of life (characterised by high variety of fruit daily, a high variety of vegetables daily and fruit between meals, and had a higher prevalence of eating just a meal with no snacking). Children who started CF at 4-5 months or 6-10 months compared with 0-3 months (AOR 1.32; 95% CI 1.09 to 1.59 and AOR 1.50; 95% CI 1.19 to 1.89, respectively; n=3,766) were significantly more likely to have a positive eating pattern. Breastfeeding was negatively associated with being overweight or obese in the 4th year of life compared with no breastfeeding (AOR 0.81; 95% CI 0.64 to 1.01; n=3,515). Introduction of CF at 4-5 months compared with 0-3 months was negatively associated with being overweight or obese (AOR 0.74; 95% CI 0.57 to 0.97; n=3,462). The authors concluded that breastfeeding and introduction of CF after 4 months were associated with a positive eating pattern in the second year of life. Introduction of CF at 4–5 months compared with 0–3 months was negatively associated with being overweight or obese.

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Brazionis et al (2013) Funding The UK Medical Research Council; the Wellcome Trust (UK); the University of Bristol; the National Health and Medical Research Council of Australia (NHMRC). DOI 2 of the 7 authors (PE and KN) had undertaken lectures and received funding from companies involved in the provision of commercial infant foods. The other authors did not have conflicts of interest to declare.	Prospective birth cohort study (ALSPAC) to assess associations between types of diet spanning infancy and toddlerhood (that is, transition diets across the CF period) and blood pressure (BP) at age 7.5 years. 'Transition diet' data were collected at 6, 15 and 24 months by food frequency questionnaire (FFQ). Principal components analysis (PCA) was used to identify dietary patterns from data collected from FFQs. Follow-up at age 7.5 years (clinic visit).	Transition diets were characterised by variation in intake of foods consumed across infancy and toddlerhood (from 6 to 24 months) as: - 'healthy' diet (more home-prepared and raw foods) - 'less healthy' (more ready-prepared, snack and processed foods).	n=1,229 participants with complete data for analysis for this study (n=14,541 pregnant women with a delivery due date between April 1991 and December 1992 were recruited for the ALSPAC study). Country UK (county of Avon)	Systolic and diastolic BP measured at 7.5 years.	Comments by authors The outcome measures were adjusted for the following potential confounders: - maternal age, education, social class, pre-pregnancy weight and height and corresponding BMI, marital status - smoking history - number of children (<16 years old) living in the family home - breastfeeding duration - birth variables (sex, gestational age, singleton or twin, birth weight) - child characteristics (height, weight, BMI and waist circumference).	Each child was assigned a score for both the healthy and less healthy diets, so the relationship between diet score and BP was also examined. Breastfeeding at 6 months was inversely associated with less healthy diet but positively associated with healthy diet (suggesting that BF at 6 months may act as a marker for overall diet quality in infant and toddlerhood). The less-healthy diet was associated with an increase in systolic BP of 0.62mmHg (95% CI 0.00 to 1.24mmHg) and an increase in diastolic BP of 0.55mmHg (95% CI 0.10 to 1.00mmHg) for every one-unit (SD) increase in the less-healthy-diet score. In contrast with systolic BP, the positive association between the less-healthy transition-diet score and diastolic BP persisted after additional adjustment for child height, BMI and waist circumference at 7.5 years.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Fall et al (2011) Funding The Wellcome Trust (UK). DOI None to declare.	Pooled data from 5 prospective birth cohort studies in LMIC to test the hypothesis that longer duration of breastfeeding and later introduction of CF in infancy are associated with reduced adult cardiovascular risk. To note - The Guatemala cohort did not collect data about the age of introduction of solid foods. - The methods used to collect infant feeding data varied between studies.	Complementary foods defined as semi-solid or solid foods. Age at which CF was introduced categorised into 6 groups: 1) ≤3 months 2) 3-6 months 3) 6-9 months 4) 9-12 months 5) 12-18 months 6) >18 months.	n=10,912 individuals (9,640 when Guatemala not included) aged 15-41 years at follow-up. Countries Brazil, India, Philippines, South Africa and Guatemala	- Adult blood pressure (systolic and diastolic) - Fasting plasma glucose concentrations - Adiposity measures Depending on the cohort, adiposity measures in adulthood included: - BMI - waist circumference - body fat percentage - triceps and subscapular skinfolds - overweight (BMI ≥25kg/m^2) and obesity (BMI ≥30kg/m^2).	Comments by the authors The potential confounding factors identified in all the cohorts were: - maternal SES - education - age - smoking - rural/urban residence - race - infant birth weight. In addition to the set of confounding variables above, the outcome measures were also adjusted for: - adult BMI (except for the adiposity outcomes) - adult height - cohort location. The authors also noted that data from LMIs may help address confounding issues associated with breastfeeding in HIC as the relationships between infant-feeding practices and social class in LMIC differ from those in HIC.	Duration of breastfeeding was not associated with adult diabetes prevalence or adiposity. There were U-shaped associations between duration of breastfeeding and systolic BP and hypertension; however, these were weak and inconsistent among the cohorts. The most frequent age at introduction of CF was 0-3 months in Brazil and South Africa, 3-6 months in the Philippines and 9-12 months in India. Age at introduction of CF was unrelated to blood pressure and glucose outcomes. Later introduction of CF was associated with lower adult BMI, waist circumference and percentage body fat, thinner skinfolds and a lower risk of overweight/obesity: BMI changed by -0.19kg/m^2 (95% CI -0.37 to -0.01kg/m^2) and waist circumference by -0.45cm (95% CI -0.88 to -0.02cm) per category increase in age of introduction of complementary foods. The authors concluded that there was no evidence that longer duration of breastfeeding is protective against adult hypertension, diabetes or overweight/adiposity in these low-/middle-income populations.

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Grote et al (2011) Funding The Commission of the European Community (5th and 6th Framework Programme); the Child Health Foundation (Munich); the LMU innovative research priority project MC-Health (Munich Center of Health Science); the International Danone Institutes. DOI None to declare. To note The formula for the study was produced by Bledina as a partner in this EU project.	Prospective European cohort study to test whether introduction of solid food influences energy intake or growth. Based on data from participants enrolled in a double-blind RCT that compared 2 groups of children fed cow's milk formula with either higher or lower protein content (see (Koletzko et al, 2009)). Both randomised formula groups were combined into one group for all analyses, because the researchers did not expect the protein intake of the formula to affect the age of introduction of solid foods. Infant food intakes were recorded by prospective 3-day weighed food diaries at monthly intervals from the ages of 1 to 9 months, and additionally at ages 12, 18 and 24 months. At 3, 6 and 9 months parents were asked about the current type of feeding and the week of introduction of solids. Follow-up at 3, 6, 9, 12 and 24 months.	Age at introduction of solid foods categorised into four groups: 1) ≤13 weeks (≤3m) 2) 14-17 weeks (3-4 months) 3) 18-21 weeks (4-5 months) 4) ≥22 weeks (≥5 months) .	n=671 singleton, healthy term infants recruited between October 2002 and July 2004 and exclusively formula fed by the end of the 8th week of life (1,090 included in original study). Countries Belgium, Germany, Poland, Italy and Spain	- Anthropometric measurements (length and weight) taken at recruitment (just after birth) and at 3, 6, 12 and 24 months. - Weight-for-age, length-for-age, weight-for-length and BMI-for-age z-scores calculated.	Comments by the authors The authors considered the following variables as potential confounders: - formula group - sex - country - mother's and father's education - birth order of the child - mother's BMI - smoking status - age - partnership status .	The median age of introduction of solid food was 19 weeks. About 7% of the infants were introduced to solid food before the end of the third month of life and by age 6 months, 97% of all children had been introduced to solids. The timing of introduction of solid food was significantly associated with the study country; the sex of the child; the nationality, marital status, and educational level of the parents; the smoking behaviour of the mother; the BMI of the mother; and the birth weight of the infant. Weight and length at 24 months were significantly associated with the country; the birth order; and the anthropometric measures at birth and at study inclusion. The following significant differences in growth in the first year of life by age of solid food introduction were observed. - Children introduced to CF ≤13 weeks were lighter at birth and grew faster between 3 and 6 months of age than the other groups of children. - Children introduced to CF ≥22 weeks had a less pronounced growth until 3 months of age and continued on a lower weight percentile than children introduced to solids earlier. However, age of solid food introduction was not found to be associated with any of the anthropometric measurements at 24 months. Also, solids were found to add additional energy to the diet during the introduction period rather than replacing formula.

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Huh et al (2011) <u>Funding</u> The National Institutes of Health (NIH). <u>DOI</u> No financial relationships to disclose.	Prospective birth cohort study (Project Viva) to study the association between timing of introduction of solid foods during infancy and obesity at 3 years of age. <u>Follow-up</u> - Home visits after delivery, at 6 months and 3 years, at which data on infant feeding practices were collected and child length/height and weight measured. Skinfold thickness also measured at 3 years. - Mailed questionnaires to update infant feeding practices at 1 and 2 years old.	Infant feeding status categorised as: - '<u>breastfed</u>' (children who were at least partly breastfed for ≥4 months) - '<u>formula fed</u>' (children who were never breastfed or stopped breastfeeding before the age of 4 months). <u>Timing of introduction of solid foods</u> defined as child's age at the earliest introduction of any solid food and categorised as: 1) <4 months 2) 4 to 5 months 3) ≥6 months.	n= 847 singleton infants, of which 568 (67%) breastfed and 279 (32%) formula fed at 4 months (n=1,579 infants initially eligible for the 3-year follow-up). Mothers were recruited between 1999 and 2002, at initial prenatal visit, with a gestational age less than 22 weeks.	<u>Primary outcome:</u> Obesity at 3 years of age (BMI for age and gender ≥95th percentile). The sum of the children's subscapular and triceps skinfold thicknesses were also calculated as an additional adiposity measure, as well as change in weight-for-age z score from 0-4 months as a proxy for infant growth before solid food introduction.	<u>Comments by the authors</u> The authors adjusted the outcome measures for the following confounders (separate models for breastfed and formula fed infants): - maternal education - household income - prepregnancy BMI - paternal BMI - child's age, gender, and race/ethnicity - birth weight - gestational age. In an additional model, the authors also adjusted for the change in the weight-for-age z-score from 0 to 4 months. <u>To note</u> The potential confounders that did not change the effect estimates such as birth weight, birth weight–for–gestational age z score, gestational age at delivery and gestational weight gain were excluded.	<u>Feeding status and introduction of CF</u> - 8% of breastfed infants vs 33% of formula fed infants started solids before 4 months. - 17% of breastfed infants vs 9% of formula fed infants started solids after 6 months (p=0.0001). <u>Introduction of CF and obesity</u> - Introduction of solids before 4 months (vs 4-5 months) was associated with an increase in obesity at 3 years in formula fed infants (AOR 6.3; 95% CI 2.3 to 16.9), which was not explained by rapid early growth. - Introduction of solids before 4 months was associated with a 0.36-unit increment in BMI z-scores (95% CI 0.10 to 0.61) at age 3 years in formula fed infants. - Introduction of solid after 6 months in formula fed infants was associated with an increase in the odds of obesity (AOR 3.6) but the CI was wide and not significant due to the small number of infants in this group (95% CI 0.8 to 16.3). - The timing of solid food introduction was not associated with later obesity risk among the breastfed infants. <u>Feeding status and obesity</u> - Change in weight-for-age z score (from 0-4 months) was larger for formula fed than breastfed infants (0.54 vs 0.35 U; p= 0.01). - At 3 years, 7% of breastfed children were obese vs 13%of formula fed children. The authors concluded that among infants who were never breastfed or who stopped breastfeeding before 4 months of age, the introduction of solids before the age of 4 months was associated with almost 6-fold increased odds of obesity at 3 years of age. The association was not explained by rapid early growth. Among infants breastfed for 4 months or longer, the timing of the introduction of solid foods was not associated with the odds of obesity.

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Lin et al (2013) Funding The Health and Health Services Research Fund; the Research Fund for the Control of Infectious Diseases (Hong Kong); the Government of the Hong Kong Special Administrative Region; the University Research Committee Strategic Research Theme of Public Health (University of Hong Kong). DOI No financial relationships to disclose.	Birth cohort study (sub-study of the prospective birth cohort 'Children of 1997') to study the association of the timing of the introduction of BMI and overweight (including obesity) into adolescence in a developed non-Western setting, in which childhood obesity is less clearly socially patterned. Baseline characteristics obtained via a self-administered questionnaire at recruitment. Follow-up - Passive: data on weight and height were obtained in 2005 from health records collected at Maternal and Child Health centres and annual check-ups of school students. - Active: data on age of introduction of solids were obtained via postal survey sent in 2008.	Timing of introduction of solid foods defined as the age when first given solid foods and categorised as: 1) <3 months 2) 3-4 months 3) 5-6 months 4) 7-8 months 5) >8 months.	For this sub-study: n=7,809 at passive follow-up. n=3,679 completed the active follow-up. (Initial cohort: n=8,327 infants recruited at the first postnatal visit to a Maternal and Child Health Centre in Hong Kong; covers 88% of all ethnic Chinese births during April and May 1997 in Hong Kong). Country Hong Kong	BMI z-scores at: - infancy (birth to <2 years) - childhood (2 to <8 years) - puberty (8 to <14 years). Overweight, including obesity, (as defined by IOTF cut-offs) was also considered as an outcome in childhood and puberty.	Comments by the authors The following potential confounders were identified (and adjusted for) by the authors: - gender - gestational age - birth weight z score - weight z score change from 0 to 3 months - breastfeeding - parity - mother's age at birth - pre- and post-natal second-hand smoke exposure - mother's birthplace - family socioeconomic position (highest parental education, interaction of mother's birthplace and highest parental education, parental occupation, household income per head at birth).	There was no association between the age of introduction of solid foods and BMI z-score, overweight (including obesity) at any growth phase. The timing of the introduction of solid food also had no clear association with BMI z-score in gender-stratified analysis. The timing of introduction of solid foods at <3 months was associated with higher birth weight z score, lower weight z-score change from 0 to 3 months and lower SES, among other. In the available case analysis, introduction of solid foods at <3 months was associated with a higher BMI z-score in childhood and puberty, particularly among boys. Introduction of solids at >8 months was also associated with a higher BMI z-score in childhood among boys. The timing of the introduction of solid food was not associated with overweight (including obesity). The authors concluded that, in a non-Western developed setting, there was no clear association of the early introduction of solid food with childhood obesity. Together with the inconsistent evidence from studies in Western settings, this finding suggests that any observed associations might simply be residual confounding by SES.

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Mihrshahi et al (2011) <u>Funding</u> The National Health and Medical Research Council; QUT Faculty of Health; HJ Heinz. <u>DOI</u> Postdoctoral fellowship of one of the authors funded by HJ Heinz; the authors declared no competing interests.	Analysis of data from the prospective cohort of the NOURISH RCT to determine which modifiable variables are associated with rapid weight gain in early life (the NOURISH RCT aims to evaluate an intervention to promote positive early feeding practices). Demographic data were collected at the first postnatal contact in hospital and birthweight was collected from hospital records. Baseline assessment took place when infants were 4-7 months, before randomisation. Data on feeding practices were collected using a self-administered questionnaire and infant weights and lengths were measured by trained assessors.	Feeding type was categorised into: 1) EBF: breastmilk only with no other food or fluids 2) breastfeeding fully: breastmilk only with occasional water or juices 3) combination feeding: breast and formula feeding 4) formula feeding only. <u>Early introduction of solids</u> defined as <4 months. <u>Feeding style</u> assessed by the questions 'Do you let your baby feed whenever s/he wants to?' and 'Do you only allow your baby to feed at set times?' and categorised as: 1) feeding on demand 2) feeding to schedule.	n=612 primiparous healthy term infants with birth weights >2500g and aged 4.3 months (SD 1.0) at the time of assessment (698 recruited for the RCT). <u>Country</u> Australia	Rapid weight gain in infancy defined as >0.67 change in weight-for-age z-score from birth to assessment (at 4-7 months).	<u>Comments by the authors</u> The results were adjusted for the following potential confounders (multivariable logistic regression models): - maternal age, education, BMI and smoking during pregnancy - infant birthweight, age and gender.	<u>Feeding practices</u> - A total of 32.5% of infants had already started on solids by the time of the assessment, of which 24% had been introduced to solids before 4 months. - Formula fed infants were more likely to have been introduced to solids early (OR 2.54; 95% CI 1.26 to 5.13; p = 0.009). <u>Feeding practices/style and weight gain</u> - No effect was observed of early introduction of solids on weight gain during the study period. - Formula feeding was found to be a factor associated with rapid weight gain during the study period (OR 1.72; 95% CI 1.01 to 2.94; p = 0.047). - Feeding on a schedule rather than on demand was also associated with rapid weight gain (OR 2.29; 95% CI 1.14 to 4.61; p = 0.020). - Male gender and lower birthweight were non-modifiable factors associated with rapid weight gain. The authors concluded that there is an association between formula feeding, feeding to schedule and weight gain in the first months of life. Mechanisms may include the actual content of formula milk (such as higher protein intake) or differences in feeding styles, such as feeding to schedule, which increase the risk of overfeeding.

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van Rossem et al (2013) Funding The Netherlands Organization for Health Research and Development (ZonMW); the European Container Terminals (ECT) B.V. DOI None to declare.	Longitudinal birth cohort study (embedded in the Generation R Study) to determine the association and direction between the introduction of solids and weight-for-height change between birth and 45 months. Mothers reported via postal questionnaire sent 2 months after birth whether they were breastfeeding, formula feeding or a combination of both. A food questionnaire at 12 months postpartum asked mothers to report the first introduction of different food types to the infant diet. Follow-up at 1, 2, 3, 4, 6, 11, 14, 18, 24, 30, 36 and 45 months (clinic visits).	Age of introduction of solids categorised as: 1) 'very early' (0-3 months, n=104) 2) 'early' (3-6 months, n=1,120) 3) 'timely' (after 6 months, n=771).	n=3,184 singleton term infants (7,295 followed from birth). Country the Netherlands (Rotterdam)	Infant length/height and weight at 1, 2, 3, 4, 6, 11, 14, 18, 24, 30, 36 and 45 months of age.	Comments by the authors The analysis were adjusted for: - maternal educational level - maternal ethnicity - smoking during pregnancy - mother's BMI - breastfeeding - history of food allergy - infant's hospital admission.	38% of mothers introduced solids after 6 months of age. Before introduction of solids, weight gain was higher in children introduced to solids early (between 3 and 6 months) (z=0.65; 95% CI 0.34 to 0.95) compared to infants introduced to solids very early (before 3 months) (z=0.02; 95% CI -0.03 to 0.08) or timely (after 6 months) (z=-0.04; 95% CI -0.05 to -0.03). Weight-for-height change did not differ between the solid introduction groups after 12 months. The authors concluded that differences in weight-for-height in childhood are not the result of early introduction of solid.

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Veena et al (2011) Funding The Parthenon Trust (Switzerland); the Wellcome Trust (UK); the Medical Research Council (UK). DOI None to declare.	Birth cohort study to examine whether longer duration of breastfeeding and later introduction of CF is associated with lower glucose concentrations and insulin resistance (IR-HOMA) in Indian children. Follow-up - At 1, 2 and 3 years old for infant feeding data. - At 5 and 9.5 years old for glucose tolerance and IR-HOMA.	Breastfeeding duration categorised into six groups: 1) <3 months 2) 3-5 months 3) 6-8 months 4) 9-11 months 5) 12-17 months 6) ≥18 months. Age at starting CF: age at which infant started taking solid foods regularly. Categorised into 4 groups: 1) <4 months 2) 4 months 3) 5 months 4) ≥6 months.	n=518 children completed feeding data and outcomes (from the 663 delivered normal babies initially recruited). Country India (Mysore)	Glucose concentrations and insulin resistance (as measured by IR-HOMA).	Comments by the authors The associations of breastfeeding duration and age at starting complementary foods with outcomes and the following potential confounders were examined by multiple linear regression: - child's sex, age and current BMI - SES - parent's education - rural/urban residence - birthweight - maternal gestational diabetes status.	All the children were initially breastfed; 90% were breastfed for ≥6 months and 56.7% started CF at or before the age of 4 months. Each category increase in breastfeeding duration was associated with lower fasting insulin concentration (β=−0.05pmol/l; 95% CI −0.10 to −0.004pmol/l; p=0.03) and IR-HOMA (β=−0.05; 95% CI −0.10 to −0.001; p=0.046) at 5 years. Age at introduction of CF was unrelated to glucose tolerance and IR-HOMA, at either 5 years of 9.5 years of age. However, early introduction of solids was associated with higher BMI at age 9.5 years (p=0.04). The authors concluded that within this cohort, in which prolonged breastfeeding was the norm, there was evidence of a protective effect of longer duration breastfeeding against glucose intolerance at 9.5 years. At 5 years longer duration of breastfeeding was associated with lower IR-HOMA.

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Voortman et al (2016a) Funding Erasmus Medical Center and Erasmus University, Rotterdam; Dutch Ministry of Health, Welfare and Sport; Netherlands Organization for Health Research and Development (ZonMw). DOI None to declare. To note 5 of the 8 authors work in ErasmusAGE, a research Centre funded by Nestle Nutrition, Metagenics Inc. and AXA.	Observational study, embedded in the population-based prospective cohort Generation R Study, to explore the association between dietary patterns in children at 1 year old and FM index and FFM index at 6 years old. Dietary intake was assessed at 1 year with a validated semi-quantitative FFQ and body composition assessed at 6 years. 3 dietary pattern approaches used: 1) an a-prior-defined diet quality score 2) a dietary patterns based on variation in food intake derived from PCA 3) a dietary patterns based on variation in FM index and FFM index derived with reduced-rank-regression (RRR).	Breastfeeding history categorised into: 1) never breastfeeding 2) any partial breastfeeding in the first 4 months of life 3) full breastfeeding in the first 4 months of life. Timing of introduction of CF categorised into: 1) <3 months 2) 3-6 months 3) ≥6 months. Diet quality score based on the intake of 10 food groups: 1) vegetables 2) fruit 3) bread and cereals 4) rice, pasta, potatoes, and legumes 5) dairy 6) meat, poultry, eggs and meat substitutes 7) fish 8) fats and oils 9) candy and snacks 10) sugar-sweetened beverages.	n=2,026 children with available dietary pattern data at 1 year and anthropometric data at 6 years (n=7,893 participants in the Generation R Study, pregnant women enrolled between 2001 and 2005). Country the Netherlands (Rotterdam)	- Dietary patterns and dietary quality score at 1 year old - Anthropometric and body composition measured at 6 years old (energy X-ray absorptiometry) - BMI - FM index - FFM index	Comments by the authors Crude models were adjusted for child sex, age at dietary assessment and total energy intake. The multivariable models were further adjusted for maternal age, BMI at enrolment, parity, folic acid supplement use, and smoking and alcohol use during pregnancy; paternal smoking and education; household income; child breastfeeding in the first 4 months of life, timing of introduction of complementary feeding, and television watching at the age of 2 years. The authors selected these covariates as potential confounders because they were associated with at least one of the studied dietary patterns.	Mean (±SD) diet quality score at the age of 1 year was 4.2 (±1.3) on a range of 0–10 (a higher score represents a healthier diet). 2 dietary pattern identified with PCA 1) 'Health-conscious': high intakes of fruit, vegetable, oils, legumes, pasta and fish 2) 'Western-like': high intakes of snacks, animal fats, refined grains, confectionery and sugar-containing beverages Adherence to the western dietary pattern at 1 year was not consistently associated with any of the body composition measures at 6 years old. Adherence to the health-conscious dietary pattern or a higher diet quality score at 1 year was associated with a higher FFM index at 6 years old but not with FM index. Children in the highest quartile of the diet score had a 0.19 SD higher FFM index (95% CI 0.08 to 0.30) than children in the lowest quartile. 2 dietary patterns identified with RRRs 1 of 2 RRR patterns (characterised by high intakes of whole grains, pasta and rice, dairy, fruit, vegetable oils and fats, and non-sugar-containing beverages) was associated positively with FFM index but not with FM index. The 2nd RRR pattern (characterised by high intake of refined grains, meat, potatoes, fish, soups and sauces, and sugar-containing beverages) was associated positively with both FFM and FM indexes. The authors concluded that dietary patterns characterised by high intake of vegetables, fruit, whole grains, and vegetable oils at the age of 1 year, were associated with a higher FFM index, suggesting that these dietary patterns can be beneficial for health in later life, as higher lean mass is associated with improved cardiovascular and metabolic health.

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Voortman et al (2016b) Funding Erasmus Medical Center and Erasmus University, Rotterdam; Dutch Ministry of Health, Welfare and Sport; Netherlands Organization for Health Research and Development (ZonMw). DOI None to declare. To note 5 of the 6 authors work in ErasmusAGE, a research Centre funded by Nestle Nutrition, Metagenics Inc. and AXA.	Observational study, embedded in the population-based prospective cohort Generation R Study, to examine the associations of total, animal and vegetable protein intake in early childhood with detailed measures of body composition at the age of 6 years. Protein intake assessed at 1 year using a validated semi-quantitative FFQ and body composition assessed at 6 years.	Breastfeeding in the 4 first months categorised into: 1) never 2) partial 3) exclusive.	n=2,911 children with available dietary pattern data at 1 year and anthropometric data at 6 years (n=7,893 participants in the Generation R Study, pregnant women were enrolled between 2001 and 2005). Country The Netherlands (Rotterdam)	- Protein intake at 1 year old - Anthropometric and body composition measured at 6 years old (energy X-ray absorptiometry) - BMI - FM index - FFM index	Comments by the authors Basic models (model 1) included energy-adjusted total protein intake, child's sex, total energy intake and age at outcome measurement. For analyses with protein from different sources, total protein intake was replaced by energy-adjusted animal protein intake and energy-adjusted vegetable protein, that is, animal and vegetable protein were adjusted for each other. Multivariable models (model 2) were further adjusted for household income; maternal age, education, BMI and smoking during pregnancy; and for child's ethnicity, birth weight SD score, breastfeeding, total fat intake, diet quality score, screen time and participation in sports. The covariates in model 2 were selected on the basis of theory or previous literature and were included if they resulted in a change of ⩾10% in effect estimates when entered individually in model 1.	At the age of 1 year, mean (± SD) daily protein intake of the children was 41.2g (±12.9), which corresponds to 12.9% of their total energy intake. Mean animal protein intake was 8.1 E% (±2.4) and mean vegetable protein intake 4.7 E% (±1.4). A 10g per day higher protein intake at 1 year was associated with a 0,05 SD (95% CI 0.00 to 0.09) higher BMI at 6 years (model 2). The association was fully driven by higher FM index (0.06 SD; 95% CI 0.01 to 0.11) but not FFM index (-0.01 SD; 95% CI -0.06 to 0.05). The association remained significant after adjustment for BMI at 1 year. Additional analyses showed that the associations of protein intake with FMI were stronger: - in girls than in boys (p=0.03) - among children who had catch-up growth in the first year of life (p=0.01) - for intake of animal protein (both dairy and non-dairy protein) than protein from vegetable sources. The authors concluded that high protein intake in early childhood is associated with higher body FM, but not FFM.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Wilson et al (1998) Funding The Scottish Home and Health Department; The Department of Health (UK). DOI None to declare.	Follow-up study of a cohort of children to investigate the relation of infant feeding practice to childhood respiratory illness, growth, body composition and BP. Infant feeding data was collected prospectively in the first two years of life. Infants recruited 1983-1986 and follow-up letters sent in 1990-1993. Mean age at follow-up was 7.2 years (range 6.9 - 10.0 years).	Timing of introduction of solids categorised as: 1) before 15 weeks 2) 15 weeks or later. Milk feeding categorised as: 1) EBF for at least 15 weeks 2) partial breastfeeding if receiving formula supplements before 15 weeks (mean duration of breastfeeding of 9.5 weeks) 3) exclusive bottle-feeding.	n=545 children were available for the follow-up (from the 674 initially recruited). Data were available for analysis for: - 545 children for respiratory illness - 410 for height, 412 for weight and BMI, 405 for body composition - 301 for blood pressure. Country UK (Dundee)	- Blood pressure (measured at follow-up either at home or at a hospital visit) in relation to duration of breastfeeding and timing of introduction of solids - Respiratory illness - Weight, height, BMI and percentage body fat	Comments by the authors The following variables were assessed as potential confounders in the analysis: - birth weight - weight at first solid feed - BMI - sex - parity - gestation - maternal height - maternal blood pressure - SES - number of people smoking per household - parental history of atopic disease. Variables identified as confounders, per outcome: Respiratory illness: - SES - parental history of atopic disease - sex of the child. Weight, BMI and percentage body fat: - birth weight - sex - weight at first solids. BP: - BMI - sex - maternal blood pressure.	Systolic BP was associated with type of milk feeding: exclusively bottle fed infants had a higher systolic BP at 7 years (94.2mmHg; 95% CI 93.5 to 94.9mmHg) than infants exclusively (90.3mmHg; 95% CI 89.5 to 91.1mmHg) or partially breastfed (90.9mmHg; 95% CI 90.2 to 91.6mmHg). No significant differences were reported in BP outcomes according to the age of introduction of solid foods. The estimated probability of ever having respiratory illness in children who received EBF for at least 15 weeks was consistently lower for EBF (17.0%; 95% CI 15.9 to 18.1%) than for partial breast feeding (31.0%; 95% CI 26.8 to 35.2%) and bottle feeding (32.2%; 95% CI 30.7 to 33.7%). Solid feeding before 15 weeks was associated with an increased probability of wheeze during childhood (21.0%; 95% CI 19.9 to 22.1% vs 9.7%; 95% CI 8.6 to 10.8%). It was also associated with increased percentage body fat (mean body fat 18.5%; 95% CI 18.2 to 18.8% vs 16.5%; 95% CI 16.0 to 17.0%) and weight in childhood (weight SD score 0.02; 95% CI -0.02 to 0.06 vs -0.09; 95% CI -0.16 to 0.02). The authors concluded that the probability of respiratory illness occurring at any time during childhood is significantly reduced if the child is fed exclusively breast milk for 15 weeks and no solid foods are introduced during this time.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Woo et al (2013) Funding Mead Johnson Nutrition, Inc; Institutional Clinical and Translational Science Award grant. DOI - ALM and JGW received funding from Mead Johnson Nutrition, Inc., as a scientific research grant. - FJM is an employee of the Mead Johnson Pediatric Nutrition Institute; no conflicts of interest. - No conflict of interest to declare for the others authors.	Multi-country prospective cohort study (embedded in The Global Exploration of Human Milk Study) to determine the association between infant feeding and anthropometry at 1 year of age. Assessment included baseline questionnaires, 5 in-person visits and weekly telephone surveillance in year 1. Data collected on infant feeding from weekly interviews, including current breastfeeding status and a 24hr food frequency recall of infant feeding.	'Breastfeeding intensity' determined during first year of follow-up as the number of times the infant had been fed human milk divided by the total number of items fed (x100), with 100% indicating EBF. EBF duration defined as the infant's age at the last report of EBF. Any breastfeeding duration defined as the infant's age when the mother reported breastfeeding cessation (cross validated with the last 24-h recall). Introduction of solid food was defined as the first reported intake of any solid or semi-solid food.	n=285 predominantly breastfeeding mothers and infants from urban populations (365 recruited). Infant-mother pairs were recruited shortly after birth, from a single hospital at each site, between January 2007 and December 2008. Enrolment required agreement to breastfeed ≥75% for at least 3 months. Countries US (Cincinnati, n=92); Mexico (Mexico City, n=89); China (Shanghai, n=104).	- Weight and length measurements (measured at in-person visits) at age 1 year. - BMI calculated as well as age and sex specific z-scores for BMI, weight-for-age, length-for-age, and weight-for-length.	Comments by the authors Variables considered as potential confounders and included in statistical analyses were: - cohort site - maternal age at delivery - maternal education level - maternal pre-pregnancy BMI - gestational weight gain - gestational diabetes - type of delivery - infant birth weight - infant sex.	Cohorts differed significantly on most baseline characteristics and on maternal obesity prevalence, gestational weight gain and infant birth weight. The median EBF differed ($p<0.001$) in the 3 urban populations (Shanghai: 8 weeks; Cincinnati: 14 weeks; Mexico City: 7 weeks). Median introduction of any solid food was >1 month earlier in Shanghai (18 weeks) than in Cincinnati (23 weeks) or Mexico City (25 weeks). Infant anthropometry at 1 year also significantly differed between cohorts. By age 1 year, infants in Shanghai were heavier and longer than Cincinnati and Mexico City infants ($p<0.001$). The timing of any solid food introduction did not significantly influence weight or length at 1 year of life (full data not shown). After adjustment for confounders, the only feeding variable associated with anthropometry was EBF duration, which was modestly inversely associated with weight-for-age but not length-for-age or BMI z-scores at 1 year. Although feeding variables differed by cohort, their impact on anthropometry differences was not consistent among cohorts. The authors concluded that across these urban, international, breastfed cohorts, differences in specific feeding practices did not explain the significant variation in anthropometry.
Wright et al (2004)	See Table C.3					

Table C.10 Micronutrients: experimental evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Abdelrazik et al (2007) Funding Not specified. DOI Not specified.	A controlled trial to weight the benefits of long-term oral iron supplementation on infant's growth against its potential hazards (EBF infants). Infants were allocated to: - treatment group (TG): multivitamin with iron (1mg/kg/day) - control group (PG): same multivitamin but without iron (healthy infants with normal basal parameters of iron status). TG subdivided according to clinical assessment into group A (well-nourished TG-A) and group B (malnourished TG-B); both further stratified according to basal blood iron status (anaemic status defined by haemoglobin cut-off value of 100g/L). Follow-up 1 year, with clinical and laboratory assessment after 3 and 12 months and concurrent collection of morbidity parameters (diarrhoea and fever).	Not specified.	n=248 EBF infants aged 4-6 months. PG: n=50 TG-A: n=86 (56 anaemic, 30 non-anaemic). TG-B: n=112 (72 anaemic, 40 non-anaemic). Country Egypt	- Weight and length gain - Morbidity risk	Comments by the authors Basal anthropometric measures were adjusted for infant gestational age and parental height. Rate of increment of z-score values was adjusted to the basal anthropometric measures.	After 6 months of treatment, weight and length gain was better in TG compared with PG ($p<0.05$) and in malnourished vs nourished infants of TG ($p<0.05$). This effect was especially evident in anaemic malnourished infants ($p<0.01$). No effects were reported on head conference. After 12 months, the same result was obtained with the fading effect of anaemia ($p>0.05$ for anaemic vs non-anaemic). Morbidity risk was linked to immunologic background of infant; OR for diarrhoea and fever was higher in malnourished compared to well nourished ($p<0.05$) with no special impact for basal iron ($p>0.05$ for anaemic vs non-anaemic) or iron therapy ($p> 0.05$ for well-nourished non-anaemic treatment vs control). The authors concluded that oral iron supplementation resulted in better effects on growth velocity of breast fed infants especially those who were initially malnourished and anaemic or at least iron depleted, with less marked morbidity than in iron-replete infants.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Andersson et al (2011) <u>Funding</u> The Regional Scientific Council of Halland; the HASNA Foundation, Halmstad; HRH Crown; Princess Lovisa's Foundation for Child Care (Stockholm); the Framework of Positive Scientific Culture, Hospital of Halland, Halmstad. <u>DOI</u> None to declare.	RCT to compare the effects of delayed vs early umbilical cord clamping on infant iron status at 4 months of age in a European setting. Infants were randomly assigned to: - <u>group 1:</u> delayed umbilical cord clamping (≥180 seconds after delivery) - <u>group 2:</u> early clamping (≤10 seconds after delivery). <u>Follow-up</u> 4 months <u>To note</u> The study design precluded either the mother giving birth or the midwife performing the intervention being blinded. All other staff members (physicians, laboratory staff, etc.) were blinded.	Not specified.	n=382 singleton term infants born after a low risk pregnancy and recruited between April 2008 and May 2009 (400 initially recruited). <u>Group 1</u>: n = 168 <u>Group 2</u>: n = 166 <u>Country</u> Sweden	<u>Primary outcome</u> Haemoglobin and iron status at 4 months of age (measured as serum ferritin, transferrin saturation, soluble transferrin receptors, reticulocyte haemoglobin, mean cell volume, mean cell haemoglobin concentration). <u>Secondary outcomes</u> Neonatal morbidity: - anaemia - respiratory symptoms - polycythaemia - need for phototherapy.	<u>Comments by SACN</u> The authors did not comment on confounding factors. However, due to the study design (randomised and blind), the nature of the exposure (timing of cord clamping), and the primary outcome (based on blood analyses), the risk of confounding is low.	At 4 months, infants showed no significant differences in haemoglobin concentration between the groups. However, infants subjected to delayed cord clamping had 45% (95% CI 23 to 71%) higher mean ferritin concentration (117µg/L vs 81µg/L, p<0.001) and a lower prevalence of iron deficiency (1 [0.6%] vs 10 [5.7%], p =0.01, RR reduction 0.90). Secondary outcomes: delayed cord clamping group had lower prevalence of neonatal anaemia at 2 days of age (2 [1.2%] vs 10 [6.3%], p =0.02,). No significant differences between groups in postnatal respiratory symptoms, polycythaemia, or hyperbilirubinaemia requiring phototherapy. The authors concluded that delayed cord clamping, compared with early clamping, resulted in improved iron status and reduced prevalence of iron deficiency at 4 months of age, and reduced prevalence of neonatal anaemia, without demonstrable adverse effects.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Majumdar et al (2003) Funding Not specified. DOI Not specified.	Prospective, double-blind, placebo-controlled trial to study the effect of iron therapy on the growth of iron-replete and iron-deficient children, and to study the change in iron status in iron deficient children with iron therapy. Iron-replete children (group I) were randomly allocated to receive iron supplements 2 mg/kg/day (group IA) or placebo (group IB). Iron-deficient children (group II) were administered iron syrup 6 mg/kg/day. Follow-up 4 months	Iron-replete: haemoglobin >110g/l, serum ferritin >12µg/l and serum transferrin saturation >10%. Iron-deficient: haemoglobin 50-110g/l, serum ferritin <12µg/l and serum transferrin saturation <10%.	n=150 healthy singleton children aged 6-24 months and with birth weights >2500g (189 children initially recruited). Group IA: n=50 Group IB: n=50 Group II: n=50 Country India	- Growth parameters (weight, length and midarm circumference) (measured every 2 weeks) - Haemoglobin levels (measured every 6 weeks)	Comments by SACN The authors did not comment on confounding factors. Due to the study design (randomised and double-blind) and to the nature of the exposure (placebo vs supplement), the risk of confounding is low for the results for the iron-replete children. However, for the iron-deficient group the study design was neither randomised nor controlled and the findings are therefore liable to confounding.	Iron therapy produced a significant improvement of mean monthly weight gain (p<0.001) and linear growth (p<0.001) in the iron-deficient children. However, it significantly decreased the weight gain (p<0.001) and linear growth (p<0.001) of iron-replete children. The authors concluded that caution should therefore be exercised while supplementing iron to children with apparently normal growth and when the iron status of the child is not known.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
da Silva et al (2008) Funding Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP); Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). DOI None to declare.	A prospective randomised study to compare the effects of different prophylactic iron does on the growth and nutritional status of non-anaemic infants. Infants randomly allocated to 1 of the 3 groups to receive the following prophylactic doses of iron supplement (ferrous sulfate) during 16 weeks: - group 1: 1 mg/kg/day - group 2: 2 mg/kg/day - group 3: 25 mg/week. Food intake was evaluated by means of the 24-hour recall method, applied in the 2nd and 4th month of supplementation.	EBF time defined as the age during which the infant ingested only breast milk, without water or tea. Predominant breastfeeding time defined as the age during which the infant was predominantly fed breast milk, but was also given water, teas or fruit juice.	n=114 singleton term infants with birth weights >2500g, aged 5.0 to 6.9 months and with capillary hemoglobin ≥110 g/L at the time of the study (135 initially randomised). Group 1: n=39 Group 2: n=36 Group 3: n=39 Country Brazil	- Weight and length - Nutritional status, evaluated by comparing z-scores for weight/age, length/age and weight/length based on the WHO MGRS (2006b) references - Morbidity, collected during monthly visits	Comments by SACN The authors commented that there were many confounding factors which affect both the immunity and the iron nutritional status of populations. Statistical analyses were performed, including chi-square test, paired *t* test and analysis of variance. However, the authors did not discuss which variables were identified as potential confounders or whether the results were adjusted for confounders.	The groups showed similar nutritional status before supplementation. There were no differences in daily nutrient intake among groups. During the study, weight and length gain, and increments in anthropometric indices did not differ statistically among supplemented groups. The occurrence and duration of morbidity episodes did not differ statistically among groups. In general, improvements were observed in both weight/age and weight/length indices in the population under study, whereas length/age showed no differences before and after supplementation. The authors concluded that different prophylactic iron doses had no different effects on the growth and nutritional status of non-anaemic infants.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Yang et al (2009) Funding No funding source involved in this study. DOI None to declare.	Data analysis from 6 RCTs to determine which subgroups of fully breastfed infants were at higher risk of ID and IDA at 6 months of age. In all studies, venous blood was obtained from infants at 6 months (±1 week) to assess haemoglobin and iron status.	Fully breastfed: breast milk was the only source of milk. Consumption of small amounts of non-iron-fortified solid food was tolerated.	n=404 fully breastfed infants with a birth weight >2500g. Infants with elevated CRP were excluded. Countries Ghana (2 RCTs), Honduras (2 RCTs), Mexico (1 RCT), Sweden (1 RCT)	Prevalence of ID (ferritin <12µg/L) and IDA (ferritin <12µg/L and haemoglobin <105g/L).	Comments by the authors Several statistical methods were used to analyse the results and identified variables associated with the outcome. For the multiple linear regression and logistic regression analyses, study site was included in the first set of models as a covariate. In a second set of models, the study site variable was substituted by the estimated timing of cord clamping (these 2 variables could not be used in the same model because of multicollinearity). Plasma ferritin and haemoglobin concentrations were also adjusted for altitude in the Mexican study.	The percentages of infants with ID were 6% in Sweden, 17% in Mexico, 13–25% in Honduras, and 12–37% in Ghana. Overall, 19.7% were ID. The percentages with IDA were 2% in Sweden, 5% in Mexico, 5–11% in Honduras, and 8–16% in Ghana. Overall, 79% were IDA. With data pooled, the key predictors of ID (20%) were male sex (AOR 4.6; 95% CI 2.5 to 8.5) and birth weight 2500–2999 g (AOR 2.4; 95% CI 1.4 to 4.3). The predictors of IDA (8%) were male sex (AOR 7.6; 95% CI 2.5 to 23.0), birth weight of 2500–2999 g (AOR 3.4; 95% CI 1.5 to 7.5), and weight gain above the median since birth (AOR 3.4; 95% CI 1.3 to 8.6). The combination of birth weight 2500–2999 g or male sex had a sensitivity of 91% for identifying ID and of 97% for identifying IDA. The authors concluded that among fully breastfed infants with a birthweight >2500g, IDA is uncommon before 6 months, but male infants and those with a birth weight of 2500–2999 g are at higher risk of ID and IDA.

Table C.11 Eating and feeding of solid foods: experimental evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Barends et al (2013) Funding Wageningen University and Research Centre. DOI Not specified. To note The vegetable and fruits purees were provided by Danone Research.	Intervention study to investigate the effects of repeated exposure to either vegetables or fruit on an infant's vegetable and fruit acceptance during the first 18 days of CF. Infants randomised into 1 of the 4 treatment groups: - group 1: target vegetable: green beans - group 2: target vegetable: artichoke - group 3: target fruit: apple - group 4: target fruit plum. 19-day study - Infants fed their target food (pureed) on every other day during 18 consecutive days. - On the other 9 days, the vegetable groups received other vegetables and the fruit groups other fruits. - On day 19, the vegetable group consumed their first fruit puree and the fruit group consumed their first vegetable puree. Vegetables or fruits were given in the laboratory on days 1, 2, 17, 18 and 19, and at home on days 3-16.	At the start of the intervention, 53% were still breastfed, and 37% of them were exclusively breastfed. Of the formula fed infants, 19% had been breastfed for 12 weeks or more. Prior to the intervention, infants were fed rice flour porridge for 5 days to accustom them to eating solids.	n=101 healthy infants aged 4-7 months who had not commenced CF. Mean age at the start of the intervention was 5.4±0.8 months. Country the Netherlands	- Vegetable and fruit intake (g) over time - Liking ratings (9 point scale) provided by mothers for infants enjoyment of each food	Comments by the authors Differences in infants' and mothers' characteristics were compared between groups using one way analysis of variance for the continuous variables (infants' age, weight, breastfeeding duration, mothers' age, BMI and neophobia) and chi-square tests for the categorical variables (gender, milk feeding type and mothers' education). As participants were randomised, it is assumed that the random factors that may lead to variations in intake were equally divided over the groups. Large differences in intake were observed, especially in the vegetable groups. These differences were not correlated significantly with breastfeeding duration and the correlation with age at the start of CF was weak but not significant. As mothers decided when their child starts CF, age difference may have played a role. But since children with different age were equally divided between the groups this could not have influenced the results.	Mean vegetable intake in the vegetable groups increased significantly over time, from 24±28 g (mean ± SD) on days 1 and 2 to 45±44g on days 17 and 18 ($p<0.0001$). Fruit intake in the fruit groups increased significantly from 46±40 to 66±42g ($p<0.01$). Fruit intake was significantly higher than vegetable intake from the start ($p<0.01$). Repeated exposure to fruit had no effect on the vegetable intake and vice versa; on day 19, the fruit group's intake of green beans on first exposure was similar to the intake observed in the vegetables group on first exposure. The mean intake of green beans and plums increased significantly with repeated exposure ($p=0.016$ and $p<0.001$, respectively*)*. Mean apple intake was high from the start and although intake increased over time, this was not statistically significant. No significant increase was observed after repeated exposure to artichoke. Maternal liking ratings for a specific food showed a high and positive correlation with the food's measured intake ($p<0.001$). The authors concluded that even though vegetable intake was generally lower than fruit intake, repeated exposure to vegetables increased vegetable intake while repeated exposure to fruit increased fruit intake. Starting CF exclusively with vegetables could be effective to stimulate vegetable intake.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Barends et al (2014) Funding Wageningen University and Research Centre. DOI Not specified. To note The vegetable and fruits purees were provided by Danone Research.	Follow-up study of (Barends et al, 2013) to determine whether the effects of introducing exclusively vegetable purees in the early complementary feeding period persist at 12 and 23 months. Infants' daily consumption of vegetables and fruits at home was reported by their parents in a 3 day food diary. Intake of the same green beans and apple purees as those offered during the baseline study was measured in the laboratory at 12 and 23 months.	Not specified.	Of the 101 original parent-infant pairs, 84 participated at 12±1.4 months and 81 at the age of 23+1.0 months. Country the Netherlands	- Infants' intake of green beans and apple purees in the laboratory at 12 and 23 months of age. - Daily vegetable and fruit intake reported in a 3 day food diary. - Mothers' rating of how much their children liked each feeding using a 9 point scale, and rated how often their child ate the particular food at home and how much the child liked it.	Comments by the authors Characteristics of the children and mothers were compared between groups using t-tests for continuous variables, and chi-square tests for the categorical variables (see (Barends et al, 2013)). To adjust for daily energy intake, analysis of variance was conduct for daily vegetable intake, daily fruit intake, and daily macronutrient intake with (vegetable /fruit) groups as between-subject factors and daily energy intake as the covariate. Analyses were also run with other characteristics as covariates, but because this did not affect the outcomes, and these characteristics did not differ between groups, only the outcomes with daily energy intakes as covariates were presented.	At 12 months, children who had been introduced exclusively to vegetables during early CF had a significantly higher vegetable intake (by 38%, p=0.02) at home than children who had been introduced exclusively to fruit purees (75±43g, 54±29g, respectively). At 23 months, the difference in vegetable intake between these groups was no longer apparent (48±43g, 57±35 g, respectively). At 12 months, intake of green beans in the laboratory did not differ significantly between vegetable and fruit groups, and at 23 months had dropped significantly for both groups. Mean apple intake was relatively high and not significantly different between both the vegetable and fruit groups at 12 and 23 months. The authors concluded that starting CF exclusively with vegetables results in a higher daily vegetable consumption till at least 12 months of age.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Birch et al (1998) Funding Growing Healthy. DOI Not specified. To note Gerber products were purchased locally, and Growing Healthy products were provided by the manufacturer.	Experimental study to investigate the number of feedings required to increase intake of a new target food and whether exposure effects generalised to other foods. Infants were assigned to one of two feeding groups: - group 1: repeated exposure to the target fruit (banana) - group 2: repeated exposure to the target vegetable (peas). 21-day study - Pre-exposure period*:* infants fed the target food on day 1, and on the subsequent 4 days received the same, similar (2 foods) and different foods, in random order (5 days). - Repeated exposure: target food offered at the same meal each day (10 days). - Post-exposure*:* target food and the other foods presented again (6 days).	Definitions of 'other foods': - same*:* another manufacturer's preparation of the target food - similar*:* 2 foods presented from the target food category, that is, fruits or vegetables - different: food presented from a different food category.	n=39 infants (21 females, 18 males) aged between 16-31 weeks (mean age 24 weeks) who have been introduced only to cereal on a regular basis prior to the infants' participation. Group 1: n=17 Group 2: n=22 Country US	Intake used as a measure of acceptance: - intake of the target food measured (g) at pre-exposure, during the exposure series, and at post exposure - intake of the same, similar and different foods was measured during pre- and post-exposure.	Comments by the authors Potential confounders factors identified by the authors: - gender - milk feeding regime - target food brand - food type (fruit or vegetable) - time of test (pre-exposure, post-exposure). Analysis of variance was performed for these factors and no interactions were significant, except for: - a main effect of time of test for the target food intake ($p<0.01$), reflecting the significant increase in infants' intake of the target food from pre- to post-exposure - a main effect of gender, with boys simply consuming more food overall, at both pre- and post-exposure. With respect to a possible response bias in the mothers that may have influenced their infants' intake, it has to be noted that they were blind to the tested hypotheses.	Exposure to the target food significantly increased consumption of the target food from a mean of 35g pre-exposure to 72g at post-exposure ($p<0.01$). Much of the pre-post exposure increase in intake occurred very early in the sequence of feeding: intake of the target food increased significantly ($p<0.01$) between initial pre-test day (35g) to the first day of the exposure (61g). Intake continued to increase during the 10 day exposure period. Intake of different food was unchanged. Intakes of same and similar foods increased with target food exposure.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Blossfeld et al (2007) Funding The European Commission Quality of Life and Management of Living Resources (5th framework Program), the European Sensory Network. DOI Not specified.	Experimental study (part of a 20 months longitudinal study) to examine infants' preferences for different food textures and to identify the key factors influencing these preferences. At 12 months of age, infants were exposed to cooked carrots prepared in 2 different textures; pureed and chopped. Testing was conducted in a home-setting, during the child's regular mealtime, using a cross-over design. The infants were fed, in counterbalanced order, pureed carrots on one testing day and chopped carrots on another. Several questionnaires, including a food preference questionnaire, were also completed by mothers as part of the longitudinal study.	Mothers were asked about breast and formula feeding history (breastfeeding duration, number of breast/formula feeds per day) but definitions not provided in papers: - 11.4% breastfed - 72.9% formula fed - 4.3% both formula and breastfed - 11.4% fed with cow milk.	n=70 infants aged 48 to 57 weeks (mean age: 52.7$\pm$2 weeks); 39 males, 31 females. Country Ireland	Primary outcomes: - intake (g) - mothers' rating of the infants' enjoyment of the different textures. Secondary outcomes: - infants' dietary variety calculated from the food preference questionnaire - infants' pickiness and willingness to try new foods assessed by questionnaire - child's eating behaviour assessed by questionnaire.	Comments by the authors A number of statistical analysis were performed to identify significant association between outcome measures and behavioural and demographical variables such as: - demographic characteristics of the infants (weight, age, gender and the number of teeth) - breastfeeding history - infants' dietary variety - early experiences (age of introduction to CF, exposure to different textures, etc.) - child's eating behaviour, pickiness and willingness to try new foods.	Infants consumed significantly more pureed carrots than chopped (p<0.001) and mothers' ratings of their infant's enjoyment for this texture was significantly higher (p<0.01). A great variability in the consumption of chopped carrots was found within the infants. Familiarity with different textures, especially chopped foods, was the strongest predictor of intake and liking of chopped carrots. Furthermore, infants with higher dietary variety (p<0.05), more teeth (p<0.05) and a greater willingness to try new and unfamiliar foods (p<0.05) were more likely to consume more of the chopped carrots. Food pickiness (p<0.05) had a negative influence on the intake of, and liking for, chopped carrots. Food fussiness had a negative influence on the intake of both pureed and chopped carrots (p<0.05 and p<0.01, respectively) even though the influence on the consumption of chopped carrots was stronger.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Coulthard et al (2014) Funding The Feeding for Life Foundation. DOI Not specified. To note All baby foods used in this study have been home-prepared by a single technician (not provided by industry).	An 11 days experimental study to examine the effectiveness of different vegetable exposure methods (variety vs single taste) over a 9 day exposure period in 2 groups of infants (introduced to solids before or after 5.5 months). Half of the infants in each age group were randomly assigned to 1 of 2 conditions for the 9-day exposure period (days 2-10): 1) Single taste group (carrot puree every day) 2) Variety exposure group (parsnip, courgette or sweet potato with daily changes). A baseline measurement of the infants' acceptance of a vegetable (carrot) was taken prior to the exposure period (day 1). At the end of this period (day 11), infants' acceptance of a new vegetable (pea puree) was measured.	Not specified.	n=60 healthy term infant who had been EBF until introduction of complementary feeding (77 initially recruited). Mean age of introduction to CF: 5.18±0.84. Early group: n=29, mean age CF 4.50±0.43 months. Late group: n=31, mean age CF 5.91+0.03 months. Country UK	- Intake (g) - Infant's enjoyment of the food	Comments by the authors All the infants recruited were EBF, to control for the effects of breastfeeding on food acceptance. Randomisation was stratified by infants' age. Despite the differences in age of start of CF between the 2 groups, there was no significant difference in the SD scores of weight or length or BMI and was therefore not adjusted for. Analysis of variance was used to examine whether there were differences in vegetable consumption and demographic factors according to the two between-participants' factors; exposure group (single taste vs variety) and age of introduction group (early vs later). Results were not significant so equality of variance could be assumed. BMI SDS scores were adjusted for the exact age and gender of the infant, as well as their height.	There was no main effect of the age of introduction to solid foods or exposure type (single taste vs variety) on consumption of the baseline vegetable (carrot), and this was also true for consumption of the new vegetable (pea) following the 9 day exposure period. However, there was an interaction between age of introduction and exposure group on consumption of the new vegetable (pea), with infants who were introduced to solid foods later and who were exposed to a variety of vegetables consuming significantly more pea puree than those in the single taste group (45.64±6.63g vs 22.62±6.20g, p<0.05). There was no significant difference in pea consumption for infants of the early introduction group according to the exposure type (41.13±6.40g vs 35.77±6.88g, p>0.05). The authors concluded that there may be a sensitive period for the acceptance of tastes between the ages of 4 and 6 months.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Fildes et al (2015) Funding The Commission of the European Community (7th Framework Programme). DOI None to declare. To note The purees used in this study were donated by Danone Nutricia Research.	Multi-centre RCT to investigate the impact of advising parents to introduce a variety of single vegetables as first foods on infants' subsequent acceptance of a new, unfamiliar vegetable. Infants were randomised into 1 of the 2 groups: - intervention group (IG): Parents received guidance on introducing five vegetable (one per day) as first foods repeated over 15 days - control group (CG): Parents received country-specific 'usual care'. 1 month post-intervention: infant's consumption and liking of an unfamiliar vegetable (artichoke puree) was recorded. An unfamiliar fruit (peach puree) was then offered which acted as a control.	Feeding method assessed with the question 'Which feeding methods did you use in the first three months': 1) entirely breastfed 2) mostly breastfed with some bottle-feeding 3) equally breastfed and bottle-fed 4) mostly bottle-fed and some breastfeeding 5) almost entirely bottle-fed (only tried breastfeeding a few times) 6) entirely bottle-fed (never tried breastfeeding) 7) other.	n=139 term infants aged 4-6 months (146 initially randomised). IG: n=71 CG: n=68 Countries UK, Greece and Portugal	Primary outcome: - intake (g) of the novel vegetable. Secondary outcome: - intake (g) of the novel fruit (maternal and researcher rated) of an the novel vegetable and of the novel fruit.	Comments by authors Equal representation of breastfed and formula fed infants was ensured across the groups and within each country, using block randomisation. Outcomes measures were controlled for country.	Primary analyses (3 countries combined) - Mean age at introduction of CF were 5.3±0.6 and 5.2±0.6 months in IG and CG, respectively. - Mean intake of the unfamiliar vegetable puree was almost 10g higher among IG compared with CG (38.91g vs 29.84g) but no significant main effect of the intervention on vegetable intake, controlling for the effect of country, was found ($p = 0.064$). - Researchers rated infants in IG as liking the unfamiliar vegetable significantly more than the control infants ($p<0.032$). -No main effect of the intervention was found for either intake or liking ratings for fruit. Secondary analysis (by country) - A significant effect of the intervention on intake of the unfamiliar vegetable was found in the UK (32.8g vs 16.5g, $p=0.003$). UK infants in IG were also rated as liking the puree significantly more than control infants by both mothers ($p<0.001$) and researchers ($p<0.001$). - In either the Greek or Portuguese sample, no significant intervention effect on infants' intake (36.3g vs 23.6g, $p=0.197$ and 46.9g vs 45.1g, $p=0.871$, respectively) or liking ratings was observed . - No effect was seen in intake or liking ratings for the unfamiliar fruit in any of the three countries. The authors concluded that in countries where vegetables are not common first foods, advice on introducing a variety of vegetables early in CF may be beneficial for increasing vegetable acceptance.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Forestell & Mennella (2007) Funding The National Institutes of Health; the Canadian Institutes of Health. DOI Not specified.	A 12 day experimental study to evaluate the effects of breastfeeding and dietary experience on acceptance of a fruit (peaches) and a green vegetable (green beans) by 7 to 8 months old infants. Infants were randomly assigned to 1 of the 2 groups for the 8-day home exposure period (days 3-10): - group GB: green beans - group GB-P: green beans and then peaches. Acceptance of both foods was assessed before (days 1 and 2) and after (days 11 and 12) the home-exposure period.	Infant feeding history categorised as: 1) breastfed, never formula fed 2) formula fed, never breastfed 3) both breastfed and formula fed.	n=45 healthy term infants aged 4-8 months; 44% had been breastfed. Only infants who had been introduced to cereal but had very little experience with fruits and vegetables qualified for the study. At the start of the study, infants had been eating cereal for 6.7±1.6 weeks. Group GB: n=16 Group GB-P: n=29 Country US	- Amount of food consumed (grams and calories) - Duration of feeding (minutes) - Rate of feeding (grams/minute) - Frequency of distaste facial expressions made/spoonful offering during first 2 minutes of feeding - Observations made by trained facial expression rater, blinded to infants' group designation - Mothers' rating of their infants' enjoyment of the food	Comments by the authors There were no significant differences between the 2 treatment groups in any of the characteristics measured (infant's age, gender and feeding history; maternal age, BMI, multiparous, education level, food neophobia and general neophobia).	Initially, infants consumed more calories from peaches than from green beans. Infants who were breastfed for the first few months of life consumed significantly more peaches ($p<0.001$), for longer periods of time ($p<0.01$), at a faster rate ($p<0.03$) and displayed fewer negative facial responses overall during feeding ($p<0.05$), compared with formula fed infants. During the exposure period, the 2 groups ate similar amounts of green beans (GB: 68.6±7.6g, GB-P: 61.9±5.8g). Repeated exposure, with or without peaches, led to significant increases in infants' consumption of green beans (from 56.8±7.3g to 93.6±10.0g, $p<0.001$) and rate ($p<0.001$). There was no significant interaction between infants' feeding history and treatment group; both breastfed and formula fed infants increased acceptance of green beans after the home-exposure period. There was a significant interaction between the treatment group and the time for the types of facial expressions made during feeding of green beans ($p<0.04$): infants who experienced green beans with peaches displayed fewer facial expressions of distaste during feeding after the 8 days exposure compared with before. The authors concluded that breastfeeding confers an advantage in initial acceptance of a food, but only if mothers eat the food regularly. Once introduced to CF, infants who receive repeated dietary exposure to a food eat more of it and may learn to like its flavour. However, because infants innately display facial expressions of distaste in response to certain flavours, caregivers may hesitate to continue offering these foods.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Gerrish & Mennella (2001) Funding The National Institutes of Health; the Gerber Companies Foundation. DOI Not specified. To note The baby foods used in this study were supplied but the Gerber Products Company.	Experimental study to test the hypothesis that acceptance of new foods by formula fed infants could be facilitated by providing the infants with a variety of flavours at the beginning of the CF, and that infants who had previously been exposed to fruit would be less likely to reject new vegetables than would infants without that experience. 12-day study Infants randomised into 1 of the 3 groups for the 9-day home-exposure: - group 1: only carrots (target vegetable) - group 2: only potatoes - group 3: variety of vegetable that did not include carrots. On days 1 and 11 all infants were fed pureed carrots and on day 12 received pureed chicken.	Not specified.	n=48 healthy term formula fed infants. Mean age of introduction to CF: 4.0±0.1 months. Group 1: n=16, 4.6±0.2 months. Group 2: n=16, 4.5±0.2 months. Group 3: n=16, 4.8±0.1 months. Country US	- Intake (g) - Duration of feeding (minutes) - Rate of feeding (g/minute) - Mothers' rating of infants' enjoyment of the food	Comments by the authors To control for potential confounders due to flavour experiences in breast milk, only formula fed infants were recruited. Absolute differences possibly due to other factors were eliminated by calculating a proportional score for each of these indexes by dividing the infant’s response to carrots after the exposure period (day 11) by the response on day 1 plus that on day 11.	Infants in the carrot and variety groups, but not those in the potato group, ate significantly more carrots following the 9 day exposure period than at baseline (p=0.002 and p=0.003, respectively). Infants' acceptance of chicken was significantly affected by the type of vegetable consumed during the exposure period, with the variety group consuming more than the carrot group (p<0.03). Exposure to fruit did not hinder infants' acceptance of carrots during their first exposure to this vegetable (day 1). However, there were significant effects of the frequency of fruit consumption: infants who ate fruits daily consumed more carrots on day 1 than did infants who ate not fruit at all (p<0.007). The authors concluded that exposure to a variety of flavours enhances acceptance of novel foods in infants.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Hetherington et al (2015) Funding The Commission of the European Community (7th Framework Programme). DOI Not specified.	Intervention study to test the effects of providing vegetables step-by-step in milk and then in cereal during CF on intake and liking of pure vegetables, and to investigate the acceptability of this strategy among mothers. 35-day study Just before the start of CF, mothers were randomised into 1 of the 2 groups: - intervention group (IG): 12 daily exposures to vegetable puree added to milk (days 1-12), then 12 x 2 daily exposures to vegetable puree added to rice (days 13-24) - control group (CG): plain milk for days 1-12, then 12 x 2 daily exposures to plain milk and rice (days 13-24). Both groups then received 11 daily exposures to vegetable puree (day 25-35). Vegetables (carrots, green beans, spinach, broccoli) were rotated daily and parsnip as offered as a new vegetable on day 35. Follow-up at 6 and 18 months (infants aged 12 and 24 months old approximately).	Mothers were free to start the 35 day CF plan whenever they decided so that they retained control of when to start the CF process. Both groups were asked not to introduce any other new foods or flavours to infants during the study and that apart from the prescribed foods, they should only offer the infants their usual milk and water.	n=36 healthy term infant aged 4.83±0.57 on day 1 (40 initially randomised). IG: n=18 CG: n=18 Country UK	- Vegetable intake (g) - Duration of feeding (minutes) - Rate of feeding (g/minutes) during home-exposure (35-day food diary completed by the mother), in the laboratory (days 25, 26, 33, 34, 35) and at follow-up	Comments by the authors Maternal characteristics across the groups were very similar. The only significant difference detected was on the averaged State Trait Anxiety Inventory, showing that mothers randomised to the IG were more anxious in comparison to the CG ($p<0.05$). Analysis of variance showed no interaction between group and time, suggesting that it was not participation in the intervention which increased anxiety but that this group was more anxious overall. No significant differences in children's characteristics and eating behaviours across the two groups were observed.	In the laboratory sessions (days 25, 26, 33 and 34), vegetable intake (carrot and green bean) was significantly higher in the IG compared with the CG (82g vs 44g, $p<0.001$). Vegetable intake increased over time from the first to the second exposure (55g vs 71g, $p = 0.04$). The main effect of vegetable type was highly significant with more carrot eaten than green beans (83g vs 43g, $p<0.001$). Infants in the IG consumed the vegetable puree at a faster rate than the CG ($p<0.01$); rate of eating increased from the first to the second exposure ($p<0.001$); and carrot was eaten more rapidly than green bean ($p<0.01$). However, when a new vegetable (parsnip) was offered at the end of the intervention (day 35), no differences in intake were found (IG: 66±9g, CG: 49±12g). Intake data recorded at home showed that the pace of eating was significantly greater for IG than CG infants ($p<0.01$). Intake and liking of carrots were greater than green beans ($p<0.001$). However, at 6 and 18 months follow-up, vegetable (carrot>green beans) but not group differences were observed (to note: no group analysis done at 18 months due to low response rate). Maternal ratings of liking did not differ by time, but by vegetable ($p<0.001$), indicating that mothers reported that their infants liked carrots more than green bean. However, ratings of liking made by the investigators were significant for group ($p<0.05$), marginally significant for time ($p=0.07$), and for vegetables ($p<0.001$) (to note: investigators were not blind). The authors concluded that advice based on a step-by-step approach may be adopted by mothers and may then contribute in a simple and pragmatic way to enhance intake of vegetables.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Maier et al (2007a) <u>Funding</u> Nestle Nutrition. <u>DOI</u> Not specified. <u>To note</u> - 2 authors (AM and PL) are affiliated to the Nestle Research Center. - Nestle PTC Singen prepared all baby foods (except cauliflower and spinach) and carried out the sensory profile.	Experimental study to investigate whether repeated exposure to an initially disliked vegetable can improve consumption in the weeks following the introduction of solid foods. During the first 1-2 months of CF, mothers were asked to identify a vegetable puree that her infant disliked so much that she would not normally offer it again. Mothers were then asked to offer that vegetable on alternate days for a 16 day period and to offer a well-liked one (carrot puree) on the other days. <u>Follow-up</u> 9 months after this phase was completed (infants aged 15-19 months), mothers completed a food consumption and acceptance questionnaire including questions regarding intake of, and liking for, the test vegetable. <u>To note</u> It is a subset of (Maier et al, 2008).	Each mother was asked if she: 1) was still breastfeeding 2) had breastfed and now had stopped (if yes, since when) 3) had never breastfed her infant.	n=49 infants aged 7.0±0.9 months at the start of the study, of which: - 24 infants had been breastfed (168±70 days) - 25 infants had been formula fed (22 exclusively on formula and 3 breastfed for 2 weeks or less). n=48 at the 9 months follow-up. <u>Country</u> Germany	- Intake (g) - Acceptance, based on maternal rating of how much the infant had liked the vegetable measured at each meal.	<u>Comments by the authors</u> The following covariates were included in the covariates analysis: - type of milk feeding (breast or formula) - infant's age and gender - experience with a variety of vegetables early in the complementary feeding -maternal food neophobia, variety-seeking behaviour with respect to food, and anxiety traits.	Over the 8 exposure days to the initially disliked vegetable, mean intake increased linearly (r=0.99) from 39±29 to 174±54g (p<0.0001). Intake of the initially liked vegetable increased from 164±73 to 186±68g (p=0.03). Paired t-tests showed that over the first 7 exposures, intake of the initially disliked vegetable was significantly less than that of the initially liked vegetable after the same number of exposures. By the eighth exposure the difference was no longer significant. After 8 exposures, 71% of the infants were eating as much of the initially disliked vegetable as they ate of the liked one. There was no significant difference between breast and formula fed infants in intake of the initially liked vegetable. However, type of milk feeding did have an effect on intake of the initially disliked vegetable. On the first day of feeding the initially disliked food, breastfed infants consumed significantly more than formula fed infants (52.5±33g vs 26±18g, p=0.003). By the 7th exposure day, intakes were the same. At the 9 months follow-up, 63% infants were still eating and liking the initially disliked vegetable. The authors concluded that when a vegetable is initially disliked it is worth persisting in feeding it for at least eight subsequent meals.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Maier et al (2008) <u>Funding</u> Nestlé Nutrition; Nestec in form of salaries to AM and PL (Nestec is a subsidiary of Nestle). <u>DOI</u> AM and PL are Nestec employees. <u>To note</u> Nestle PTC Singer supplied the baby foods and carried out the sensory profiling.	Experimental study to investigate, in 2 different European regions, the effects of breast or formula feeding and experience with different levels of vegetable variety early in the CF period on new food acceptance in the 2 months following first introduction of solid foods. The study consisted of 3 phases. *Phase A (days 1-12)* Day 1: all infants fed carrot puree (lab). Days 2-10: infants split in 3 groups (home): - <u>group 1 (no change):</u> 1 vegetable (carrot) - <u>group 2 (low variety)</u>: 3 vegetables (artichoke, green beans, pumpkin) each given for 3 consecutive days - <u>group 3 (high variety):</u> 3 vegetables (same as Group 2) but with daily changes. Days 11: all infants fed carrot puree (lab). Days 12: all infants fed new veg, a zucchini-tomato puree (lab). *Phase B (days 13-23)* Days 13-22: all infants receive on alternate days the new vegetable (zucchini-tomato) and	The 2 levels of milk feeding were: - <u>formula-fed</u>: breastfed <15 days - <u>breastfed</u>: breastfed for >30 days.	n=147 healthy infants who had not begun vegetables; mean age at the start of the study: 5.2<u>+</u>0.1 months. Dijon: n=72; 45 of them breastfed at least 1 month (mean 3.9<u>+</u>0.2 months). Aalen: n=75; 38 of them breastfed at least 1 month (mean 4.6<u>+</u>0.3 months). <u>Countries</u> Germany (Aalen) and France (Dijon)	Indicators of new food acceptance in the lab were: 1) the quantities of the new foods eaten (g) 2) liking ratings - the mother and observer rated how much they thought the infant had liked the meal using a 9 point scale. During the period between phases B and C, mothers completed food diaries to evaluate the variety of foods offered to infants.	<u>Comments by the authors</u> The 3 experimental groups were, as far as possible, balanced in terms of breast and formula feeding, sex and maternal parity. Statistical analysis was performed for the following covariates: - maternal characteristics (such as age, BMI, parity, neophobia, anxiety traits) - infants' characteristics (such as sex, age, weight, height, breastfeeding duration) - infants' temperament (difficult, unadaptable, unresponsive, unpredictable) - region.	On day 1, intake of carrot did not differ significantly between breast and formula fed infants, or among variety groups. Breastfeeding was associated with higher intakes of the 4 new foods (zucchini-tomato, peas, meat and fish) (p<0.0001). Type of variety experience had a significant effect (p<0.0001) with the high vegetable variety group (group C10) producing the greatest increase in intake of new food. Both breastfeeding and high variety were associated with higher liking scores as rated by mothers (p=0.005 and p<0.0001, respectively) and observers (p=0.008 and p<0.0001, respectively). A significant interaction (p<0.0009) was observed between type of milk feeding and type of variety experience, with the combination of breastfeeding and high variety being associated with the greatest intake of new foods. The effect was still detectable up to 2 months later at the end of the intervention period.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
	carrots (home). Day 23: all infants fed new veg, a pea puree (lab). *Phase C (14 days)* (each mother decided when to start this new phase) Day 1C: all infants fed meat puree (lab). Days 2C-12C: all infants receive on alternate days the meat puree and vegetable puree of mother's choice (home). Day 13C: all infants fed meat puree (lab). Day 14C: all infants fed new food, fish puree (lab). Follow-up 2 months					

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Maier-Noth et al (2016) Funding Nestlé Nutrition; Nestlé Research Center in form of salaries to AM and PL. DOI Authors AM and PL were employed by Nestlé Research Center when the studies were designed and executed. There are no patents, products in development or marketed products to declare.	Follow-up study of (Maier et al, 2008) and (Maier et al, 2007a) to examine the longer term effects of 3 contexts of exposure to food related stimuli: breastfeeding, experiencing a variety of vegetables early in the CF and repeated exposure to an initially disliked vegetable. The objective was to evaluate the persistence of increased acceptance of vegetables at about 15 months, 3 and 6 years of age. Experimental groups: see (Maier et al, 2007a; Maier et al, 2008). Follow-up - Follow-up 1 (15 months) and 2 (3 years): questionnaire (list of vegetables, mothers to note if child eat and/or like the item). - Follow-up 3 (6 years): questionnaire and experimental (2 laboratory sessions in which children are offered 1 new, 4 liked and the initially disliked vegetable).	See (Maier et al, 2008).	n=147 healthy infants (Dijon n=72; Aalen n=75). Mean age at the start of the study: 5.2±0.1 months. Follow-up 1: n=107 (73%) (14.6±0.2 months). Follow-up 2: n=96 (65%) (3.2±0.1 years). Follow-up 3: n=75 (51%) (6.0±0.04 years). At each follow-up, the proportions of infants in each of the groups were similar to those in the initial study. Countries Germany (Aalen) and France (Dijon)	Vegetable acceptance assessed by: - mothers (questionnaires) at follow-up 1 and 2 - the child (7-point hedonic scale), intake (g) and willingness to taste (number of vegetables tasted) at follow-up 3 .	Comments by the authors Analyses of variance performed to determine the effect on the vegetable acceptance of: - the type of milk (breast vs formula) - the early variety experience (no, low, high, see (Maier et al, 2008)) - the region - the interaction between type of milk and variety.	Repeated exposure The follow-up results showed that repeated exposure to an initially disliked vegetable early in the CF, which increased its acceptance in the short term (see (Maier et al, 2007a)) was also associated with continued acceptance in the long term (73% at 3 years and 57% at 6 years). Breastfeeding and early variety exposure: Follow-up 1 (15 months) Breastfed children were reported to like more vegetables than did formula fed children (15.0 ± 0.6 vs 13.2 ± 0.7; p=0.05). There was no effect of the early variety experience (p=0.20). Follow-up 2 (3 years) The number of vegetables eaten and liked did not differ by type of milk feeding (p=0.25) or by the early variety experience (p=0.0635). Follow-up 3 (6 years) The child-reported liking for the new and for the familiar vegetables showed a significant early variety effect (p=0.0002 and p=0.03 respectively) but no effects of type of milk feeding (p=0.92 and p=0.47 respectively). The mean intake of the 2 new vegetables showed significant main effects of the type of milk feeding (9.0 ± 1.0g vs 5.4 ± 1.4g; p=0.04) and of early variety experience (high: 14.1 ± 1.5g; low: 4.3 ± 1.5g; low: 3.2 ± 1.4g; p<0.0001). For mean consumption of the familiar vegetables, there were significant main effects of early variety experience (p=0.03) but not of type of milk feeding. For willingness to taste, there were significant main effects of type of milk feeding (p=0.004) and of early variety experience (p=0.0001). The authors concluded that breastfeeding and early experiences with vegetable variety during CF are effective in promoting acceptance of new vegetables in childhood.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella & Beauchamp (1996) Funding The National Institute on Deafness and Other Communication Disorders; Monell Institutional Funds. DOI Not specified. To note Nutramigen was supplied by the Nutritional Division of Mead Johnson.	Experimental cross-sectional study to investigate the age-related changes in the acceptance of the PHF Nutramigen and to determine whether the infants' response to a novel formula was related to their mothers' willingness to try new foods. Two groups of mother-infant pairs were recruited: - group 1: tested when infants were <2 months of age and retested at 7 to 8 months. - group 2: only tested at 7 to 8 months. On 2 consecutive testing days, half of the infants in each group were fed their familiar brand of milk- or soy-based formula on day 1 and Nutramigen on day 2; the order was reversed for the remaining half. At the end of each feed, the mother was given a bottle of the regular brand of formula to feed her infant.	All infants of group 1 were exclusively formula fed when tested at 1-2 months (except 1 infant that was also fed juice and 2 were occasionally fed cereal). All infants tested at 7-8 months were fed juice, cereal, fruits and vegetables in addition to a soy- or milk-based formula. A few were also fed meat.	n=28 healthy formula fed infants who had never experienced any type of PHF. Group 1: n=14 1st session mean age: 47.9±6.0 days; 2nd session mean age: 217.8±6.2 days. Group 2: n=14 mean age: 235.0±6.9 days. Country US	- Intake (ml) and time spent feeding (min) - Mothers' attitudes about food and eating habits (derived from questionnaires measuring variety seeking tendency, food neophobia, propensity to approach/avoid new foods).	Comments by the authors A proportional score [Nutramigen/(Nutramigen + regular formula)] was calculated for each parameter to eliminate absolute differences in response that may be due to individual differences and maturation of sucking ability.	The 1st comparison (group 1 <2 months vs group 2 7-8 months) showed that there was a significant effect of age on the infants' intake of Nutramigen relative to regular formula (p=0.00004). Post hoc t tests found that although both groups of infants consumed less Nutramigen, the older infants rejected it more (p=0.000002) than did the younger infants (p=0.038). The 2nd comparison of group 1 infants at 2 different ages found a significant effect on the relative amount of Nutramigen consumed (p=0.00022). Older infants consumed significantly less Nutramigen (p=0.0004) and spent less time feeding (p=0.000195). A comparison of the 2 groups of older infants found that a single exposure to Nutramigen did not alter the infants' response to Nutramigen (p=0.65) or duration of the feed (p=0.81). When mothers offered their infants their regular formula approximately 10 minutes after the formal test, the amount consumed by the younger infants did not differ on the 2 testing days (regular vs Nutramigen test days; p=0.16) implying that these younger infants satiated equally on the 2 test days. In contrast, the older infants consumed significantly more of their regular formula on the day they were tested with Nutramigen (Group 1 p= 0.01; Group 2 p= 0.001). There was a significant correlation between the mothers' eating habits and the younger infants (<2 months) response to Nutramigen. Mothers who exhibited a greater willingness to consume new foods (p=0.003) or less food neophobia (p=0.04) had infants who consumed relatively more Nutramigen.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella & Beauchamp (1998) Funding The Ross Products Division of Abbott Laboratories; Monell Institutional Funds. DOI Not specified. To note Alimentum is produced by Ross Products Division. Abbot Laboratories.	Experimental cross-sectional study to investigate whether a sweeter and less sour PHF than Nutramigen that still retain a distinct, unpalatable flavour would engender the same degree of rejection and, if yes, to determine at which age the rejection first becomes apparent. On 2 consecutive days, formula fed infants received their normal brand of cows' milk or soya based formula at 1 testing session and Alimentum during the other. Mothers were unaware of the order of testing which was counterbalanced between subjects.	Not specified.	n=56 formula fed infants aged 2-40 weeks who had no prior exposure to PHF. Country US	Infants proportional intake of PHF relative to total consumption [hydrolysate/(hydrolysate + regular formula] was plotted against infant's age in weeks.	Comments by SACN The authors did not comment on confounding factors. The results were presented as a proportional response [hydrolysate/(hydrolysate + regular formula].	There was a significant correlation between the infants' age and their acceptance of Alimentum relative to their regular brand of cows' milk or soy based formula (p<0.0001). Rejection of the PHF first became apparent in infants between the ages of 17 and 24 weeks (p=0.003). All infants in this study were receiving solids foods at 4 months of age, however, whether infants ≤4 months were receiving solids or were exclusively formula fed did not appear to alter acceptance of Alimentum. A comparison of these data with the findings from (Mennella & Beauchamp, 1996) revealed that although adults judged the overall flavour profile of Alimentum to be sweeter and less sour than Nutramigen, the infants <2 months of age accepted, and those 7 to 8 months of age rejected, the hydrolysates to a similar degree.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella et al (2004) Funding The National Institutes of Health; The Annenberg Foundation. DOI Not specified. To note Enfamil and Nutramigen were supplied by the Nutritional Division of Mead Johnson.	Longitudinal experimental study to investigate the impact of early experience with infant formulas on subsequent preferences. Infants were randomised into 1 of 4 groups by the 2nd week of life (7 months exposure): - group 1: milk-based formula (Enfamil) for 7 months (Control group) - group 2: Nutramigen for 7 months - group 3: Nutramigen for 3 months and then Enfamil for the remaining 4 months - group 4: 1st 2 months Enfamil, then 3 months Nutramigen, followed by 2 months Enfamil. After 7 months of exposure (when infants aged 7.5 months), infants were videotaped on 3 separate days while feeding, in counterbalanced order, Enfamil, Nutramigen, and Alimentum (a PHF to which no infants had been exposed).	Not specified.	n=53 formula fed, term newborns. Group 1: n=14 Group 2: n=12 Group 3: n=15 Group 4: n=12 Country US	- Intake (ml) and duration of formula feeding (minutes) - Frequency of negative facial expressions during the first 2 minutes of feeding - Mothers' judgements of infants' acceptance/ enjoyment of the formulas during each of the 3 test sessions	Comments by the authors There were no significant differences among the 4 groups in the ages of mothers and infants, the number of females/males, or the infants' weights and lengths at the start of the study. There also were no significant group differences for any of the various measures of infant temperament, the age at which infants were introduced to solid foods, or maternal measures of food and general neophobia (all p>0.10).	There were no significant differences between the groups in the infants' acceptance of the formula they were fed during the 7 months exposure period (p=0.44). There was a significant interaction between groups on the infants' acceptance of the 3 types of formulae when tested at the end of the exposure period (p<0.00005). - The 3 groups of infants exposed to Nutramigen consumed significantly more and spent more time feeding on Nutramigen and Alimentum compared to those infants who were fed only Enfamil during the 1st 7 months of life (p<0.05). - However, group 2 had the greatest acceptance of the Nutramigen compared to the other 3 groups. There was a significant effect of group on the number of negative facial expressions displayed while feeding the formulas (p<0.5); infants in Groups 2, 3 and 4 made significantly fewer negative facial responses while ingesting Nutramigen when compared to infants only exposed to Enfamil (Group 1). The authors concluded that for each of the 4 interrelated measures of behaviour (intake, duration of formula feeding, facial expressions, and mothers' judgments of infant acceptance), previous exposure to Nutramigen significantly enhanced subsequent acceptance of both Nutramigen and Alimentum. Seven months of exposure led to greater acceptance than did 3 months.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella et al (2008) <u>Funding</u> The National Institutes of Health (NIH); the Institut National de la Recherche Agronomique (INRA). <u>DOI</u> Not specified. <u>To note</u> Infant foods were supplied by Gerber Products Company.	2 experimental studies to investigate the effects of an 8-day exposure to a particular food or a variety of foods between and/or within meals on the acceptance of fruit and vegetables in infants. Mother-infants pairs were randomised to one of the 2 studies and within each study were randomised into 1 of the experimental groups. Each study consists of an 8-day home exposure with 2 lab exposures before (days 1 and 2) and after (days 11and 12). *Study 1 (fruits)* Home exposure: - <u>group P:</u> only pear - <u>group FV</u>**:** variety of fruits with daily changes (peach, prune and apple). Lab to evaluate acceptance of: - days 1 and 11: pears - days 2 and 12: green beans. *Study 2 (vegetables)* Home exposure: - <u>group GB:</u> only green bean - <u>group BM</u> (between-meal variety): fed only 1 vegetable each day (green and orange vegetables	<u>EBF</u>: exclusively breastfed until they started introducing cereals. <u>Exclusively formula fed</u> (EFF): never experienced breastmilk. <u>Breast and formula fed</u> (BFF): the remaining.	n=74 healthy term infants aged 4-9 months who had at least 2 weeks experience eating cereal or fruit from a spoon and little experience with the target fruits and vegetables. *Study 1 (fruits):* - <u>group P</u>: n=20, 6.7$\underline{+}$0.2 months (6 EBF, 3 EFF, 11 BFF) - <u>group FV</u>: n=19, 6.7+0.2 months (3 EBF, 3 EFF, 13 BFF). *Study 2 (vegetables):* - <u>group GB</u>: n=11, 6.6+0.4 months (1 EBF, 2 EFF, 8 BFF) - <u>group BM</u>: n=12, 6.3+0.4 months (3 EBF, 0 EFF, 9 BFF) - <u>group BM-WM</u>: n=12, 6.4+0.4 months (2 EBF, 3 EFF, 7 BFF). <u>Country</u> US	- Total intake (g) - Caloric intake (kcal) - Length (min) of each feed - Rate of feeding (g/min) - Mothers' rating of their infants' enjoyment of foods	<u>Comments by the authors</u> To minimise potential confounds due to different levels of satiation, the 4 test sessions occurred at the same time of day as the home exposure meals and at least 1 hour after they were last formula or breastfeed. For the fruit study, there were no significant differences between the experimental groups in any of the measures taken with the exception that mothers in the group FV rated their infants higher on approachability when compared to the infants in the group P. For the vegetable study, there were no significant differences among experimental groups for any of the measures.	*Study 1* - The 2 groups did not differ in their initial acceptance of pear (day 1) or green beans (day 2) or their average daily intake during home exposure. - Following the 8-day home exposure, a significant increase in pear consumption was observed for both groups (1.5±0.1 times more for group P and 1.5±0.2 for group FV, $p<0.05$) but this was not generalizable to green beans. *Study 2* - The 3 groups did not differ in their initial acceptance of green beans (day 1) or carrot and spinach (day 2) or their average daily intake during home exposure. - After the 8-day home exposure, infants in the BM-WM group consumed significantly more green beans (p=0.0002), and carrots and spinach (p=0.03). For the 2 other groups, there was a tendency to eat more green beans (GB group: p = 0.07, BM group: p = 0.08) but not for carrot and spinach. The authors concluded that not only can infants clearly discriminate flavours but that repeated opportunities to taste a particular or a variety of foods may promote willingness to eat fruits and vegetables.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
	alternated daily) - group BM-WM (between-meal and within-meal variety): fed 2 vegetables each day (1 green, 1 orange). Lab to evaluate acceptance of: - days 1 and 11: green beans - days 2 and 12: alternative spoonful of carrots and spinach.					

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella et al (2011) Funding The Eunice Kennedy Shriver; National Institute of Child Health and Human Development. DOI None to declare. To note The formulas used were provided by Mead Johnson Nutritionals.	A randomised clinical trial aiming to characterise the timing and duration of a sensitive period in human flavour learning in early infancy (<4 months), using response to PHF relative to cow's milk based formula (CMF) as a model system. Infants were randomised into 1 of 6 groups at 0.5 months (7 months exposure): - group 1: CMF for 7 months (control group) - group 2: PHF for 7 months (control group) - group 3: PHF for 1 month from 1.5 month of age (and CMF otherwise) - group 4: PHF for 3 months from 1.5 month of age (and CMF otherwise) - group 5: PHF for 1 month starting at 2.5 months (and CMF otherwise) - group 6: PHF for 1 month starting at 3.5 months (and CMF otherwise). At the beginning of each 1 month cycle a brief taste test was conducted. Acceptance of PHF on one day and CMF on another day was tested when infants were 7.5 months old (that is, at the end of the 7 months exposure period).	Infants included in the study were exclusively or predominantly formula fed (that is, can be breastfed once or twice a day for the first months of life).	n=69 formula fed, healthy full term newborns (79 initially enrolled). Group 1: n=13 Group 2: n=12 Group 3: n=11 Group 4: n=11 Group 5: n=11 Group 6: n=11 Country US	Monthly assessment of intake (ml) and maternal ratings of infants' enjoyment of the formula of the past month and of the formula of the subsequent month. At the end of the study: - intake (ml) - maternal ratings of infants' enjoyment of the formula - frequency of distaste/rejection behaviours during the first 2 minutes of feeding.	Comments by the authors To eliminate absolute differences in responses that might be due to individual differences such as infant size, a proportional score [PHF/(PHF+CMF)] score was calculated for each measure.	Acceptance at monthly visits for Groups 3, 5, 6 (1 month exposure) - Infants in Groups 3, 5 and 6 consumed significantly less PHF than CMF at the beginning of the 1st month of exposure (p<0.0001). - Infants in Group 6 consumed significantly less PHF during their initial taste test (3.5 months) than did infants in Groups 3 and 5 (1.5 month). - When compared with PHF intake at the beginning of the month, PHF intake significantly increased at the end of 1 month of exposure for each of the 3 groups (p<0.0001) and was nearly as great as CMF acceptance. Acceptance at 7.5 months: duration and PHF acceptance (groups 1, 2, 3, 4) - There were significant differences based on the duration of PHF exposure in relative intake (p<0.001), maternal perceptions (p<0.001), and rejection/distaste behaviours (p=0.002). - 3 months exposure led to similar acceptance to that at 1 month exposure (Groups 4 and 3) Although PHF acceptance in these 2 groups was greater than that of the CMF control group (Group 1), it was less than the group exposed to PHF for 7 months (Group 2). Acceptance at 7.5 months: timing and PHF acceptance (groups 3, 5, 6) - Significant differences were observed based on the timing of exposure in relative intake (p=0.02), maternal perceptions (p=0.01) and rejection/distaste behaviours (p=0.04). Infants who started feeding PHF before 3.5 months consumed relatively more PHF than did the CMF control group. However, if feeding PHF began when infants were 3.5 months old, intake of PHF was no different than the CMF control group.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Mennella & Castor (2012) Funding The Eunice Kennedy Shriver National; Institute of Child Health and Human Development. DOI None to declare. To note The formulas were provided by Mead Johnson Nutritionals.	RCT to determine the effects of duration of exposure to extensively protein hydrolysed formula (ePHF) before 4 months on the acceptance of a food (broth) containing an exemplar of the flavour during complementary feeding. Infants were randomised into 1 of the 4 groups at 0.5 months (8 months exposure): - group 1: ePHF for 1 month (and CMF otherwise) - group 2: ePHF for 3 months (and CMF otherwise) - group 3: ePHF for 8 months - group 4: CMF for 8 months (control group). Infants' acceptance of a savoury and plain broth were measured at 8.5 months of age.	Not specified.	n=47 formula fed infants (57 initially enrolled). Country US	- Total intake (g) and rate (g/min) of each feed - Mothers' rating of their infant's enjoyment of the broth during each test session	Comments by the authors Weight-for-height z-scores were covaried for all analyses to account for effects of body weight. To eliminate absolute differences in responses that might be due to individual differences, a relative score was calculated for each infant and each measure by dividing infant response to savoury broth by responses to savoury broth plus plain broth.	No significant effects of the experimental group on relative intake (p=0.007) and rate of feeding (p=0.01) was found. Infants randomised to feed ePHF for 3 or 8 months (group 2 and 3, respectively) ate more of the savoury broth (p=0.002 and 0.005, respectively), and consumed it at a faster rate relative to the plain broth (p=0.004 and 0.03, respectively), than the CMF control group (group 4). The 1 month ePHF experimental group (group 1) and the control group (group 4) did not differ, and maternal ratings of infant enjoyment of the savoury relative to plain broth showed no significant group effects, suggesting mothers were unaware of the differences in acceptance. The authors concluded that the duration of flavour exposure affects infants' earliest responses to foods: a 3-month exposure to this formula shifted the hedonic tone for savoury flavour.
Savage et al (2016)	See Table C.5					

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Sullivan & Birch (1994) Funding Gerber Products Company National Institutes for Health. DOI Not specified.	Longitudinal randomised study to examine the effects of dietary experience and milk feeding regimen on acceptance of their first vegetable by 4-6 months old infants. Infants were randomised into 1 of the 4 treatment groups to receive on 10 occasions for a 10 day period: - group 1: salted peas - group 2: salted green beans - group 3: unsalted peas - group 4: unsalted green beans. Intake of salted and unsalted versions was also measured before, immediately after and 1 week after completion of the exposure period.	Not specified.	n=36 healthy infants age 17-27 weeks (mean 22 weeks) who had just begun being fed solid foods (cereals or cereals and fruits). 19 infants were breastfed (of which 10 received some supplementary formula); 17 infants were exclusively formula fed. Infants received cereals as a first solid food at a mean age of 15 weeks. Country US	- Intake of the vegetable consumed during the 10 day exposure period - Intake of salted and unsalted versions before and after exposure - Adult ratings of the infants' behavioural responses	Comments by the authors As a control for other factors that could contribute to increases intake (such as. growth or improved skills), infants were fed another solid food at the beginning and end of the study. Infants' initial intake of both salted and unsalted versions of one vegetable was also measured. To control for potential differences between boys and girls, the groups were balanced for sex.	After repeated exposure, infants increased their intake of the new food ($p<0.001$), and increased intake was observed regardless of whether the infants were exposed to salted or unsalted versions of the vegetable. There was no clear evidence that the presence of salt enhanced infants' acceptance. Adult ratings of the infants' responses during feeding were related to infants' intake: the more infants consumed during a feeding, the higher the adults rated infants' liking. Adults' ratings of infants' nonverbal responses were positively correlated with infants' intake ($p<0.05$). There was a significant increase in ratings for both vegetables, regardless of whether they were salted or unsalted. Breastfed infants showed greater increases in intake of the vegetable following exposure ($p<0.05$) and had an overall greater level of intake than formula fed infants ($p<0.01$). The authors concluded that infants increase their acceptance of a novel food after repeated dietary exposure to that food and that breastfeeding may facilitate the acceptance of solid foods.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Taylor et al (2017) Funding Lottery Health Research; Meat & Livestock Australia; Karitane Products Society; Perpetual Trustees; New Zealand Federation of Women's Institutes; the University of Otago. DOI None to declare. To note Kind contributions received from Heinz Watties, Ltd.	RCT to determine whether a baby-led approach to complementary feeding results in a lower BMI than traditional spoon-feeding. Women randomised to: 1) the control condition 2) the BLISS intervention. The BLISS intervention included lactation consultant support (≥5 contacts) to extend EBF and delay introduction of CF until 6 months as well as 3 personalised face-to-face contacts at 5.5, 7.0 and 9.0 months. Adherence to BLW was measured by questionnaire at 6, 7, 8, 9, 12 and 24 months and brief feeding questionnaires were administered at 2, 4, 6, 7, 8, 9, 12, and 24 months. Energy intake at 7, 12, and 24 months was determined from 3-day weighed diet records collected on randomly assigned days. All outcomes were collected by staff blinded to group randomization. Trial duration: 2 years	EBF: no other liquids or solids than breastmilk since birth. BLW: the infant feeds himself or herself family foods with the family, ideally while breastfeeding on demand. This trial used a slightly modified form of BLW to minimise the risk of choking and iron deficiency (Daniels et al, 2015). Satiety responsiveness : eating appropriately in response to appetite. Food responsiveness: eating in response to environmental food cues rather than hunger. Enjoyment of food: having a positive attitude to food. Food fussiness: rejection of new and familiar foods.	n=206 women (mean age 31.3 years) recruited in late pregnancy from December 2012 to March 2014 as part of a community intervention. 85 of them (41.3%) where first time mothers. Control: n= 101 (n=84 at 12 months; n=78 at 24 months). BLISS: n=105 (n=94 at 12 months; n=88 at 24 months). Country New Zealand (maternity hospital in Dunedin)	Primary outcome: - BMI z-score at 12 and 24 months. Secondary outcomes (assessed by questionnaires at 12 and 24m) include energy self-regulation and eating behaviours assessed with questionnaires at 6, 12 and 24 months and energy intake assessed with 3 -day weighted diet records at 7, 12 and 24 months.	Comments by the authors The randomised design of this study should remove group differences in known and unknown confounders (randomisation was stratified for parity and education). All outcomes were adjusted for infant age, infant sex, and stratification variables (parity [first child vs subsequent child] and maternal educational attainment [tertiary vs non tertiary]). Regression analysis was used to compare the groups for energy self-regulation and eating behaviours, adjusting for birth weight, infant age and sex, and the stratification variables. Energy intake was analysed similarly using quantile (median) regression.	The mean (SD**)** BMI z-score was not significantly different at 12 months (control group, 0.20 [0.89]; BLISS group, 0.44 [1.13]; adjusted difference 0.21; 95% CI −0.07 to 0.48) or at 24 months (control group, 0.24 [1.01]; BLISS group, 0.39 [1.04]; adjusted difference 0.16; 95% CI −0.13 to 0.45). Prevalence of overweight did not differ significantly between the 2 groups at 12 months or 24 months (6.4% in the control group vs 10.3% in the BLISS group [RR 1.8; 95% CI 0.6 to 5.7]). No significant differences were observed in energy intake at any point. Lower satiety responsiveness was observed in BLISS infants at 24 months but not at 12 months. Parents of BLISS infants reported less food fussiness at 12 months but not at 24 months. Parents of BLISS infants were also more likely to report a greater enjoyment of food at 12 months and 24 months and BLISS infants made significantly more meal decisions than control infants at 12 months. BLISS infants were EBF for longer (21.7 weeks; 95% CI 13.0 to 23.8 weeks) compared with control infants (17.3 weeks; 95% CI 6.0 to 21.7 weeks; p=0.002), and 64.6% met the WHO guideline for delaying solid foods until 6m compared with 18.1% of control infants. Considerable differences were also observed in the age when infants first fed themselves: BLISS infants were more likely to feed themselves most or all of their food than control infants at every age.

Table C.12 Eating and feeding of solid foods: observational evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Coulthard et al (2009) Funding The UK Medical Research Council; the Wellcome Trust; the University of Bristol. DOI None to declare.	Study to follow up children from the ALSPAC who had been introduced to lumpy solids (chewy foods) at different ages and to assess their dietary intake and feeding difficulties at 7 years of age. Data were collected from self-report questionnaires completed by the mother at 6 months, 15 months and 7 years of age. Each questionnaire contained a range of questions with a section asking about feeding the child, including frequency of eating a list of foods and drinks as well as feeding difficulties. To note This is a follow-up study of (Northstone et al, 2001).	CF describes the progression of infants from an entirely milk-based diet to one which is based on a variety of solid foods. Age of introduction to lumpy foods assessed at 15 months by the question 'Babies first solid meals are usually a puree. When did your child first start having meals with lumps in? Give age started in months'.	n=7,821 singleton children aged 7 years whose mothers were recruited when pregnant as part of the ALSPAC (83.6% of the initial 9,360 mothers returned the 7 years questionnaire). Most of these children were introduced to CF between 3 and 4 months, as recommended at that time. Children divided into 3 groups based on the age at which lumpy solids were introduced: 1) <6 months (n=946; 12.1%) 2) 6 to 9 months (n=5,457; 69.8%) 3) >10 months (n=1,418; 18.1%). Country UK	Primary outcome: -age of introduction of lumpy foods, assessed by questionnaire at 15 months. Secondary outcomes: - feeding difficulties, assessed by questionnaire at 7 years - dietary range, assessed by questionnaire at 7 years.	Comments by authors Statistical analysis performed to adjust results for the following potential confounding variables: - sex of infant - mother's age - maternal education - whether mother had a partner - number of siblings - housing tenure - financial difficulties - overcrowding - age at which the child's first tooth erupted - duration of breastfeeding - feeding difficulties at 6 months - child fed with home-cooked or prepared food - child fed with raw fruits or vegetables.	At 7 years of age, children introduced to lumps after 10 months ate less of many of the food groups at 7 years, including all 10 categories of fruit and vegetables, than those introduced to lumpy food between 6 to 9 months (p<0.05-0.001). This group were also reported as having significantly more feeding problems at 7 years old (p<0.05-0.001). These included not eating sufficient amounts, refusal to eat the right amount and being choosy with food. The authors concluded that there is a critical period for exposure to different textures during CF period. Early exposure, not only to a variety of tastes but also of textures, is important in the long-term development of child food preferences and feeding skills. Early exposure to fruit and vegetables is particularly important.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Lange et al (2013) Funding The Regional Council of Burgundy; the IFR92; the PRNH-INRA-INSERM; the French National Research Agency (ANR); Blédina, Nestlé, Symrise, Cedus and Valrhona. DOI Not specified.	Longitudinal survey of infants' and young children's eating habits (OPALINE - Observatory of Food Preferences in Infants and Children) to (i) describe maternal feeding practices in the first year (breastfeeding duration, age at introduction of solid foods, variety of new food introduced) and to (ii) investigate whether these have an impact on infants' acceptance of new foods introduced into their diets from the beginning of CF to the age of 15 months. Feeding practices recorded by mothers: - number and timing of feedings with milk or formula recorded one week per month during the first year of life - CF diary from start of CF to 15 months: types of new foods offered (including description of texture, if salt and sugar were added, if home-made or commercially food) and the infants' acceptance of these foods for the first 4 presentations.	Duration of EBF: number of days between the date of the first food or milk other than breast milk and the date of birth. Age of introduction to CF: age of introduction of the first food in a series of 5 consecutive feeding occasions with <3 days between feeding occasion. Food variety: number of new foods introduced in the study period from the start of CF to the age of 15 months.	n=203 infants (47% boy and 53% girls) whose mothers were recruited into the OPALINE study during the last trimester of pregnancy. Country France	- Variables related to infants' diets and parents feeding practices (computed from the food diaries), including EBF duration, age of introduction to CF and food variety. - Infants' acceptance of new foods (assessed by parents and converted into scores of -3, -1, 1 and 3).	Comments by the authors Statistical analysis performed to assess the relationship between outcome measures and potential confounding factors: - maternal age, education level and parity - infant gender - caregiver during the CF period (i.e. parents/family or day care/nanny etc). The effects of the duration of EBF, age of introduction to CF and food variety on new food acceptance were analysed using linear regression.	Duration of EBF was highly variable, with a median duration of 68 days. 16% of mothers completed between 5 and 6 months of EBF and 5.5% completed 180 days of EBF. Age of start of CF (median: 171 days): - before 6 months for about 74% of infants (with about 7% before 4 months) - after 6 months for 26% of infants. The number of new foods introduced was 13.4 per month on average. From the start of the CF period to 15 months of age, the majority (91%) of new foods were accepted. Acceptance differed according to food category (p<0.0001), with fruits and vegetables being the least well accepted categories at the beginning of CF. Linear regression analysis found that neither duration of EBF nor the age of introduction of CF influenced new food acceptance. However, the earlier vegetables were introduced, the higher infants' acceptance of new vegetables was. No difference was found in new food acceptance between infants introduced to CF before or after 6 months of age (p=0.22). New food acceptance from the 3rd month after the start of CF was significantly associated with the total number of new foods introduced during the 2 months period following the start of CF (p=0.02). This was particularly marked for fruit *(*p=0.04), vegetable *(*p=0.002) and meat (p=0.02).

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Northstone et al (2001) <u>Funding</u> The Wellcome Trust. <u>DOI</u> Not specified.	Longitudinal study (part of the ALSPAC) to document the dietary patterns of infants and to investigate the effect of age of introduction of lumpy solids on foods eaten and reported feeding difficulties at 6 and 15 months of age. Information about dietary patterns of the infants and any difficulties experienced by the mothers in feeding her child collected by self-completion questionnaires at 6 months and 15 months. <u>To note</u> There is a follow-up of this study at 7 years of age, see (Coulthard et al, 2009).	<u>CF</u> is the process of expanding the diet of an infant to include foods and drinks other than breast milk or infant formula. <u>Age of introduction to lumpy foods</u> assessed at 15 months by the question 'Babies first solid meals are usually a puree. When did your child first start having meals with lumps in? Give age started in months'.	n=9,360 mothers of infants born in 1991/1992, as part of ALSPAC. Multiple births and ethnic minorities were excluded from the analysis. Children divided into 3 groups based on the age at which lumpy solids were introduced: 1) <u><6 months</u> (n=1,006; 10.7%) 2) <u>6 to 9 months</u> (n=6,711; 71.7%) 3) <u>>10 months</u> (n=1,643; 17.6%). <u>Country</u> UK	- Age of introduction of lumpy foods - Dietary variety - Mother's perception of difficulty in feeding their child	<u>Comments by authors</u> Statistical analysis performed to adjust results for the following potential confounding variables: - sex of infant - mother's age - maternal education - whether mother had a partner - number of siblings - housing tenure - financial difficulties - overcrowding - age at which the child's first tooth erupted.	Compared to infants introduced to lumpy solids between 6 and 9 months, infants introduced to lumpy solids before 6 months consumed at greater variety of family foods at 6 months ($p<0.005$ for bread, biscuits, meat, fish, potatoes, raw veg and raw fruits). However, by 15 months, there was very little difference between these 2 groups in the proportion of children having family foods. Those introduced at 10 months or later had been given fewer solids of all types by 6 months of age, and at 15 months were less likely to be having most of the family foods. Compared to those introduced at 6 to 9 months, a significantly greater proportion of those introduced early (<6 months) ate snack foods such as crisps and chocolate ($p<0.005$) and sweets ($p<0.05$) at 6 months. This was also true for mint and sweets at 15 months ($p<0.005$). The group introduced at the oldest age (>10 months) was more likely than those introduced at 6 to 9 months to have sweets at 6 months ($p<0.005$) and sugar at 15 months ($p<0.005$). At both 6 months and 15 months, mothers reported more feeding difficulties in those infants introduced at the oldest age (>10 months) than in the two other groups. The authors concluded that late introduction to lumps (after 10 months) may be associated with increased difficulty in feeding the child by 15 months.

Table C.13 Oral health: systematic reviews and meta-analyses

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Avila et al (2015) Funding Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES); Fundação de Amparo à Pesquisa do estado de Minas Gerais (Fapemig); Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq); Pró-Reitoria de Pesquisa da UFMG (PRPq/UFMG). DOI None to declare.	The aim of this study was to systematically review the scientific evidence relating to the association between feeding practice (breastfeeding vs bottle feeding) and dental caries in childhood. 7 studies included: - 5 cross-sectional - 1 case-control - 1 cohort 2 of the cross-sectional studies were included in the meta-analysis.	All studies considered categorical data regarding the presence and absence of breastfeeding, bottle feeding or mixed feeding, although the criteria used to define types of feeding differed between studies. One author considered breastfeeding or bottle feeding at birth; two authors considered feeding habits up to 6 months or more, one author considered exclusive breastfeeding up to 12 months, and others considered feeding habits during infancy.	Children with exclusively primary dentition aged 18 to 60 months. 3 studies recruited children from kindergartens, and 4 recruited children from hospital and health centres. The sample size of the studies ranged from 218 to 2,395 children. Only two studies used a representative sample and both collected the sample from kindergartens. Countries Syria, China, Kuwait, Sri Lanka, South Africa and Italy	Dental caries.	Comments by the authors As none of the studies were adjusted for all the confounding factors, all are susceptible to residual confounding. Confounding variables can include social class, hygiene and sugar in bottle content, ethnicity, early preventive dental visits, water fluoridation and on-demand feeding at night.	A meta-analysis of 2 cross-sectional studies showed that breastfed children were less affected by dental caries than bottle fed children (OR 0.43; 95% CI 0.23 to 0.80). Four studies showed that bottle fed children had more dental caries ($p<0.05$), while three studies found no such association ($p>0.05$). The authors concluded that the scientific evidence indicated that breastfeeding can protect against dental caries in early childhood.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Peres et al (2015) <u>Funding</u> The Bill and Melinda Gates Foundation. <u>DOI</u> None to declare.	Systematic review with meta-analysis to investigate whether breastfeeding decreases the risk of malocclusions. <u>48 studies were included</u> and of these, 41 presented data for at least one meta-analysis.	<u>Categorisation of breastfeeding:</u> 1) ever breastfeeding vs never breastfeeding (18 studies) 2) EBF vs absence of EBF (9 studies). In this category, all studies that provided information about EBF, independently of its duration, compared with the absence of EBF were combined 3) breastfeeding for long periods vs breastfeeding for short periods (32 studies).	n=27,023 participants included in the overall meta-analysis. <u>Countries</u> Studies were predominantly conducted in LMIC.	All kinds of malocclusion, such as nonspecific malocclusion, anterior open bite, posterior cross-bite, overbite and overjet.	<u>Comments by authors</u> The meta-analysis was not stratified by adjustment for confounders due to the absence of adjusted studies. The authors also noted that the lack of information on whether children were fed with breast milk at the breast or in a bottle may be considered as a potential confounder.	Results revealed that participants ever exposed to any type of breastfeeding were less likely to develop malocclusions than those never breastfed (OR 0.34; 95% CI 0.24 to 0.48). Participants who were EBF for a period of time were less likely to develop a malocclusion (OR 0.54; 95% CI 0.38 to 0.77) compared to those who were not exclusively breastfed. Individuals who were breastfed for longer periods were 60% less likely to develop malocclusions compared to those who were breastfed for shorter periods (OR 0.40; 95% CI 0.29 to 0.54). The authors concluded that breastfeeding decreases the risk of malocclusions.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Tham et al (2015) Funding The World Health Organization. DOI None to declare.	Systematic review, meta-analysis and narrative synthesis to synthesise the current evidence for the associations between breastfeeding and dental caries, with respect to specific windows of early childhood caries risk. 63 studies included: - 14 cohorts, 6 of these nested within RCTs of breastfeeding promotion interventions - 3 case-controls - 46 cross-sectional. The majority of studies (n=46) were not included in the meta-analyses due to methodological differences in the measures of exposure and outcomes, or reporting of correlational analyses only.	In the assessment for meta-analysis, exposure to breastfeeding was assessed in two specific time windows: 1) up to 12 months of age (upper and lower incisors) 2) beyond 12 months of age (increased risk of caries due to other teeth erupting). As very few mothers EBF infants until 12 months or beyond, within these time windows studies were categorised into: 1) never breastfed compared to any breastfeeding 2) more vs less breastfeeding. This category was created to include all studies, which compared groups with relatively more (longer duration of breastfeeding) and relatively less breast milk exposure (shorter duration).	Children and adolescents from both general and high-risk populations (such as low SES). Countries Studies were predominantly conducted in high and middle income countries (Brazil, US, Belarus, Finland, UK, Japan, Thailand, Burma, India, Tanzania, South Africa, Italy, Phillipines, Kuwait, China, Nigeria, Sweden, Australia, Bangladesh, Greece, Canada, Singapore, Israel, Uganda, Sri Lanka, Syrial, Jordan, Lithuania, DRC,) with only eight studies from low income countries.	Development of dental caries in deciduous or permanent teeth.	Comments by authors The authors identified key confounders that should be controlled for in breastfeeding and dental caries studies: - SES - infant's age - mother's educational level - number of teeth - exposure to sugar in the diet (food or other liquid).	Children exposed to longer vs shorter duration of breastfeeding up to age 12 months had a reduced risk of caries (5 studies; OR 0.50; 95% CI 0.25 to 0.99; I2 86.8%). Children breastfed >12 months had an increased risk of caries when compared with children breastfed <12 months (7 studies; OR 1.99; 95% CI 1.35 to 2.95; I2 69.3%). Amongst children breastfed >12 months, those fed nocturnally or more frequently had a further increased caries risk (5 studies; OR 7.14; 95% CI 3.14 to 16.23; I2 77.1%). There was a lack of studies on children aged >12 months simultaneously assessing caries risk in breastfed, bottle-fed and children not bottle or breastfed, alongside specific breastfeeding practices, consuming sweet drinks and foods, and oral hygiene practices limiting the authors' ability to tease out the risks attributable to each. The authors concluded that breastfeeding in infancy may protect against dental caries but that further research was needed to understand the increased risk of caries in children breastfed after 12 months.

Table C.14 Oral health: observational evidence

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Al-Dashti et al (1995) <u>Funding</u> Not specified. <u>DOI</u> Not specified.	Cross sectional study to determine if 'nursing caries' were prevalent in Kuwait and to investigate whether and to what extend the practice of breast as compared with bottle feeding was associated with its occurrence. Mothers of pre-school children were interviewed and their children received a dental examination.	<u>Breastfed</u>: infants breastfed immediately after birth. <u>Bottle fed</u>: solely bottle fed immediately after birth. <u>Mixed fed</u>: breastfeeding supplemented with the bottle. <u>Nursing caries</u>: caries affecting at least 2 maxillary incisors.	n=227 children (101 boys and 126 girls) aged 18 to 48 months. <u>Country</u> Kuwait <u>To note</u> - Kuwait has low levels of fluoride in the water supplies (0.1 to 0.3mg/l). - Breastfeeding has always been an important practice in Kuwait as according to Islamic rules, the mother is encouraged to breastfeed her infants for a period of 2 years.	- DMF teeth - Nursing caries Diagnostic criteria: WHO.	<u>Comments by Avila et al, 2015</u> The authors did not adjust for any confounders.	47% of the children were caries free; 18% had 5 or more DMF teeth; and 19% had nursing caries. <u>Feeding practices and caries</u> - Of the 179 breastfed children, 54% were caries free. - Of the 15 bottle fed children, 20% were caries free. - Of the 30 mixed fed, 23% were caries free. Breastfed children were less often affected by caries than bottle fed children ($p<0.05$) or than the bottle and mixed fed groups combined ($p<0.001$). <u>Nursing caries</u> - 17% (35 of 209) of the breastfed and mixed fed children had nursing caries vs 53% (8 of 15) for the bottle fed group ($p<0.01$). - Nursing caries was positively associated with the practice of breastfeeding at night 'at will' after 6 months of age ($p<0.01$). - Among bottle fed children, those without nursing caries had been provided with a bottle for a shorter time than those with nursing caries (14.9 vs 20.0 months; $p<0.001$). The authors concluded that bottle fed children were more likely to develop caries, including nursing caries, particularly when the practice was continued to an older age.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Behrendt et al (2001) Funding Not specified. DOI Not specified.	Retrospective study to document the feeding habits and dental caries associated with the nursing bottle syndrome. Children were grouped according to their medical history and parent questionnaires into 1 of the 5 groups: - group 1: Prolonged use of nursing bottles beyond the first year of age - group 2: Prolonged use of nursing bottle and vessels with bill-shaped extensions beyond the first year of age - group 3: Prolonged use of vessels with bill-shaped extensions beyond the first year of age - group 4: Use of pacifiers dipped in sugary substances - group 5: Prolonged and excessive breastfeeding beyond the first year of age.	Nursing bottle syndrome: specific pattern of dental caries in infants caused by the long-term exposure of the teeth to natural sweets or acidic beverages from nursing bottles.	n=186 children (101 boys and 85 girls) aged 1 to 6 years (average 41.2 months). From 01/01/1998 to 31/12/1998, all patients from the Policlinic of Paediatric Dentistry (Giessen) aged 1 to 6 years old with nursing bottle syndrome were included in this study. Country Germany (Giessen)	Causes and extend of dental caries expressed as the DMF index .	Comments by the authors The association between the extend and the possible causes of caries, and the drinks and drinking vessels was evaluated according to age and gender.	Drinking/sucking behaviour of children included in the study: Group 1: 128 children (68.8%) Group 2: 12 children (6.5%) Group 3: 41 children (22.0%) Group 4: 5 children (2.7%) Group 5: 0 children (0%). The favourite drinks used in vessels with bill-shaped extensions were fruit juices (67.9%), sweetened teas (32.0%) and unsweetened teas (26.4%) while lemonades and cola-drinks were given to the children less often (15.1%). In spite of varying numbers of patients in each group, the results of this study shows that the different forms of "sucking-nutrition" caused similar damage to the teeth. The DMF teeth values ranged between 8.3 and 11.4. There were no significant differences between DMF teeth values of any of the groups (p=0.41). It is also notable that hardly any child had had teeth.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Du et al (2000) <u>Funding</u> Not specified. <u>DOI</u> Not specified.	Cross-sectional study to describe the prevalence, severity and patterns of caries in 2 to 4 years old children and to evaluate the association between caries experience of the children and their feeding patterns and socio-economic background in terms of mothers' education and family income. Dental caries established by oral examination in the schools. Feeding and breastfeeding practices and demographics were assessed by questionnaires completed by the mother (given through the schools).	<u>Method of feeding</u> categorised into: 1) Wholly bottle-fed (8%) 2) Wholly or partially breastfed (92%).	n=426 children (250 boys and 176 girls) aged 24-47 months (mean 40 months) randomly selected from 6 kindergartens in one suburban area of Hanchuan (25% of those attending these schools). <u>Country</u> China (Hanchuan)	- Prevalence of caries - Rampant caries (defined as carious labial or palatal surfaces of 2 or more upper deciduous incisors) - Tooth type caries pattern (prevalence in molars, incisors, and/or canines Diagnostic criteria: WHO.	<u>Comments by the authors</u> Variables entered into multiple logistic regression analysis: - children gender - children age - mothers' education - family income - feeding patterns.	36% of children had caries. 7% had rampant caries while 21% showed evidence of caries in primary incisors. Method of feeding showed a statistically significant association with rampant caries ($p<0.01$) and incisor caries ($p<0.05$), with a higher prevalence in children who were bottle fed; children who had been wholly bottle-fed had five times the risk of having rampant caries compared to children who were breastfed (OR 5.27; 95% CI 2.16 to 12.89). There was no statistically significant relationship between level of mothers' education or family income with caries prevalence and patterns of disease.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Feldens et al (2010) Funding Not specified. DOI Not specified.	Prospective cohort study (part of a larger birth cohort study) to investigate feeding practices in the first year of life associated with S-ECC at the age of 4 years. The following feeding practices were investigated: - night time bottle use - bottle use for drinks other than milk - frequency of breastfeeding - high frequency of daily meals/snacks - high density of sugar - high density of lipids. Feeding practices were assessed at 6 and 12 months of age by face-to-face interviews. A 24-hour dietary recall was also used at 12 months. Follow-up at 4 years of age.	S-ECC: ≥1 caveated, missing or filled smooth surfaces in primary maxillary anterior teeth, or DMF surface values ≥5 (NIH definition).	n=340 children aged 4 years old (500 singleton, healthy term infants initially included in the birth cohort). Country Brazil (São Leopoldo)	S-ECC Diagnostic criteria: NIH definition.	Comments by the authors Multivariable model adjusted for: - child's age - child's gender - maternal schooling - per capita income - tooth brushing with fluoride paste - number of teeth at 12 months.	The multivariable model showed a higher adjusted risk of S-ECC for the following dietary practices at 12 months: - breastfeeding ≥7 times daily compared to those breastfed 0, 1 or 2 a day (RR 1.97; 95% CI 1.45 to 2.68) - high density of sugar (i.e. >50% simple carbohydrates in 100g food) (RR 1.43; 95% CI 1.08 to 1.89) - bottle use for liquids other than milk (RR 1.41; 95% CI 1.08 to 1.86) - number of meals and snacks >8 daily compared to <7 (RR 1.42; 95% CI 1.02 to 1.97). Mother's education ≤8 years was also associated with the outcome (RR 1.50; 95% CI, 1.03 to 2.19).

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Hong et al (2014) Funding The National Institutes of Health (NIH). DOI Not specified.	Longitudinal cohort study (embedded in the birth cohort study IFS) to assess the longitudinal effects of breastfeeding duration on caries experience of primary second molars at five years old and nine years old. Information regarding breastfeeding, formula use, beverage intakes, general health/illnesses, and oral health behaviours such as children's fluoride exposures was obtained through parents' responses to periodic questionnaires.	Children were classified into 2 mutually exclusive groups based on breastfeeding duration: 1) <6 months (71% children) 2) ≥6 months (29% children).	n=509 children with complete data for dental exams at 5 and 9 years old, baseline demographics and breastfeeding duration (1,390 new-borns initially recruited from March 1992 to February 1995 for the IFS). Country US	- Dental caries (yes/no) at 5 and 9 years - Number of decayed and/or filled surfaces (DFS) at 5 and 9 years	Comments by the authors Multivariable model adjusted for: - breastfeeding duration - gender - hypoplasia - parental education level - family income level - gestational weeks - birth weight - age at time of dental exam - average daily fluoride intake (mg) - home tap water fluoride level (ppm) - average daily soda pop intake (oz/day) - daily tooth-brushing frequency.	16% of children had caries experience on primary second molars at 5 years old and 36% at 9 years old. For primary second molars at 5 years old, 18%of children breastfed <6 months had caries (mean DFS=0.55) while only 9%of children breastfed ≥6 months had caries (mean DFS=0.33). From 5 to 9 years old, caries incidence was 32% and 31% for children breastfed <6 months and ≥6 months, respectively. In multivariable regression analyses, shorter breastfeeding duration was positively associated with caries experience of primary second molars at five years old (p=0.005), both before and after controlling for other important factors).

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Majorana et al (2014) Funding None to declare. DOI None to declare.	Cohort study to investigate the potential association between feeding practices, maternal and environmental smoking exposure and SES as risk factors for caries development in toddlers aged 24 to 30 months. Feeding practices, sweet dietary habit, maternal smoking habit during pregnancy and environmental exposure to smoke, SES, and fluoride supplementation during pregnancy and during the first year of life was obtained throughout a questionnaire administered to mothers at 6, 9 and 12 months after delivery. Clinical examination of children took place May - October 2010 when children where aged 24 to 30 months.	Feeding practices were classified using cut-off points for the percentages of breast milk and formula administered to the infant at each meal: 1) EBF: 100% breastfed for 6 months 2) moderate-high mixed feeding: 58-99% breastmilk 3) low mixed feeding: 1-57% breastmilk 4) exclusive use of formula.	n=2,395 singleton, healthy term infants recruited at birth between May 2008 and April 2009 in 1 of the 2 obstetric wards of Brescia Hospital (2,610 infants initially recruited). Country Italy (Brescia)	Caries lesions Diagnostic criteria : ICDAS.	Comments by the authors Ordinal logistic regression used to analyse associations between caries severity level, feeding practices, SES and behavioural factors such as smoking (maternal and environmental).	80.84% of toddlers had caries; 48.60% had low caries severity level, 27.52% had moderate caries severity level, and 4.30% had high caries severity. Caries prevalence and severity levels were significantly lower in children who received higher proportions of breast milk (EBF, moderate-high mixed feeding) than in those who received lower proportions (low mixed feeding, exclusively infant formula) at 6 months of age ($p<0.01$). No moderate and high caries severity levels were observed in EBF children. High caries severity levels were significantly associated with sweet beverages ($p<0.04$) and SES ($p<0.01$). Toddlers whose mothers smoked ≥5 cigarettes/day during pregnancy showed a higher caries severity level ($p<0.01$) respect to those whose mothers did not smoke. Environmental exposure to smoke during the first year of life was also significantly associated with caries severity. No association was observed between caries severity level and fluoride supplementation.

Study reference	Study design	Definitions	Participants	Outcome measures	Confounders	Findings
Qadri et al (2012) Funding Not specified. DOI Not specified.	Cross-sectional cohort survey to determine the prevalence and severity of ECC in pre-school children aged 3 to 5 years in Syria as well as assess its association with different feeding practices. Feeding practices assessed by parents' interviews. Dental caries established by oral examination in paediatric dentistry.	The children were categorised into: 1) predominantly breastfed 2) predominantly bottle-fed.	n=400 children (209 girls and 191 boys) aged 3 to 5 years (mean 4.2±0.5 years) randomly selected from 20 different kindergartens. Country Syria	- ECC - DMF teeth - DMF surface Diagnostic criteria: WHO and ICDAS.	Comments by the authors Logistic regression to analyse association between DMF teeth and ECC outcomes and dietary practices and children's age and sex.	70.0% of children had carious defects, 36.2% had restorations and 25.7% had had extractions. 72.3% of all boys and 69.9% of all girls were found with carious defects but this difference was not significant (p=0.787). 48% of children of the total sample were diagnosed with ECC. The number of children with a healthy dentition clearly decreases with age, while the severity of the lesions increased. Breastfed children were found to be less likely to have ECC (OR 0.27; 95% CI 0.18 to 0.41; p<0.001) and had fewer DMF teeth (OR 0.61; 95% CI 0.39 to 0.97; p=0.038). The number of teeth affected was also significantly higher in predominantly bottle-fed children with ECC compared with children who were breastfed (Z-statistic -2.1, p=0.036). Dietary practices and age variables were significantly related to DMF teeth and ECC respectively (p=0.048, p<0.001). Age had the strongest and most consistent relationship with all outcomes.

Annex D UK infant feeding practice

Table D.1 Incidence of breastfeeding by country (UK, 1980 - 2010)

	1980	1985	1990	1995	2000	2005	2010
% who breastfed initially	%	%	%	%	%	%	%
United Kingdom	-	-	62	66	69	76	81
England	-	-	-	-	-	78	83
Wales	-	-	-	-	-	67	71
England & Wales	67	65	64	68	71	77	82
Scotland	50	48	50	55	63	70	74
Northern Ireland	-	-	36	45	54	63	64
Unweighted bases							
United Kingdom	*n/a*	*n/a*	*n/a*	*9130*	*9492*	*12290*	*15724*
England	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*6075*	*7336*
Wales	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*2135*	*2633*
England & Wales	*n/a*	*n/a*	*n/a*	*n/a*	*5440*	*8210*	*9969*
Scotland	*n/a*	*n/a*	*n/a*	*n/a*	*2274*	*2194*	*3107*
Northern Ireland	*n/a*	*n/a*	*n/a*	*n/a*	*1778*	*1886*	*2648*
Weighted bases [a]							
United Kingdom	*n/a*	*n/a*	*5533*	*5181*	*9492*	*12290*	*15722*
England	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*6075*	*7335*
Wales	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*2135*	*2633*
England & Wales	*3755*	*4671*	*4942*	*4598*	*5441*	*8210*	*9959*
Scotland	*1718*	*1895*	*1981*	*1863*	*2274*	*2194*	*3108*
Northern Ireland	*n/a*	*n/a*	*1497*	*1476*	*1778*	*1886*	*2650*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.2 Estimated incidence of breastfeeding standardised by the composition of the sample by country (UK, 1985 - 2010)

	1985	1990	1995	2000	2005	2010
% who breastfed initially	%	%	%	%	%	%
England & Wales						
Unstandardised percentage	65	64	68	71	77	82
Standardised percentage[a]	65	62	62	62	67	72
Scotland						
Unstandardised percentage	48	50	55	63	70	74
Standardised percentage[1]	48	46	48	54	57	60[b]
Northern Ireland						
Unstandardised percentage	-	36	45	54	63	64
Standardised percentage[a]	-	36	41	47	51	51

[a] Standardised for mother's age and age finished full-time education. 1985 is the base year for standardisation for England, Wales and Scotland whereas the year used for Northern Ireland is 1990.

[b] In the 2010 IFS Early Results report, a rounding error meant that the standardised figure for Scotland (60%) was reported incorrectly in the text and table so it appeared (wrongly) that the increase in incidence in Scotland was largely due to changes in sample composition.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.3 Prevalence of breastfeeding at ages up to 9 months by country (UK, 1995 - 2010)

	Total[a]				Country							
					England		Wales		Scotland		Northern Ireland	
	1995[3]	2000	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
	%	%	%	%	%	%	%	%	%	%	%	%
Birth	66	69	76	81	78	83	68	71	71	74	62	64
2 days	n/a	n/a	72	76	74	78	63	64	66	69	57	57
3 days	n/a	n/a	70	74	72	76	59	61	63	67	54	53
4 days	n/a	n/a	67	72	70	75	56	58	61	64	50	51
5 days	n/a	n/a	66	71	68	73	55	57	59	63	49	49
6 days	n/a	n/a	64	70	66	72	53	55	58	62	47	48
1 week	56	55	63	69	66	72	52	55	57	61	46	47
2 weeks	53	52	60	66	62	68	48	51	54	58	44	44
6 weeks	42	42	48	55	50	57	37	40	44	50	32	33
4 months	27	28	34	42	35	44	24	29	31	39	20	22
6 months	21	21	25	34	26	36	18	23	24	32	14	16
9 months	14	13	18	23	19	24	12	18	15	21	10	9
Unweighted bases	*7198*	*7267*	*9416*	*10768*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1910*
Weighted bases[b]	*5181*	*7267*	*9416*	*10769*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1908*

[a] It should be noted that the analysis on the prevalence of breastfeeding is based on all mothers who completed Stage 3 (infants aged 8 to 10 months old) of the survey, while incidence of breastfeeding is based on all mothers who completed Stage 1 (infants aged 4 to 10 weeks old) of the survey. This means there are some small differences in the estimates about incidence of breastfeeding compared with the prevalence of breastfeeding at birth.

[b] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.4 Reasons given by mothers for stopping breastfeeding within one or two weeks (UK, 2005 and 2010)

	Infant's age when breastfeeding ceased			
	Less than 1 week		1 week, but less than 2 weeks	
Top ten reasons given by mothers who stopped breastfeeding (more than one reason could be provided)	**2005**	**2010**	**2005**	**2010**
	%	%	%	%
Infant would not suck / rejected breast	35	33	24	22
Painful breast / nipples	24	22	30	21
Insufficient milk	25	17	42	28
Infant too demanding / always hungry[a]	n/a	11	n/a	17
Inconvenient / formula is more convenient	1	11	1	11
Found breastfeeding difficult / exhausting[b]	3	9	2	8
Had little / no support	5	8	4	5
Domestic reasons (coping with other relatives / children)	4	6	7	7
(Too) stressful/causing distress	7	6	8	8
Breastfeeding took too long / was tiring	10	5	17	6
Unweighted bases	*1497*	*1726*	*412*	*525*
Weighted bases[c]	*1428*	*1514*	*435*	*532*

[a] New code in 2010.

[b] 'Exhausting' added in 2010.

[c] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.5 Whether mothers who initially breastfed would have liked to have breastfed for longer (UK, 2010)

	Infant's age when breastfeeding ceased	
	Less than 1 week	**1 week, but less than 2 weeks**
	%	%
I would have liked to breastfeed for longer	80	85
I breastfed for as long as I intended	14	9
I breastfed for longer than I intended	3	3
Unweighted bases	*1726*	*525*
Weighted bases[a]	*1514*	*532*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.6 Prevalence of exclusive breastfeeding at ages up to 6 months by country (UK, 2005 and 2010)

	Total UK		Country							
			England		Wales		Scotland		Northern Ireland	
	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
	%	%	%	%	%	%	%	%	%	%
Birth	65	69	66	71	58	57	61	63	55	52
1 week	45	46	46	47	38	36	42	40	35	33
2 weeks	38	40	39	41	32	32	37	35	31	27
3 weeks	33	35	34	36	28	28	32	32	25	23
4 weeks	28	30	29	31	21	23	25	28	20	19
6 weeks	21	23	22	24	15	17	19	22	13	13
2 months (8 weeks)	18	21	18	21	12	15	17	20	11	12
3 months (13 weeks)	13	17	14	18	9	13	12	17	8	9
4 months (17 weeks)	7	12	8	13	4	9	6	12	4	6
5 months (21 weeks)	3	5	3	5	2	3	3	5	2	3
6 months (26 weeks)	*	1	*	1	*	*	*	1	*	1
Unweighted bases	*9416*	*10768*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1910*
Weighted bases[a]	*9416*	*10769*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1908*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.7 How exclusive breastfeeding status was lost (UK, 2005 and 2010)

		How exclusive feeding status was lost				
	All mothers who fed exclusively at birth	**Formula**	**Other liquids**	**Formula / Other liquids**	**Solids**	**Solids and other combination**
	%	%	%	%	%	%
Birth	100	100	100	100	100	100
1 week	66	55	89	60	100	100
2 weeks	58	45	74	49	100	99
3 weeks	51	37	65	39	100	99
4 weeks	44	28	55	31	99	99
6 weeks	34	17	37	17	95	99
2 months (8 weeks)	30	13	28	15	94	99
3 months (13 weeks)	25	7	19	11	94	98
4 months (17 weeks)	18	1	9	5	79	89
5 months (21 weeks)	7	*	2	2	37	30
6 months (26 weeks)	1	*	*	*	3	7
Unweighted bases	*7397*	*4672*	*676*	*458*	*821*	*631*
Weighted bases[a]	*7437*	*4588*	*777*	*513*	*740*	*660*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.8 Age at which milk other than breastmilk was first introduced by mother's age and socio-economic classification (UK, 2005 and 2010)

Percentage of mothers who had given milk other than breastmilk[a] by:	Total		Age of Mother					Socio-economic classification				
	2005	2010	Under 20	20-24	25-29	30-34	35 or over	Managerial & professional	Intermediate occupations	Routine & manual occupations	Never worked	Not classified
	%	%	%	%	%	%	%	%	%	%	%	%
Birth	35	31	54	45	28	24	24	20	30	39	46	32
1 week	54	52	71	66	50	45	46	42	51	61	64	54
4 weeks	69	66	82	80	65	61	59	57	67	75	73	68
6 weeks	76	73	84	85	71	68	67	65	73	81	77	74
2 months	79	75	87	87	73	70	70	67	76	82	80	76
4 months	88	83	90	91	82	79	80	78	83	88	85	83
6 months	92	88	95	94	87	86	86	85	90	92	89	87
9 months[b]	96	95	100	97	95	94	94	94	96	96	95	94
Unweighted bases	*9416*	*10768*	*273*	*1204*	*2850*	*3783*	*2632*	*4696*	*2248*	*2438*	*567*	*819*
Weighted bases[c]	*9416*	*10769*	*585*	*2001*	*3002*	*3050*	*2083*	*3747*	*2105*	*2880*	*1055*	*982*

[a] At each stage of the survey mothers were asked at what age they had first given their baby any sort of milk other than breastmilk. It is not possible from the information collected in the survey to be sure of the exact type of milk other than breastmilk that mothers first gave to their baby, although in the majority of cases it can be assumed that it was infant formula.

[b] Based on a reduced number of cases excluding those infants who had not reached 9 months by Stage 3 (infants aged 8 to 10 months old)See IFS 2010 for details of weighting.

[c] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.9 Cow's milk given at Stages 2 (4-6 months old) and 3 (8-10 months old) by country (UK, 2005 and 2010)

	Stage 2 (4-6 months)		Stage 3 (8-10 months)		Country							
	Total		Total		England		Wales		Scotland		Northern Ireland	
	2005	2010	2005	2010	Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3
	%	%	%	%	%	%	%	%	%	%	%	%
As main milk	1	*	6	4	*	4	1	3	*	3	1	4
Whole	1	*	5	3	*	3	*	3	*	2	1	3
Semi-skimmed	*	*	1	*	*	1	*	*	*	*	*	1
Skimmed	*	*	*	*	0	*	*	0	0	*	*	0
As an occasional drink	1	3	19	24	3	24	3	26	3	21	4	28
To mix food	2	2	23	29	2	29	2	30	1	28	3	32
All using cows' milk	**2**	**4**	**39**	**42**	**4**	**42**	**5**	**42**	**3**	**37**	**5**	**44**
Unweighted bases	*10814*	*10768*	*9416*	*10768*	*5721*	*4935*	*2138*	*1804*	*2534*	*2119*	*2172*	*1910*
Weighted bases[a]	*10814*	*10769*	*9416*	*10769*	*5721*	*4935*	*2138*	*1804*	*2534*	*2119*	*2171*	*1908*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.10 Age by which solid foods had been introduced by country (UK, 2005 and 2010)

	Total		England		Wales		Scotland		Northern Ireland	
	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
% who had introduced solids by…	%	%	%	%	%	%	%	%	%	%
6 weeks	1	2	1	2	2	2	1	2	2	2
8 weeks	2	2	2	2	3	3	2	3	3	3
3 months (13 weeks)	10	5	9	5	13	9	13	6	11	7
4 months (17 weeks)	51	30	50	28	65	44	60	32	51	35
5 months (22 weeks)	82	75	81	75	88	83	85	74	78	75
6 months (26 weeks)	98	94	98	94	98	96	98	95	98	95
9 months (39 weeks)[a]	100	99	100	99	100	98	100	99	100	99
Unweighted bases	*9416*	*10768*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1910*
Weighted bases[b]	*9416*	*10769*	*4563*	*4935*	*1582*	*1804*	*1666*	*2119*	*1605*	*1908*

[a] Based on a reduced number of cases excluding those infants who had not reached this age by Stage 3 (infants aged 8 to 10 months old).
[b] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.11 Why mother began giving solids when she did by age of introduction of solids (UK, 2005 and 2010)

	Total		Age at which baby first given solids				
	2005	2010	By 3 months or earlier	After 3, by 4 months	After 4, by 5 months	After 5, by 6 months	After 6 months
	%	%	%	%	%	%	%
Baby not satisfied with milk	63	52	64	64	56	31	31
Experience from previous baby	32	30	27	30	29	31	38
Baby able to sit up and hold food in hand[a]	n/a	29	15	22	31	35	37
On advice from health visitor/other health professional	35	27	20	23	25	35	31
Baby waking during the night[b]	1	26	23	30	29	18	16
On advice from friends/relatives	15	17	20	21	16	12	19
Leaflets/written information	14	13	9	8	10	24	25
Baby not gaining enough weight	6	5	5	5	6	5	7
Baby was interested in mother's/other people's food	1	5	2	3	5	5	5
Other reason	6	7	6	7	6	11	11
Unweighted bases	*9416*	*10768*	*535*	*2576*	*4816*	*2261*	*453*
Weighted bases[c]	*9416*	*10769*	*575*	*2607*	*4888*	*2088*	*464*

[a] Option not included on prompted list in 2005.

[b] Option not included on prompted list in 2005, but a small proportion of mothers mentioned it spontaneously.

[c] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.12 Frequency with which mothers gave different types of food at Stage 3 (8-10 months old) of the survey (UK, 2010)

	Frequency[a]		
	At least once a day	1-6 times a week	Less than once a week or never
Fresh foods (such as fruit, vegetables, home-made foods)	87	10	3
Fruit	81	15	5
Vegetables	80	14	5
Breakfast cereals	80	10	10
Cheese, yoghurt, fromage frais	68	21	11
Bought ready-made foods (such as jars)	41	26	33
Puddings or desserts	32	25	43
Bread	27	41	31
Butter/margarine and other spreads	18	28	54
Rice or pasta	17	59	24
Potatoes	17	65	18
Biscuits, sweets, chocolate or cakes	11	24	64
Crisps and corn snacks	10	26	64
Chicken/other poultry	7	72	21
Beans, lentils and chickpeas	3	37	59
Beef	3	51	46
Fish	3	53	44
Potato products	3	13	84
Tofu, quorn, textured vegetable protein	3	7	91
Lamb	2	30	67
Pork	2	31	67
Eggs	2	25	73
Nuts	*	2	98

[a] (Unweighted base: 10768; weighted base: 10769). The small number of mothers who had not introduced their baby to solids by Stage 3 are treated as never having introduced these foods.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.13 Proportion of infants who were given vitamin drops (2005 and 2010)

	Total	
	2005	**2010**
% of infants who were given vitamin drops at:	%	%
Stage 1 (4-10 weeks)	3	7
Stage 2 (4-6 months)	4	9
Stage 3 (8-10 months)	7	14
Stage 1 mothers (unweighted bases)	*12290*	*15724*
Stage 2 mothers (unweighted bases)	*10814*	*12565*
Stage 3 mothers (unweighted bases)	*9416*	*10768*
Stage 1 mothers (weighted bases)[a]	*12290*	*15722*
Stage 2 mothers (weighted bases)[a]	*10814*	*12568*
Stage 3 mothers (weighted bases)[a]	*9416*	*10769*

[a] See IFS 2010 for details of weighting.

Source: Infant Feeding Survey 2010 (McAndrew et al, 2012)

Table D.14 Percentage contribution of food groups (food sources) to average daily energy intake

	4-6 months	7-9 months	10-11 months	12-18 months
Food group[a]	**%**	**%**	**%**	**%**
Infant formula	51	39	31	10
Breast milk	18	8	4	2
Commercial infant foods	16	17	14	6
Cereals/cereal products	3	10	15	24
Milk/milk products	4	9	13	27
Meat/meat products	1	4	6	8
Vegetables/pulses	3	4	5	7
Fish/fish dishes	0	1	2	2
Fruit	3	4	4	6

[a] Some food groups are not included due to small numbers of consumers.

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.15a Average daily intake of non-milk extrinsic sugars (NMES) from all sources

	4-6 months	7-9 months	10-11 months	12-18 months
Average sugar (NMES[11]) intake (g)	8.1	12.8	14.3	19.8
Average % total energy	4.3	6.2	6.2	7.7

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D. 15b Percentage contribution of food groups (food sources) to average daily NMES intake

	4-6 months	7-9 months	10-11 months	12-18 months
Food group	%	%	%	%
Infant specific foods				
Commercial infant foods, of which:	44	34	25	11
Fruit based foods and dishes	15	13	11	5
Cereal based foods and dishes	14	9	6	2
Commercial infant foods	7	6	4	2
Non-infant specific foods				
Cereals and cereal products	4	10	16	23
Milk and milk products	20	29	29	27
Sugar, preserves and confectionery	2	5	7	12
Beverages	2	3	5	10

Source: DNSIYC 2013 (Lennox et al, 2013)

[11] In 2015, SACN recommended that a definition of 'free sugars' should be adopted in the UK for public health nutrition purposes to replace the concept of non-milk extrinsic sugars (NMES) on which sugar intake recommendations had been based since 1991 (SACN, 2015). DNSIYC (2013) measured sugar intakes using the NMES definition and in this context it is therefore appropriate to report sugar intakes as intakes of NMES rather than 'free sugars'.

Table D.16a Average daily sodium and salt intakes for children aged 4 to 18 months

	4-6 months	7-9 months	10-11 months	12-18 months
Average daily sodium intake (mg)	238	422	605	907
Average daily salt intake (mg)	604	1072	1536	2303

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.16b Percentage contribution of food groups (food sources) to daily sodium intake (mg) for children aged between 4 and 18 months of age

	4-6 months	7-9 months	10-11 months	12-18 months
Food group	%	%	%	%
Cereals and cereal products	6	17	24	29
Milk and milk products	6	12	14	22
Commercial infant foods	16	15	10	3
Infant formula	44	25	17	5
Breast milk	16	5	2	1

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.17 Average daily intake of minerals from all sources (including dietary supplements) as a percentage of RNI

		4-6 months	7-9 months	10-11 months	12-18 months
Mineral		%	%	%	%
Iron	Mean	135	94	98	93
	Median	131	95	97	88
	sd	66	35	37	39
Calcium	Mean	98	109	122	226
	Median	95	108	118	221
	sd	30	31	38	74
Magnesium	Mean	115	124	136	159
	Median	107	119	133	157
	sd	42	36	39	43
Potassium	Mean	106	159	180	200
	Median	101	154	174	199
	sd	34	43	53	55
Zinc	Mean	118	104	107	109
	Median	116	102	103	106
	sd	34	28	32	32
Copper	Mean	142	165	173	126
	Median	136	159	168	122
	sd	44	55	61	44
Selenium	Mean	112	180	206	145
	Median	111	174	197	140
	sd	41	61	68	44
Iodine	Mean	157	171	196	248
	Median	155	162	182	234
	sd	48	60	82	114
Sodium	Mean	85	132	173	181
	Median	72	112	157	175
	sd	38	73	90	70
Bases (unweighted)		*329*	*630*	*449*	*1275*

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.18 Proportion of participants with average daily intake of minerals from all sources (including dietary supplements) below the LRNI

	4-6 months	7-9 months	10-11 months	12-18 months
Mineral	%	%	%	%
Iron	12	14	10	13
Calcium	2	1	0	0
Magnesium	10	3	2	0
Potassium	1	0	0	0
Zinc	3	3	5	4
Selenium	0	0	0	1
Iodine	0	1	0	0
Sodium	10	11	4	1
Bases (unweighted)	*329*	*630*	*449*	*1275*

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.19 Proportion of participants with average daily intake of vitamins from all sources (including dietary supplements) below the LRNI

	4-6 months	7-9 months	10-11 months	12-18 months
Vitamin	%	%	%	%
Vitamin A	0	0	0	2
Thiamin	0	0	0	0
Riboflavin	0	0	0	0
Niacin equivalents	0	0	0	0
Vitamin B_6	8	1	1	0
Vitamin B_{12}	5	1	0	0
Folate	0	0	0	0
Vitamin C	0	0	0	0
Bases (unweighted)	*329*	*630*	*449*	*1275*

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.20 Average daily intake of vitamins from all sources (including dietary supplements) as a percentage of RNI

Vitamin		4-6 months %	7-9 months %	10-11 months %	12-18 months %
Vitamin A	Mean	272	283	270	175
	Median	246	262	250	152
	sd	119	128	135	94
Thiamin	Mean	313	330	324	223
	Median	294	318	314	214
	sd	109	81	78	61
Riboflavin	Mean	221	253	284	249
	Median	227	249	276	243
	sd	79	78	95	88
Niacin equivalents	Mean	184	217	233	258
	Median	183	214	229	253
	sd	52	53	55	53
Vitamin B_6	Mean	336	281	214	202
	Median	248	250	197	193
	sd	253	132	89	63
Vitamin B_{12}	Mean	521	504	625	732
	Median	533	475	576	713
	sd	279	239	291	335
Folate	Mean	218	250	273	206
	Median	214	246	261	204
	sd	73	71	78	58
Vitamin C	Mean	304	310	295	208
	Median	305	301	290	185
	sd	97	101	113	115
Vitamin D non-breastfed[a]	Mean	117	127	111	55
	Median	115	126	111	27
	sd	34	44	50	55

		4-6 months	7-9 months	10-11 months	12-18 months
Vitamin		%	%	%	%
Vitamin D breastfed excluding breast milk[b]	Mean	41	52	54	37
	Median	27	44	45	21
	sd	44	39	51	40
Bases (unweighted)		*329*	*630*	*449*	*1275*

[a] Vitamin D intake does not include values for breastfed children as the vitamin D content of breast milk is not known. The bases are: 240 for 4-6M, 489 for 7-9M, 381 for 10-11M and 1177 for 12-18M. Note breastfeeding status is defined by whether it was recorded in the four-day diary.

[b] Vitamin D intake includes values for breastfed children excluding the contribution from breast milk (therefore excluding any exclusively breastfed children (n=2)) as the vitamin D content of breast milk is not known. The bases are 89 for 4-6M, 141 for 7-9M, 68 for 10-11M and 98 for 12-18M. Note breastfeeding status is defined by whether it was recorded in the four-day diary.

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.21 Mean length (cm), weight (kg), head circumference (cm) and percentage of the sample above UK-WHO growth standard percentiles, by sex

	Boys					Girls				
Measurements[a]	**All**	**4-6 months**	**7-9 months**	**10-11 months**	**12-18 months**	**All**	**4-6 months**	**7-9 months**	**10-11 months**	**12-18 months**
Mean length cm	**76.5**	69.4	73.3	76.4	80.3	**75.1**	67.6	71.5	74.7	79.1
sd	**5.1**	2.7	2.8	2.9	3.6	**5.3**	3.3	3.1	2.7	3.3
> 0.4th percentile %	**100**	100	100	100	100	**100**	100	100	100	100
> 2nd percentile %	**99**	99	99	99	98	**99**	99	99	98	99
> 9th percentile %	**96**	96	97	96	94	**96**	94	95	98	96
> 25th percentile %	**87**	84	90	88	83	**89**	89	89	88	88
> 50th percentile %	**71**	66	76	77	66	**73**	72	72	77	72
> 75th percentile %	**49**	50	49	49	45	**52**	50	56	55	48
> 91st percentile %	**27**	23	35	31	22	**29**	29	30	29	27
> 98th percentile %	**14**	12	17	16	11	**11**	15	13	8	8
> 99.6th percentile %	**5**	6	6	5	5	**4**	6	4	2	4
Bases (unweighted)	***1217***	*158*	*299*	*195*	*565*	***1174***	*150*	*272*	*199*	*553*
Mean weight kg	**10.3**	8.4	9.6	10.2	11.2	**9.6**	7.8	8.6	9.4	10.6
sd	**1.5**	0.9	1.0	1.0	1.3	**1.6**	1.1	1.1	1.1	1.3
> 0.4th percentile %	**100**	100	100	100	100	**100**	100	100	100	100
> 2nd percentile %	**100**	98	100	99	100	**100**	100	99	100	100
> 9th percentile %	**98**	95	99	98	98	**98**	96	96	99	98
> 25th percentile %	**92**	89	93	95	92	**93**	89	91	90	94
> 50th percentile %	**75**	59	77	75	77	**76**	66	70	74	78
> 75th percentile %	**50**	37	52	50	51	**49**	32	41	46	55
> 91st percentile %	**26**	14	27	26	29	**22**	13	19	19	27
> 98th percentile %	**8**	4	6	7	10	**7**	4	7	5	9
> 99.6th percentile %	**3**	1	3	1	3	**1**	2	0	1	2
Bases (unweighted)	***1316***	*164*	*320*	*213*	*619*	***1264***	*154*	*285*	*216*	*609*

	Boys					Girls				
Measurements[a]	**All**	**4-6 months**	**7-9 months**	**10-11 months**	**12-18 months**	**All**	**4-6 months**	**7-9 months**	**10-11 months**	**12-18 months**
Mean head circumference (cm)	**46.8**	44.4	46.1	46.7	47.9	**45.6**	43.3	44.6	45.5	46.8
sd	**1.9**	1.5	1.4	1.6	1.5	**1.9**	1.4	1.4	1.4	1.4
> 0.4th percentile	**100**	100	100	100	100	**100**	100	100	100	100
> 2nd percentile	**100**	99	100	100	100	**100**	100	100	100	100
> 9th percentile	**98**	98	98	96	98	**99**	99	98	98	99
> 25th percentile	**93**	89	95	91	93	**95**	89	92	94	96
> 50th percentile	**79**	75	85	76	77	**80**	75	77	72	84
> 75th percentile	**59**	52	62	57	55	**56**	47	54	46	57
> 91st percentile	**33**	25	36	31	33	**30**	22	24	24	31
> 98th percentile	**16**	12	18	12	16	**11**	11	10	7	11
> 99.6th percentile	**5**	6	6	2	6	**4**	2	3	5	3
Bases (unweighted)	***1231***	*164*	*305*	*200*	*562*	***1191***	*152*	*282*	*210*	*547*

[a] The percentiles presented here are typical of those presented in growth charts.

Source: DNSIYC 2013 (Lennox et al, 2013)

Table D.22 Iron status analytes, by age

Iron Status including haemoglobin		5-11 months	12+ months
Ferritin (µg/l)	Mean	37.3	28.3
	Median	28.0	24.0
	sd	30.2	18.8
	Upper 2.5 percentile	127.0	79.0
	Lower 2.5 percentile	5.0	7.0
	% below reference[a,b]	7%	11%
	Bases (unweighted)	*165*	*298*
Transferrin receptors (sTfR)(µg/ml)	Mean	6.9	8.6
	Median	6.1	6.8
	sd	3.2	5.9
	Upper 2.5 percentile	17.6	26.6
	Lower 2.5 percentile	4.3	4.2
	% above reference[c]	6%	15%
	Bases (unweighted)	*164*	*296*
Haemoglobin (g/dL)	Mean	11.5	11.7
	Median	11.5	11.7
	sd	1.1	1.0
	Upper 2.5 percentile	13.4	13.5
	Lower 2.5 percentile	9.3	9.9
	% below reference[a,b]	13%	15%
	Bases (unweighted)	*171*	*325*
Iron deficiency anaemia	% below reference	3%	2%

[a] Ferritin: 5-6M <9µg/l, 7-9M <5µg/l; Haemoglobin: 0-6M <10.5g/dL, 7-9 M <10g/dL. See DNSIYC 2013 for more details.
[b] Ferritin: 10M+<12µg/l; Haemoglobin: 10M+ <11g/dL. See DNSIYC 2013 for more details.
[c] Transferrin Receptors: All ages >11µg/ml. See DNSIYC 2013 for more details.

Source: DNSIYC 2013 (Lennox et al, 2013)

Annex E Glossary

Acute otitis media (AOM)	Infection of the middle ear usually caused by a complication of viral infection in the upper respiratory tract.
Birthweight	Birthweight is the first weight of the fetus or newborn obtained after birth. For live births, birthweight should preferably be measured within the first hour of life, before significant postnatal weight loss has occurred.
Breastfeeding	The feeding of an infant with milk taken from the breasts, either directly by the infant or expressed and given to the infant via a bottle or other drinking vessel.
Breastfeeding intensity	Breastfeeding intensity is defined as the proportion of daily feedings that are breast milk.
Body mass index (BMI)	An individual's weight in kilograms divided by the square of height in metres (kg/m^2). Often used as an indicator of adiposity with recognised limitations (Pietrobelli et al, 1998).
Bottle feeding	Feeding an infant from a bottle, whatever is in the bottle, including expressed breast milk, water, infant formula, etc.
Bioavailability	Bioavailability is defined as the efficiency with which a dietary component is used systemically through normal metabolic pathways. It is expressed as a percentage of intakes and is known to be influenced by dietary and host factors.
Cardiovascular disease	Cardiovascular disease is the most common cause of death in the UK and includes coronary heart disease, angina, heart attack and stroke.
Catch-up growth	Rapid growth following a period of restriction. Ultimately, it may redress wholly or partly the accrued deficit in weight or size though there may be consequences for body composition and metabolic capacity. This phenomenon is also often seen in children who are born small-for-gestational-age or with a low birthweight.

Cohort study	Systematic follow-up of a group of people for a defined period of time or until a specified event. Also known as a longitudinal study. A cohort study may collect data prospectively or retrospectively.
Complementary feeding	The WHO defines complementary feeding as "the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants" so that "other foods and liquids are needed, along with breast milk." (PAHO, 2003). For the purposes of this report, complementary feeding refers to the period when solid foods are given in addition to either breast milk or infant formula to complement the nutrients provided by breast milk (and/or infant formula) when breast milk (and/or infant formula) alone is not sufficient to meet the nutritional requirements of the growing infant. Complementary feeding replaces the term 'weaning' which can be misinterpreted to mean the cessation of breastfeeding rather than the introduction of solid foods. Complementary feeding includes all liquids, semi-solid and solid foods, other than breast milk and infant formula.
Diabetes	A metabolic disorder involving impaired metabolism of glucose due to either failure of secretion of the hormone insulin, insulin-dependent or type 1 diabetes, OR impaired responses of tissues to insulin, non-insulin-dependent or type 2 diabetes.
Diet and Nutrition Survey of Infants and Young Children (DNSIYC)	Survey providing detailed information on the food consumption, nutrient intakes and nutritional status of infants and young children aged 4 up to 18 months living in private households in the UK. Fieldwork was carried out between January and August 2011.
Diversification of the diet	Diversification of the diet refers to the progression from an exclusively milk-based diet to an eating pattern which includes a wide range of foods.
Doubly labelled water (DLW) method	Doubly labelled water is water in which both the hydrogen (H) and oxygen (^{16}O) have been partly or completely replaced for tracing purposes (that is, labelled) with 'heavy', non-radioactive forms of these elements: ^{2}H and ^{18}O. The DLW method measures the rate of disappearance of these 2 tracers given to an individual in water as they are washed out of the body. ^{18}O disappears faster from the body than ^{2}H because it is lost in both urine and as carbon dioxide in breath. ^{2}H is

only lost from the body in urine. The difference between how fast ^{2}H and ^{18}O disappear provides a measurement of carbon dioxide production and this can then be converted into the amount of energy used.

Dual-energy X-ray absorptiometry (DEXA)	A technique used to measure bone mineral density.
Early childhood caries (ECC)	ECC is defined as one or more decayed, missing or filled tooth surface in any primary tooth of children aged under 71 months. In children younger than 3 years of age, any sign of decay on the smooth surface of the teeth is indicative of severe early childhood caries (S-ECC) (American Academy of Pediatric Dentistry, 2008)
Estimated average requirement (EAR)	Estimated Average Requirement of a group of people for energy or protein or a vitamin or mineral. About half of a defined population will usually need more than the EAR, and half less.
Ever breastfed	Infants who have been put to the breast, even if only once, including infants who have received expressed breast milk but have never been put to the breast.
Exclusive breastfeeding	Exclusive breastfeeding is defined as no other food or drink, not even water, except breast milk (including milk expressed or from a wet nurse) for 6 months of life, but allows the infant to receive oral rehydration solutions, drops and syrups (vitamins, minerals and medicines).
Fat free mass (FFM)	The non fat component of body composition comprising muscle, bone, skin and organs.
Fat mass (FM)	The component of body composition made up of fat.
Formula, Infant formula	A breast milk substitute commercially manufactured to Codex Alimentarius or European Union standards.

Free sugars	All added sugars in any form; all sugars naturally present in fruit and vegetable juices, purées and pastes and similar products in which the structure has been broken down; all sugars in drinks (except for dairy-based drinks); and lactose and galactose added as ingredients (Swan et al, 2018).
Full breastfeeding	Describes groups of infants who individually are either exclusively or predominantly breastfed.
Gastroenteritis	Case defined as: someone who presented to the General Practitioner with loose stools or significant vomiting < 2 weeks, in the absence of a known non-infectious cause and preceded by a symptom-free period of 3 weeks.
Gestational age	The age of a fetus calculated from the first day of the mother's last menstrual period.
GRADE system	The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system is an approach to grading evidence and recommendations (Guyatt et al, 2011). The assessment of the evidence using the GRADE system involves consideration of within-study risk of bias (methodological quality), directness of evidence, heterogeneity, precision of effect estimates and risk of publication bias (www.gradeworkinggroup.org). The interpretation of GRADE evidence assessments is that where the quality of the evidence is rated as HIGH, there is considerable confidence that the true effect lies close to that of the estimate of the effect; when rated as MODERATE, there is moderate confidence in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; when rated as LOW, confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Where the quality of evidence is rated as VERY LOW, there is very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect (COT, 2016b).
Hazard ratio (HR)	The hazard ratio is a comparison of the effect of different variables on survival or other outcomes that develop over time.

Head circumference	The circumference of the head measured at the level of the frontal and occipital prominences, its largest diameter.
Healthy Start	UK-wide government scheme to offer a nutritional safety net for pregnant women, new mothers and children under 4 years of age in very low income families, and encourage them to eat a healthier diet. The scheme provides vouchers to put towards the cost of milk, fruit and vegetables or infant formula, and coupons for free Healthy Start vitamin supplements.
High income country (HIC)	The World Bank defines economies into four income groupings: low, lower-middle, upper-middle, and high. Income is measured using gross national income (GNI) per capita, in US dollars, converted from local currency using the World Bank Atlas method. Estimates of GNI are obtained from economists in World Bank country units; and the size of the population is estimated by World Bank demographers from a variety of sources, including the United Nation's biennial World Population Prospects. Currently a HIC is defined as having a GNI per capita of $12,236 or more (https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries).
Hypernatraemic dehydration	An abnormally high serum sodium concentration (>150mEq/l) caused by dehydration.
Incidence of breastfeeding	Proportion of babies who were breastfed initially. This includes all babies who were put to the breast at all, even if this was on one occasion only. It also includes giving expressed breast milk to the baby.
Infant	A child not more than 12 months (1 year) of age.
Infant Feeding Survey (IFS)	National survey of infant feeding practices conducted every 5 years from 1975 to 2010. The survey provided national estimates of the incidence, prevalence, and duration of breastfeeding (including exclusive breastfeeding) and other feeding practices adopted by mothers in the first 8 to 10 months after their infant was born. In the more recent surveys these estimates were provided separately for England, Wales, Scotland and Northern Ireland, as well as for the UK as a whole.

Intervention study	Comparison of an outcome (for example, disease) between two or more groups deliberately subjected to different exposures (for example, dietary modification or nutrient supplementation).
Linear growth	An increase in the length or height of an infant/child.
Low and middle income country (LMIC)	The World Bank defines economies into four income groupings: low, lower-middle, upper-middle, and high. Income is measured using GNI per capita, in US dollars, converted from local currency using the World Bank Atlas method. Estimates of GNI are obtained from economists in World Bank country units; and the size of the population is estimated by World Bank demographers from a variety of sources, including the UN's biennial World Population Prospects. Currently a LMIC is defined as having a GNI per capita of $1,006 to $3,955 (https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries).
Longitudinal study	In a longitudinal study, individual subjects are followed through time with continuous or repeated monitoring exposures, health outcomes, or both.
Low birthweight	Low birthweight is defined as less than 2,500g (up to and including 2,499g). Infants may be low birthweight because they are born too early or are unduly small for gestational age.
Lower reference nutrient intake (LRNI)	The estimated average daily intake of a nutrient which can be expected to meet the needs of only 2.5% of a healthy population. Values set may vary according to age, gender and physiological state (for example, pregnancy or breastfeeding).
Macronutrients	Nutrients that provide energy, including fat, protein and carbohydrate.
Malocclusion	Malocclusion describes the alignment of teeth which are considered not to be in a normal position in relation to adjacent teeth (that is, the teeth are not correctly aligned).
Margin of exposure	This approach provides an indication of the level of health concern about a substance's presence in food. EFSA's Scientific Committee states that, for substances that are genotoxic and carcinogenic, an MOE of 10,000 or higher is of low concern for public health.

Meta-analysis	A quantitative pooling of estimates of effect of an exposure on a given outcome, from different studies identified from a systematic review of the literature
Micronutrients	Essential nutrients required by the body in small quantities, including vitamins and minerals.
Mixed feeding	'Partial breastfeeding' or 'mixed feeding' describes the use of breast milk alongside other liquid or solid foods, for example infant formula or 'weaning' foods.
Nursing caries	Nursing caries is a specific form of rampant decay of the primary teeth of infants that affect at least two maxillary incisors. These carious lesions occur on surfaces generally considered to be at low risk to decay, such as proximal surfaces of mandibular anterior teeth, facial surfaces of maxillary anterior teeth, and lingual surfaces of posterior teeth. A key feature of nursing caries is the usual absence of decay of the mandibular incisors, thus differentiating this condition from classical rampant caries. (Ripa, 1988; Al-Dashti et al, 1995)
Nutrient deficiency	Impaired function due to inadequate supply of a nutrient required by the body.
Odds ratio (OR)	A measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared with the odds of the outcome occurring in the absence of that exposure. The OR is adjusted to address potential confounding.
Parity	Number of times a female is or has been pregnant and carried the pregnancies to a viable gestational age.
Parous women	Women who have given birth.
Partial breastfeeding, or mixed breastfeeding	Breast milk is used alongside complementary feeding, for example infant formula or solid foods
Ponderal growth	A measure of leanness calculated as the relationship between mass and height (weight/length)

Postpartum amenorrhea	Absence of menstruation following childbirth.
Predominant breastfeeding	Breast milk is the main source of nutrition though other liquids (such as drinks, teas or oral rehydration solutions) may be given provided that they are not food-based
Premastication	The process where by an adult chews food or another item such as a herb or traditional medicine and then feeds it to the infant. This is sometimes referred to as prechewing.
Protein hydrolysed formula (PHF)	Supplies protein nutrients in a 'predigested form'. They are available on prescription for infants with diagnosed cows' milk allergy and those infants who are unable to tolerate other intact proteins.
Rampant caries	Sudden onset of widespread caries that affects most of the teeth and penetrates quickly to the dental pulp.
Randomised controlled trial (RCT)	A study in which eligible participants are assigned to two or more treatment groups on a random allocation basis. Randomisation assures the play of chance so that all sources of bias, known and unknown, are equally balanced.
Reference nutrient intake (RNI)	The average daily intake of a nutrient sufficient to meet the needs of almost all members (97.5%) of a healthy population. Values set may vary according to age, gender and physiological state (for example, pregnancy or breastfeeding).
Relative risk (RR)	The ratio of the rate of disease or death among people exposed to a factor, compared with the rate among the unexposed, usually used in cohort studies (World Cancer Research Fund & American Institute for Cancer Research, 2007).
Responsive feeding	Aa form of 'responsive parenting', in which parents are aware of their child's emotional and physical needs and react appropriately to their child's signals of hunger and fullness.
Risk factor	A factor demonstrated in epidemiological studies to influence the likelihood of disease in groups of the population.

Safe intake	Safe Intakes are set for some nutrients if there is insufficient reliable data to establish DRVs. They are based on a precautionary approach and are 'judged to be a level or range of intake at which there is no risk of deficiency, and below a level where there is a risk of undesirable effects (DH, 1991).
Solid foods	Foods other than breast milk or formula milk introduced to the infant diet at the commencement of complementary feeding.
Systematic review	An extensive review of published literature on a specific topic using a defined search strategy, with a priori inclusion and exclusion criteria.
Tolerable upper level (TUL)	A tolerable upper intake level (TUL) is intended to specify the level above which the risk for harm begins to increase, and is defined as the highest average daily intake of a nutrient that is, likely to pose no risk of adverse health effects for nearly all persons in the general population, when the nutrient is consumed over long periods of time, usually a lifetime.
Weaning	The process of expanding the diet to include foods and drinks other than breast milk or infant formula (DH, 1994). The term complementary feeding is preferred to describe diversification of the diet because 'weaning' has also been used to describe curtailment of breastfeeding.
Young child	A child aged between 12 and 36 months (1 and three years).
Z-score	The Z-score (or standard deviation (SD) score) is defined as the difference between an observed value for an individual and the median value of the reference population, divided by the standard deviation value of the reference population. Z-scores are used for height, weight and head circumference.

Annex F Abbreviations

ALSPAC	Avon Longitudinal Study of Pregnancy and Childhood
AOD	Aortic root diameter
AOM	Acute otitis media
AOR	Adjusted odd ratio
BLW	Baby-led weaning
BMD	Bone mineral density
BMI	Body mass index
BP	Blood pressure
BPA	Bisphenol A
BRAFO	Benefit:risk analysis for foods
COMA	Committee on Medical Aspects of Food and Nutrition Policy
CF	Complementary feeding
CI	Confidence interval
COT	Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
DEXA	Dual-energy x-ray absorptiometry
DFS	Decayed and/or filled surface
DH	Department of Health
DHSS	Department of Health and Social Security
DLW	Doubly labelled water method
DMF	Decay, missing, filled (teeth or surface)
DNSIYC	Diet and Nutrition Survey of Infants and Young Children
DOI	Declaration of interest
DRV	Dietary reference value
EAR	Estimated average requirement
EBF	Exclusive breastfeeding
ECaC	European Code against Cancer programme
ECC	Early childhood caries
EFSA	European Food Safety Authority
ESPGHAN	European Society for Paediatric Gastroenterology, Hepatology and Nutrition

FAO	Food and Agriculture Organization
FFM	Fat free mass
FFQ	Food frequency questionnaire
FM	Fat mass
FSA	Food Standards Agency
FS	Fractional shortening
GNI	Gross national income
GRADE	Grading of recommendations assessment, development and evaluation
HDL	High-density lipoprotein
HIC	High income countries
HR	Hazard ratio
ICDAS	International caries detection and assessment system
ID	Iron deficiency
IDA	Iron deficiency anaemia
IFS	Infant Feeding Survey
IOM	Institute of Medicine
IQ	Intelligence quotient
LAD	Left atrial diameter
LDL	Low-density lipoprotein
LRNI	Lower reference nutrient intake
LRTD	Lower respiratory tract disease
LRTI	Lower respiratory tract infection
LMIC	Low and middle income countries
LV	Left ventricular
MCV	Mean corpuscular volume
MOE	Margin of exposure
NCHS	National Centre for Health Statistics
NDNS	National Diet and Nutrition Survey
NHANES	National Health and Nutrition Examination Survey
NICE	National Institute for Health and Care Excellence
NMES	Non-milk extrinsic sugar

OR	Odd ratio
PAHO	Pan American Health Organization
PBDE	Polybrominated diphenyl ether
PCA	Principal components analysis
PHE	Public Health England
PHF	Protein hydrolysed formula
PROBIT	Promotion of Breastfeeding Intervention Trial
PUFA	Polyunsaturated fatty acid
PWV	Pulse wave velocity
RCPCH	Royal College of Paediatrics and Child Health
RCT	Randomised controlled trial
RE	Retinol equivalents
RNI	Reference nutrient intake
RR	Relative risk
SACN	Scientific Advisory Committee on Nutrition
SD	Standard deviation
SES	Socio-economic status
SMCN	Subgroup on Maternal and Child Nutrition
SWS	Southampton Women's Survey
TEE	Total energy expenditure
TUL	Tolerable upper limit
UNICEF	United Nations International Children's Fund
UNU	United Nations University
UVB	Ultraviolet B
WHO	World Health Organization
WHO MGRS	World Health Organization Multicentre Growth Reference Study

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