An evidence based guide to weaning preterm infants

Caroline King

Abstract

There have been national guidelines for weaning infants for many decades in the UK however none have addressed preterm infants until the COMA report of 1994 which gave brief recommendations. More recent publications don't include recommendations for preterm infants and it is acknowledged that for this group there is a need for separate guidelines; however none to date have been published. In this article the evidence base around weaning preterm infants is discussed and updated guidelines are suggested.

It is suggested that preterm infants should be considered for weaning between 5 and 8 months uncorrected age to ensure that sensitive periods for the acceptance of solids are not missed and to allow development of appropriate feeding skills. The exact time within this 3 month window will depend on the individual infants' needs and cues. Although prematurity is usually defined as birth before 37 completed weeks, those healthy preterm infants born from 34 completed weeks onwards in general may be weaned according to the same guidelines as for term infants.

To allow for a degree of motor development which may help with positioning it is suggested that it may be useful to delay weaning until after 3 months corrected age. However the assessment of infant cues are paramount when making the final decision and each baby should be treated as an individual according to his/her own developmental readiness.

Keywords guidelines; preterm; weaning

Introduction

In this article weaning is defined as the introduction of solid food into an infants' diet, also known as complementary feeding.

There have been national guidelines for weaning infants for many decades in the UK however none have addressed preterm infants until the COMA report of 1994 which gave brief recommendations.[1] More recent publications don't include recommendations for preterm infants and it is acknowledged that for this group there is a need for separate guidelines[2]; however none to date have been published. In this article the evidence base around weaning preterm infants is discussed and guidelines are presented.

Why are specific guidelines needed?

As in-patients many of these infants receive extensive high technology care and individualised nutrition. However, this vulnerable group who are known to be at risk for poor growth receive very little general or individualised advice on weaning, particularly its timing. There is a risk that poor weaning practice could lead to nutritional compromise, which the preterm infant is poorly equipped to withstand.

Caroline King *BSc SRD is a Paediatric Dietitian (Neonatal Specialist) at the Department of Nutrition & Dietetics, Hammersmith Hospital, Imperial Hospitals NHS Trust, Du Cane Road, London W12 OHS, UK.*

Difficulties around weaning can be accentuated by conflicting advice from health professionals, family and friends, many of whom have little experience with this group of infants. In addition mothers may experience more anxiety compared to mothers of term infants which can impact on feeding. This guideline seeks to give information based on published evidence where ever possible in an attempt to avoid conflicting advice[3] and to supply a recognised need.[4]

When have preterm babies been weaned in the past?

Studies carried out around 20 years ago found weaning occurred between 2 weeks and 4 months corrected age[5] and by 4 months uncorrected.[6] Another more recent study found two peak times for weaning 12 and 16 weeks uncorrected age, but there was a wide range.[7]

Preterm infants born in the mid 1990s were more likely to be on solids both at 6 and at 12 weeks corrected than term infants.[8] In another study 21% of babies studied were weaned before reaching 5 kg[9] as with term babies this study showed that breast fed preterm babies were weaned later than formula fed. Others have found weaning occurring around 7 weeks corrected age[10]; and in more recent samples 22 and 24 weeks uncorrected respectively.[11,12]

Guidelines for term babies

In 2001 the Scientific Advisory Committee on Nutrition (SACN), discussed the World Health Organisation (WHO) recommendation for exclusive breastfeeding for the first 6 months with introduction of solids thereafter. It was acknowledged that this recommendation applies to populations and that the considerations for low birth weight infants would have to be met under a different recommendations.[13]

In 2003 the UK adopted a version of the recently updated WHO guidelines on weaning.[2] WHO advised exclusive breastfeeding to 6 months, whilst the UK government adapted this to advise the delay of solid food until 6 months: while encouraging exclusive breastfeeding. It was acknowledged that this was a guideline for populations and adapted guidelines may be needed for special groups of infants.

In the USA it was also felt that in certain circumstances some special groups may need to start solids at a different time from the population guidance.[14]

Why wean

It is useful to look at the reasons why this process occurs and then evaluate how it applies to preterm infants. There are many reasons for initiation of the weaning process, not all will be covered here. Instead those factors most pertinent to the debate around weaning preterm infants will be discussed, through a comparison of term and preterm data.

Iron

Exclusively breast-fed term infants appear to maintain iron status until approximately 6 months,[15,16] whereas those fed a cow's milk formula not fortified with iron will become depleted by approximately 4 months and preterm infants by approximately 2 months.[15] Maintenance of iron status therefore may be given as a reason for weaning. It is recommended that breast fed preterm

infants are routinely supplemented with 2–4 mg iron/kg/day post discharge, or, if not breastfed, given formula which will supply an equivalent amount.[17] Post discharge formula with a higher iron level than term formula is useful for the first few months corrected age, however after that time iron fortified formula designed for term infants appears to be sufficient to maintain iron status for the majority. There is some evidence that formula with levels as low as 0.8 mg/kg maintain normal iron status in the first months following discharge from the neonatal unit.[18] However there were small numbers of extremely low birthweight infants in this cohort who may need the higher dose in the early months post discharge to replenish their initially smaller stores.

In term infants there is evidence for up regulation of iron absorption between 6–9 months allowing adaptation to lower iron intakes.[19] In this study complementary foods were found not to reduce iron absorption from breast milk, the equivalent study has not been carried out in preterm infants and would useful additional information to help form appropriate weaning advice.

A randomised controlled trial evaluated weaning at a mean age of 15 or 17 weeks uncorrected, with guidance on using foods which were of high nutrient density.[20] The early weaning group were advised to use preterm formula to make up weaning solids, but the main milk drink was not controlled for in either group, and was either breast milk or term formula. At 6 months the early weaning group had significantly higher haemoglobin and serum iron, although no babies in either group were anaemic.

In summary; maintenance of iron intake is not a prime reason for weaning in preterm infants, as breast fed babies are recommended to receive an iron supplement until they are assessed as having sufficient iron in their diet and formula fed babies are now usually given an iron enriched post discharge formula.

Energy

Term infants will reach the point where milk consumption does not satisfy energy requirements and the introduction of solid food helps by providing relatively energy dense nutrition.[21] They are sensitive to dietary energy density but below a certain level they cannot up regulate volume sufficiently to supply needs.[22]

In the initial stages the weaning diet will not make a significant contribution to energy needs but eventually, with appropriate choice of food groups, it will do. In normal development there appears to be a pattern of increase in energy density of the diet over the first year of life.[23]

Reduced intake of breast milk has been shown following introduction of solids in well fully breast fed infants.[24,25];though reduced growth has not been shown.[25–28]

There is contradictory evidence with respect to formula-fed term infants, one paper showing no reduction[24] another showing a decrease in formula intake with weaning.[26] Some have shown that weaning can lead to a reduction in dietary energy density[29] however this need not always be the case.[30]

As with term infants there is some evidence that introduction of solids in preterm infants leads to a reduction in milk intake.[5]

In summary; for formula fed preterm infants a higher energy density feed could be given if needed, so for this group strictly speaking weaning is not needed to provide a more nutrient dense diet until later in the first year. However for breast fed babies energy will eventually become limiting and complementary feeding will be needed to supply needs.

Oro motor development

In the first year of life a large number of anatomical, developmental and neurological changes occur which influence feeding in term infants allowing the change from exclusive milk feeding to solids by spoon and by hand.[31]

Throughout the first 2–3 years feeding skills are continuously refined, ultimately resembling mature feeding behaviour: a combination of developmental changes and experience with food aiding the acquisition of these skills.[32,33]

The newborn takes milk initially via suck feeding involving reflexive rhythmic up and down jaw and tongue movement. Progression is made to the more mature oral patterns as the tongue is able to move independently of the jaw; a step towards aiding the oral manipulation of soft food. Then as the reflexive suck diminishes lateral tongue movements develop to enable chewing of more textured food[33] It is not known how much this progression is pre-programmed and how much learnt, but infants who lack the opportunity to practise skills at the appropriate time appear to be a risk of later feeding problems.

Lip seal, to enable spoon clearance has been suggested as a sign of readiness to wean,[1] however efficient lip seal is not usually seen until around 8 months in term infants and therefore is not a useful sign.[34]

The protrusion or extrusion reflex of the tongue occurs in full term neonates in response to touching the tongue tip; it diminishes after 4–6 months aiding the acceptance of solids. It has been described as the tongue thrust reflex[1] and it has been suggested that weaning should occur once this reflex is seen to diminish.[1] The term ''protrusion reflex'' is a better description of this normal developmental stage as ''tongue thrust'' is a commonly used term suggestive of neurological impairment. Some tongue protrusion often persists even after weaning has started, gradually disappearing with the progression of solids: in term infants this tongue movement may persist until 9 months.[34] The first solids are often approached with in-out tongue movements so some food will be pushed out of the mouth.[31]

In term infants lip seal develops and tongue protrusion subsides over variable periods of time, probably aided by the introduction of semi-solids by spoon. In the absence of firm evidence it seems reasonable to assume that preterm babies also learn to refine these skills once semi-solids have been introduced, rather than waiting for them to develop independently. For this reason it seems appropriate to wait for lip seal and tongue protrusion to diminish but not disappear before weaning is started.

In summary it is not necessary to wait for lip seal to develop and tongue protrusion to diminish before weaning – in fact they may only mature with the aid of weaning.

Development of taste

The term taste is used in this section, although flavour would be a better description as flavour is a combination of taste and odour.

Neonates are born with a preference for sweet tastes, and neutrality or aversion to others,[35] however altered facial expressions are demonstrated in both preterm and term infants when presented with acid, sugar and bitter tastes.[36]

It has been suggested that rejection of bitter taste doesn't occur until beyond the neonatal period,[37] and indeed infants up to 4 months old have been shown to easily become fully

acclimatised to bitter tasting protein hydrolysate formula, beyond which acceptance of such formulas greatly diminishes.[38]

By 4–6 months a preference for salt taste has been demonstrated in term infants by some,[39,40] which may coincide with the ability of the kidney to handle a higher solute load[41]; however others have not made the same finding.[42,43] An increase in acceptance of salt may be more dictated by maturation than experience.[40,44] One study which found no preference for salted food did not control for mothers possibly overriding their infants satiety cues.[42]

As the sucking reflex diminishes the older infant begins to exert more control over feeding, willingly ingesting or refusing food. Refusal could be the result of many factors including satiety, and unfamiliar textures or tastes.

From 4–5 months a term infant can express a wide variety of communicative behaviours especially at meal times e.g. vocalising eagerness when items associated with feeding are seen and communicating hunger, discomfort, food preferences, satiety and the preferred speed of delivery of food.[40,45,46] These cues can be subtle so it is key that the person feeding watches the baby carefully to avoid overriding them.

From around a year a child may more consciously begin to take control by refusing food, reflecting their increasing autonomy.[33,47,48] This is different from refusal of an unknown food (neophobia) which can develop around 12 months but is more usual at later ages.

A larger variety of flavours given in the initial stages of weaning enhances acceptance of a novel food later.[49,50]

In one study feeding of a strong tasting protein hydrolysate formula from the first week of life increased acceptance of an alternative unpalatable novel formula at 7 months.[38]

Once weaning commences infants given repeat exposure to a food will increase acceptance in most cases.[43] In this study infants were given the test food once a day for 10 days.

Sight of food alone is not sufficient to increase acceptance. In young children it has been shown that they must also get the opportunity to taste and touch food.[51,52] There is evidence that repeat exposure to an initially refused new food will increase acceptance. In toddlers it is thought to take at least 10 exposures to enhance acceptance of a new food – with a suggested frequency of 2–3 exposures per week.[51,53] Facial expressions assumed to be distaste could lead to reduced exposure of a particular food,[54] however this may not mean that the food will not be accepted eventually with continued exposure. Development of food acceptance is enhanced with the inclusion of the child in family meals giving plenty of opportunity to watch, learn and imitate feeding.[55–57] Strong family similarities have been noted in preferred foods.[58]

Persistent refusal of a particular food may be due to genetic variation in taste perception which has been shown for bitter[59] and sweet.[60] In these situations if only a few foods are refused it will not compromise nutritional input.

In one survey 19% of a sample of 95 mothers thought a wide variety of tastes was important but another 14% believed that weaning foods should be bland.[61] Where carers have perceived that babies only like bland foods, or if they are not adventurous themselves they will need encouragement to be bold with the variety of tastes they give their babies. Good reviews around this area include.[62–64]

The fetus is exposed to amniotic fluid flavoured by mothers diet while in utero.[65] It is thought that this exposure to the mothers diet continues via breast feeding.[66] However it is not known how far this applies to babies who are tube fed who don't have frequent close contact with their mothers.

In summary; it is not known how any sensitive period for taste is affected by preterm birth. However, from data on term infants it seems highly likely that the later a preterm infant is introduced to new tastes the less likely they are to accept a wide variety of foods. A continued emphasis on offering a wide variety of foods in an appropriate social context is likely to be of long-term benefit.[67]

Acceptance of new textures

From around 6 months to early childhood chewing is continuously developed.[47,68] Observational evidence suggests that this skill is aided by provision of foods of an appropriate texture.[33]

There is discussion around the introduction of solids to term infants with a move towards allowing the infant to take and eat food itself when he/she is ready, often termed ''baby led weaning''.[69] This has developed for many reasons one being that there does not seem to be any evidence to support puree as the first food texture in healthy term infants. With this approach first foods can be quite highly textured. However preterm infants will often not have the skills to begin weaning in this way. To ensure safety with baby led weaning it is recommended that a term infant is able to sit unaided, grasp food and take it to their mouth, actions which may be delayed in a preterm infant. The proponents of baby led weaning speculate that this approach encourages infants to take a wider variety of foods. Future research in this area with respect to term, and an appropriately modified approach preterm infants, would be of interest as there may be advantages for both groups.

The later that weaning is started the more rapidly an infant should progress through textures with the promotion of finger foods as soon as the infant shows cues that they are ready to try them. This may help develop hand eye co-ordination and allow the child more control during feeding. As with term infants it is essential that the infant is never left unattended when eating.

It has been suggested that delay in introduction of lumpy foods can lead to feeding problems if a sensitive period is missed, probably between 6 and 9 months.[70–73] These were all observational studies and therefore do not conclusively prove this relationship, nevertheless the well accepted concept of programming during a sensitive period in development would explain it.[33] The introduction of lumpy food should not be delayed until the appearance of teeth as they are not needed by the infant for chewing.[32]

The ability to chew foods is probably aided by giving foods of the appropriate texture at the appropriate time. Although the theory of a critical or sensitive time for acceptance of lumps has not been tested in a randomised controlled trial there are many anecdotal observations of feeding problems following delay of the usual weaning pattern - due to severe chronic illness, surgery, nasogastric feeding or gastrostomy feeding.

In summary; it seems prudent to advise that most preterm infants should at least be offered lumps before 9 months uncorrected age. Some infants may progress rapidly with increasingly textured food, others with more delayed development will need to go more slowly – individualised advice is essential.

Sleeping time

More frequent waking for feeds and particularly night waking is often used as a cue for weaning. However there is evidence from

studies in term infants that starting solids did not alter sleep patterns. One study randomised babies to solids at bed time from either 4 weeks or 4 months after birth and found no difference in sleep time between groups.[74] Another was observational and found that age of giving solids was not related to the frequency of night feeding.[24] Although a review of the literature found that breast fed term infants were more likely to be sleeping through the night at 9 months if they had been weaned before 12 weeks, this effect wasn't seen in formula fed infants, and in preterm infants there was no relationship between time of weaning and sleep in either breast or formula groups.[75]

Conclusion

Behavioural and developmental issues may be more important to consider than nutritional ones when deciding why to wean preterm infants; although close attention is also needed to ensure nutritional adequacy through the weaning period. It is suggested that most preterm infants may be ready to wean some time between 5 and 8 months from birth.

Potential problems perceived with weaning between 5 and 8 months from birth

Weaning between 5 and 8 months from birth may appear to some to be potentially problematic as it may be considered too early. The following is an examination of problems which have been suggested and exploration of the strength of the evidence for them, and a final summary.

Gastrointestinal

Immature gut barrier function In preterm infants gut barrier function has been assessed both by milk protein and sugar absorption; with the former showing increased absorption by the preterm gut intact into the circulation[76] and the latter that the gut barrier appears to adapt rapidly post natally independent of gestational age or birth weight.[77]

There is work suggesting that in infants born at 32–36 weeks gestation, gut permeability is reduced by the 30th postnatal day.[78] Earlier it was shown that by 37 post-conceptual weeks, macromolecular absorption in premature infants was similar to those born at term during their first postnatal month.[79]

Animal studies suggest that the current practice of giving antenatal steroids to a mother threatening preterm delivery may accelerate intestinal mucosa, as well as lung maturation,[80] although this has not been shown in humans.

The initiation of enteral feeding may enhance this process as it is associated with an earlier decrease in intestinal permeability[81] and improved mineral absorption.[82] This evidence indicates that the maturation of the preterm infants gut barrier function occurs well before weaning would be considered and is accelerated by enteral feeds and possibly by the administration of ante natal steroids.

Immature digestive capacity Despite their immaturity the majority of preterm infants are digesting and absorbing whole proteins, lactose and dietary fats well before they reach term due date; some many months earlier.

Preterm infants are able to digest simple carbohydrate and protein from early on postnatally.[83–86] Pancreatic function in infants born <28 weeks gestation may take 2 weeks to reach normal levels.[87] Baseline pepsinogen is lower in preterm compared to term infants however there is evidence that it is secreted appropriately in response to enteral nutrition.[88] Pepsin activity is dependent on a pH below 5, in moderately premature infants gastric acid secretion appears sufficient.[89,90] External factors such as medication which raises stomach pH above 5 may adversely affect protein digestion.[91]

Fat digestion will be the most compromised early on as pancreatic lipase takes the longest to mature. However, there is evidence that ability to digest fat is adequate in preterm infants.[92,93] Rate of maturation is dependent on post conceptual age, postnatal age and timing of enteral feeding.[94] Dietary fat can enhance gastric lipase in preterm infants[95]: gastric and lingual lipase being especially important in the preterm infant.[96] As breast milk contains both amylase and bile salt stimulated lipase,[97,98] breast-fed infants have additional mechanisms to digest starch and lipid.

The human fetus demonstrates low lactase levels up until late in gestation. However, in infants born as early as 26 weeks post conception, enteral feeding, particularly with human milk leads to a significant rise in lactase activity.[99,100]

In summary the digestive capacity of the preterm infant starts lower than in the term born counterpart but maturation accelerates post natally to give adequate function by the time weaning is likely to occur.

Immature motor function The post-prandial motor response of the neonates small intestine has been shown to be related to volume of enteral bolus and number of days enteral feeds have been given: post conceptional age was not an important determinant of motor response.[101] Similarly early enteral feeding accelerates the development of mature gut motility patterns compared to late fed control preterm infants.[102] This indicates that development of gut motor function is accelerated post delivery, whatever the gestation of the infant, as long as enteral feeds are given.

Insufficient gut hormones In fetal mammals amniotic fluid is swallowed and exerts a trophic effect on the stomach ensuring normal gastric acid secretion.[103] Therefore being kept nil by mouth for long periods post delivery is unphysiological and risks delaying post natal gut maturation. If enteral feeding is instituted shortly after birth even minimal feedings in preterm infants can lead to a significant increase in gut hormones.[104] This does not occur in infants given intravenous nutrition alone.[105]

Summary Although the human gut may develop according to a preset biological clock, up until approximately 25 weeks gestation[106,107] all the evidence points to precocious maturation as a response to the trigger of enteral feeding; particularly if human milk is used rather than formula. *A preterm enterally fed infant will have a more mature gut once it reaches term date than its counterpart born at term*.

Renal immaturity

The number of nephrons continues increasing in preterm infants until approximately 36 weeks' post-conceptual age. However individual functional maturation occurs from birth, be it term or preterm, triggered by the contraction of extra cellular water which occurs post natally.[108] This precocious renal maturation

suggests adequate preparation for weaning in preterm infants. One study has indicated normal serum biochemistry in preterm infants weaned from 2 weeks corrected age.[5] This is well before it is recommended that weaning should occur, and as with term infants it is important to ensure that carers do not give food with an unacceptably high renal solute load.

High risk of allergy

It has often been suggested that preterm infants are at increased risk of food allergy due to immaturity of the gut and immune system, however, if anything evidence points to the opposite.

A large epidemiological study found that in a group of 443 children with atopic eczema there was a significant lack of subjects born before 37 weeks' gestation.[109] Others have either confirmed that preterm infants have a lower incidence of eczema compared to term infants[110–112] or found no difference.[113–116]

One group looked at low birth weight and prematurity separately and found only fetal growth restriction to be associated with increased risk of atopic disease.[117] Preterm infants have been found to have low levels of antibodies to cows milk[118,119] and gliadin.[118]

In a randomised controlled study of weaning in preterm infants unpublished data on skin prick tests at 18 months found no difference in results between those weaned at a mean age of 15 vs. 18 weeks uncorrected; around half of the original cohort of 68 were tested with only 2 positives (Foote,K & Marriot, L personal communication).

A prospective randomised study of hydrolysed protein preterm formula in infants at high risk of allergy has been reported. Randomisation to hydrolysed formula in the neonatal period failed to show any reduction in the incidence of allergic disease at either 4 or 12 months, although the risk of atopic dermatitis was reduced at 12 months.[120]

There are some studies which have suggested that preterm infants are at increased risk of allergies. In a group of small for gestational age infants, of which an unspecified number were preterm a high level of allergy was reported at 12 months.[121]

Another group has shown significantly more allergic symptoms cumulatively to the age of 11 years in human milk fed preterm infants compared to those fed formula, however, incidence was not different between groups or the general population at 11 years.[122] While another found that preterm infants with a strong family history of atopy were more at risk of atopic symptoms; there was no link with breast feeding or the time of starting allergenic foods.[123]

In a group of preterm infants followed prospectively introduction of 4 or more foods before 17 weeks post term was associated with higher risk of eczema at one year.[124] However the authors and an accompanying editorial pointed out that at that time an authoritative statement on the introduction of solids and the development of allergy was still not possible,[125] and certainly not for preterm infants.

Preliminary data from a further study showed a higher incidence of atopy at 8 months in those weaned early (at 12 rather than 16 weeks), but at 12 months there was no difference.[7]

Preterm infants do seem to be at more risk of wheeze[126] (in this study atopy was only associated with later not early wheeze) this may be due to lung damage in the neonatal period.[127]

It seems likely that preterm infants are no more likely to develop atopic disease than term infants.

The current guidelines for babies at low risk of allergy is to introduce any foods from the start of weaning, as long as they are low in salt.[128] However, if there is a family history of atopy a more cautious approach is recommended.[129] It seems reasonable to apply the same strategies to preterm infants.

Developmental and oro motor immaturity

Head control and trunk stability provide the necessary gross motor skills for the fine motor control of hands and mouth needed during weaning.

There is evidence that motor development matures according to post conceptional rather than post natal age and that both fine and gross motor development are adversely affected by preterm birth.[130]

Preterm infants who have prolonged illnesses often have poor somatic growth, which can contribute further to gross motor delay; resulting in poor head control, reduced trunk stability and immature oral-motor skills. It is useful to wait until a certain level of motor and developmental maturity has been achieved prior to weaning: head control being important, however many preterm infants will not be able to sit unaided even though other cues are present indicating that weaning could start.

There is some evidence that waiting until around 3–4 months corrected age will allow some progression with motor skills ensuring adequate head control; as all preterm infants appear to have delayed motor development[130]; however individual assessment of cues remains essential.

In high risk preterm infants the majority have been observed to hold their head in the midline at 4 months corrected and well over half able to sit supported at this age. There have been observations that some carers may delay weaning foods of a more challenging texture as they assume their infant is not able to manage them, presumably due to motor delay.[46] However these infants may in fact be able and ready to move onto more textured food, and would benefit from the opportunity to start experiencing these foods. Mothers of more robust term infants give them more opportunity for motor activity – so may also allow them more self feeding opportunities[131] this may also apply to mothers of preterm infants.

Concerns have been raised that weaning an infant with immature oro motor function constitutes passive over, or force feeding.[6,132] However term infants as young as 4 months and certainly by 6 months can direct feeding interactions by showing food preferences and satiety,[40,45] and there is some evidence that preterm infants can also do this.[46]

Feeding skills are continuously refined over the early years as infants move towards a more adult type diet. The risk of leaving weaning too late must be balanced against the risks of passive over feeding. If weaning is left too late progress may be more difficult due to the overshooting of periods where the infant is receptive to change.

To reduce the risk of feeding problems it is important that the person feeding prepares an optimal environment.[133] Caregiver/infant interaction is vital, the caregiver has the responsibility to closely observe and react to the infants' cues to recognise both hunger and satiety.

Obesity

Some have suggested that early introduction of solids to preterm infants, particularly cereals, could result in obesity.[6] Although this has been a concern in term infants it has not been borne out by longitudinal follow-up studies.[75,134]

Obesity is a problem rarely seen in preterm infants whatever their age at weaning. In fact, despite reporting early introduction of cereals in a preterm cohort no problem with obesity was reported.[6] The time when rapid weight gain is often seen is the period soon after discharge, before weaning has started.

Compromised nutritional density of diet

This is a risk as many of the traditional first weaning foods have a lower energy density than the milk they will replace. Italian mothers of preterm infants were found to start with fruit and didn't move onto meat until 5 weeks after the initiation of weaning,[11] this would reduce the nutrient density of the diet as the infants would have been likely to reduce the volume of milk taken once solids were started.[5]

In young malnourished children it has been suggested that an minimum energy density of 0.7 kcal/g (roughly equivalent to breast milk) is needed to optimise catch up growth.[135] Meals must also be offered sufficiently frequently to allow enough food to be eaten.[135]

Intervention, in the form of a randomised controlled trial to promote early weaning along with specific advice to optimise nutrient density of the diet, lead to greater energy intake and greater weight and length at 6 months compared to a control group.[20]

It appears then that introduction of solids leads to a risk of reduction in dietary nutrient density, which could compromise growth. Advice to ensure maintenance of nutrient density in the weaning diet is advisable.

In those infants where poor growth is an issue dietetic supervision during weaning is recommended.

Summary

In the majority of cases there is not sufficient evidence to back the suggestion that weaning between 5 and 8 months from birth will put the preterm infant at risk.

Special considerations for sick preterm infants

Feeding problems

Prevalence Preterm infants are at high risk of feeding problems.[45,136–140] Some evidence suggests that this is linked to severity of illness in the perinatal period rather than prematurity per se,[141,142] although not all.[12]

An assessment at 6 months corrected age of babies born preterm found a range of significant ongoing feeding difficulties and aversive behaviours compared to babies born at term. Counter intuitively their mothers didn't report any significant feeding aversion or negative feelings around feeding. However they were more likely to be using pureed food, and therefore have more rapid, less stressful meal times than if more challenging textures were offered.[45]

Delayed coordination may lead to a longer time for feeding development and self feeding: in these circumstances smooth puree is the easiest texture to offer initially.

If the infant has an immature suckle pattern in response to solids, smooth puree is easy to suck and swallow and should reduce risk of gagging or vomiting. A gradual progression through to family foods is then recommended.[143] Foods prepared at home are easier to modify with respect to texture as well as acclimatising the infant to the flavours of the families' usual foods. Healthy preterm infants will in general progress normally to more textured foods and may not need to have puree food for long.

In those who have undergone a particularly stormy course and who establishment of oral feeding has been delayed, an early programme of oral desensitisation to promote ingestion of both milk and solids may be necessary.

Gastro-oesophageal reflux disease Preterm infants are at higher risk of gastro-oesophageal reflux disease (GORD) and this itself has been linked with feeding problems.[139,144,145] Although interestingly one observation found that GORD was not associated with sucking problems in preterm infants.[146]

There is evidence that nausea,[147] pain[148] and gastrointestinal illness[149,150] are the prime determinants of feeding problems rather than the vomiting they are often associated with. Therefore with respect to GORD acid reflux is the prime factor to control to avoid the pain of oesophagitis, whereas non acid reflux may not be a cause for concern in the majority of infants. Term infants with GORD have been found to have significantly more oral motor dysfunction and less age appropriate feeding skills compared to controls.[145] This suggests that in preterm infants with confirmed GORD a gradual progression through purees and onto lumps would be of benefit. As such infants may take longer to reach feeding milestones they are a group who may benefit from weaning at the earlier end of the suggested age range. However this has not been formally evaluated and would benefit from further study.

There has been a suggestion that starting solids early may be useful to reduce GORD symptoms, thought there is little evidence to back this view. It may have developed through the observation that spontaneous resolution of symptoms often occurs around the time of weaning. In fact there is a risk that solids may exacerbate GORD by prolonging gastric emptying. This risk needs to be balanced with the possible advantage of weaning at an earlier age as discussed above.

Respiratory compromise In preterm infants respiratory compromise has been associated with high risk of feeding problems.[137–139] Early endotracheal intubation can lead to poorer oral feeding many weeks after extubation.[151]

Infants who develop chronic lung disease (CLD) can present particular problems. As they must stop breathing while swallowing and as respiration takes precedence over feeding, infants with respiratory problems are often poor feeders.[152] Results of a questionnaire highlight the feeding problems to which infants with CLD are prone when on solids.[137] In this study infants with CLD were weaned later than controls; the author speculates that this delay may have put them beyond a sensitive period for acceptance of solids.

These infants often need multi disciplinary input to help progress with oral nutrition, it may be particularly important to

ensure the timely introduction of solids to enhance acceptance later on.

Prior nasogastric tube feeding In infants, term or preterm, prolonged early nasogastric tube feeding is associated with feeding difficulties.[153–155]

Placement of a nasogastric feeding tube for >3 weeks has been linked to delayed feeding skills and altered oral sensitivity in healthy preterm infants at 11–17 months.[156] Chronic low grade inflammation around the tube placement site has been suggested as a possible aetiological factor.[71]

Infants who had at least 2 weeks of non oral nutrition during their first 3 months were found to have abnormal physiological responses to touch (assessed at 3–18 months) including gagging and distress.[157]

Nutritional factors

Preterm infants with ongoing chronic problems will be more at risk of a range of nutritional problems and would benefit from regular assessment to identify where they are particularly at risk. The highest risk is poor energy and protein intake however assessment of intake of certain micronutrients is also advisable. Zinc stores in preterm infants could be low depending on nutritional management and severity of illnesses in early neonatal period,[158] low stores could limit growth therefore a balanced weaning diet is essential. Iron stores are low in all preterm infants and it is important to ensure that they receive good dietary sources and not rely on supplements.

Calcium and phosphorus input seems to influence how rapidly bone mineralisation is normalised following preterm birth[159–161]; although some spontaneous resolution appears to occur.[162] Those on lower mineral intake still do catch-up with term infants, but with up to a 2 year lag,[163] even exceeding the bone mineral content of their term counterparts by 5 years.[164] In addition it has been found that once into adulthood early mineral input did not positively affect bone mineral status,[165] nevertheless it seems prudent to normalise bone mineral content as early as possible. Although calcium and phosphorus are normally adequate from dairy sources, breast fed infants require a vitamin D supplement. If a supplement of vitamin D is needed it is usually given as part of a multivitamin as there is currently no suitable single vitamin D supplement.

Caregiver factors

The severity of perinatal risks partly predicts an infants sleeping and eating problems. However the intensity of parents post traumatic reactions was an important independent factor.[166]

In a study of preterm infants born in the 1990s early weaning was associated with less positive health behaviours in the mother.[8]

Early food refusal has been linked to psychosocial problems in the family and less positive perceptions of parenting by the parents[167]; however it is often not possible to say which came first – the infants feeding problem or the parents' negative perceptions.

When a child is not given sufficient control over own intake this can disrupt the childs acceptance of a variety of foods and decrease awareness of satiety cues.[168] Caregivers should be given the support necessary to enable them to be responsive to their childs' cues and needs.

Positioning

Caregivers have been reported to have difficulties in positioning preterm babies for feeding.[45] This may be as a result of inability of the infant to stabilise the head, neck, shoulders and trunk through immaturity and through delay following prolonged illness. Guidance on appropriate positioning should help facilitate weaning and ensure that weaning is not unnecessarily delayed.

Infants need the opportunity to touch and feel food to start to develop the skills to feed themselves. Where ever possible finger foods should be encouraged as they are often better tolerated than food from a spoon, possibly because with finger foods children are more in control of what goes in their mouths. Finger foods should start when the infant begins to be able to hold objects and starts to bring them to their mouths. For infants who find bringing their hands to the mid line difficult it may be useful to have physiotherapy and/or occupational therapy involvement.

Weaning guidelines

Previous guidelines

Government guidelines on weaning from 1994 include a section on preterm infants with several recommendations,[1] the advice is summarised as follows:

1. Wean once at least 5 kg achieved
2. No tongue thrust reflex
3. Able to eat from spoon
4. Weaning diet must continue to ensure nutritional adequacy in particular with respect to iron, zinc, calcium, phosphorus and energy.

The relevance of the above four points are considered in the light of evidence previously discussed.

1. If weaning is left until 5 kg some of those born earliest who are growing below the 2nd centile could be 10 months uncorrected age before they reach this weight and risk being beyond or towards the end of sensitive periods for texture and taste. Therefore it is suggested that setting a weight criterion is not a helpful guide.
2. Loss of tongue thrust (protrusion) reflex is not a useful indicator of when a preterm infant is ready for weaning, and often persists during the initial stages of spoon feeding. It is believed that reduction of this reflex may, in fact, be aided by introduction of solids.
3. Ability to eat from a spoon involves a degree of lip seal. However this does not develop until after weaning in term infants. Preterm infants may have delayed development of skills preventing lip seal despite being ready to wean in other respects. If weaning is delayed until a mature pattern of spoon-feeding is possible, other sensitive periods for acceptance of solids may be missed. The development of lip seal may be aided by provision of spoon feeds.
4. The need to ensure nutritional adequacy of the weaning diet is fully endorsed.

Suggested new guidelines

Previous guidelines may no longer be appropriate so new ones are needed to accommodate the specific needs of the current preterm population.

Preterm infants, particularly those who have had a complex neonatal course are at high risk for feeding problems and delayed development of appropriate feeding skills.

Many of these problems can be addressed by starting weaning at a time when infants are showing readiness cues.

Correcting for prematurity and following the recommendations given for healthy term infants will often result in delaying weaning beyond 10 months uncorrected age which may compromise nutrition and delay key opportunities for development of feeding skills. A graded introduction of textures will allow preterm infants at high risk of feeding problems to develop feeding skills at their own pace. Well preterm infants may be able to proceed with textures more rapidly.

It is likely that the majority of infants born prematurely will be ready to start weaning somewhere between the ages of 5–8 months from the date of birth (uncorrected). However there is evidence that the motor development necessary for safe and successful transition to solid foods may not have been achieved until at least 3 months corrected age. The exact age will vary from one infant to another so advice given on the cues and physical development required is needed. Such advice is available in a separate document available on the dietitians web page at www.bapm.org. This is a joint consensus statement which has been composed by a group of UK paediatric dietitians and speech and language therapists. It is based on a review of the literature, Delphi questionnaire results and consensus meeting held in London on 26th June 2007. There is also practical advice in the form of a booklet produced by Bliss, a UK based charity for sick and preterm infants www.bliss.org.uk.

Although prematurity is usually defined as <37 weeks those well preterm infants born closer to term (i.e.>34 weeks) may be ready to start weaning at approximately 6 months of age (corrected) as advised for infants born at term.

Conflict of interest

No conflict of interest declared. ◆

REFERENCES

1 COMA. Weaning and the weaning diet. London: Department of Health, HMSO; 1994.
2 Department of Health. Infant feeding recommendation. Available at: http://www.dh.gov.uk/assetRoot/04/09/69/99/04096999.pdf; 2004.
3 Rea J. *J Neonatal Nurs* 1997; **3:** 19–23.
4 Fanaro S, Vigi V. *J Pediatr Gastroenterol Nutr* 2007; **45**(Suppl. 3)**:** S204–9.
5 D'Souza SW, Vale J, Sims DG, et al. *Arch Dis Child* 1985; **60**(3)**:** 215–8.
6 Ernst JA, Bull MJ, Rickard KA, et al. *J Pediatr* 1990; **117**(2 Pt 2)**:** S156–66.
7 Hampton SM. *Proc Nutr Soc* 1999 Feb; **58**(1)**:** 75–8.
8 Fewtrell MS, Lucas A, Morgan JB. *Arch Dis Child Fetal Neonatal Edn* 2003; **88**(4)**:** F296–301.
9 Norris FJ, Larkin MS, Williams CM, et al. *Eur J Clin Nutr* 2002; **56**(5)**:** 448–54.
10 Cooke RJ, Griffin IJ, McCormick K, et al. *Pediatr Res* 1998 Mar; **43**(3)**:** 355–60.
11 Fanaro S, Borsari G, Vigi V. *J Pediatr Gastroenterol Nutr* 2007; **45**(Suppl. 3)**:** S210–4.
12 Buswell CA, Leslie P, Embleton ND, et al. *Dysphagia* 2009; **24**(1)**:** 20–5.
13 SACN. Minutes of the Scientific Advisory Group on Nutrition (SACN) meeting on Jan 27th 2001. Available at: www.sacn.gov.uk; 2001.
14 Gartner LM, Morton J, Lawrence RA, et al. American Academy of Pediatrics. *Pediatr* 2005; **115**(2)**:** 496–506.
15 Aggett PJ, Barclay S, Whitley JE. *Acta Paediatr Scand Suppl* 1989; **361:** 1965–91.
16 Pisacane A, De Vizia B, Valiante A, et al. *J Pediatr* 1995; **127**(3)**:** 429–31.
17 Tsang RC, Uauy R, Koletzko B, et al. 45243. 2nd edn. Cincinnati Ohio: Digital Educational Publishing Inc; 2005.
18 Griffin IJ, Cooke RJ, Reid MM, et al. *Arch Dis Child Fetal Neonatal Edn* 1999; **81**(1)**:** F45–9.
19 Domellof M, Lonnerdal B, Abrams SA, et al. *Am J Clin Nutr* 2002; **76**(1)**:** 198–204.
20 Marriott LD, Foote KD, Bishop JA, et al. *Arch Dis Child Fetal Neonatal Edn* 2003; **88**(4)**:** F302–7.
21 Reilly JJ, Wells JC. *Br J Nutr* 2005; **94**(6)**:** 869–72.
22 Islam MM, Peerson JM, Ahmed T, et al. *Am J Clin Nutr* 2006; **83**(4)**:** 851–8.
23 Capdevila F, Vizmanos B, Marti-Henne C. *J Am Coll Nutr* 1998; **17**(3)**:** 256–62.
24 Heinig M, Nommsen LA, Peerson JM, et al. *Acta Paediatr* 1993; **82:** 999–1006.
25 Cohen RJ, Brown KH, Canahuati J, et al. *Lancet* 1994; **344**(8918)**:** 288–93.
26 Mehta KC, Specker BL, Bartholmey S, et al. *Pediatrics* 1998 Sep; **102**(3 Pt 1)**:** 569–73.
27 Carruth BR, Skinner JD, Houck KS, et al. *J Am Coll Nutr* 2000; **19**(3)**:** 405–12.
28 Simondon KB, Gartner A, Berger J, et al. *Am J Clin Nutr* 1996 Oct; **64**(4)**:** 537–45.
29 Michaelsen K, Jorgensen MH. *Eur J Clin Nutr* 1995; **49:** 467–83.
30 Dewey KG, Cohen RJ, Brown KH, et al. *Am J Clin Nutr* 1999; **69**(4)**:** 679–86.
31 Arvedson J, Rogers B, Brodsky L. Anatomy, embryology and physiology. In: Arvedson J, Brodsky L, eds. *Pediatric swallowing and feeding assessment and management*; 1993. p. 46.
32 Bosma. *Clin Nutr* 1986; **5:** 210.
33 Stevenson RD, Allaire JH. *Pediatr Clin North Am* 1991; **38**(6)**:** 1439–53.
34 Morris Evans. Pre-feeding skills. Tuscon Arizona: Therapy Skills Builders; 1987.
35 Mennella JA, Beauchamp GK. *Nutr Rev* 1998 Jul; **56**(7)**:** 205–11.
36 Steiner JE. *Adv Child Dev Behav* 1979; **13:** 257–95.
37 Kajiura H, Cowart BJ, Beauchamp GK. *Dev Psychobiol* 1992; **25**(5)**:** 375–86.
38 Mennella JA, Griffin CE, Beauchamp GK. *Pediatrics* 2004; **113**(4)**:** 840–5.
39 Beauchamp GK, Cowart BJ, Moran M. *Dev Psychobiol* 1986; **19**(1)**:** 17–25.
40 Harris G, Thomas A, Booth DA. *Dev Psychobiol* 1990; **26:** 534–8.
41 Kare MR, Beauchamp GK. *Am J Clin Nutr* 1985; **41**(2 Suppl)**:** 418–22.
42 Fomon SJ, Thomas LN, Filer Jr LJ. *J Pediatr* 1970; **76**(2)**:** 242–6.
43 Sullivan SA, Birch LL. *Pediatrics* 1994; **93**(2)**:** 271–7.
44 Hill DL, Mistretta CM. *Trends Neurosci* 1990; **13**(5)**:** 188–95.
45 Mathisen B, Worrall L, O'Callaghan M, et al. *Adv Speech Lang Pathol* 2000; **2**(1)**:** 9–17.
46 Pridham K, Steward D, Thoyre S, et al. *Early Hum Dev* 2007; **83**(5)**:** 293–305.
47 Gisel EG. *Dev Med Child Neurol* 1991; **33**(1)**:** 69–79.
48 Reilly S, Skuse D, Mathisen B, et al. *Dysphagia* 1995; **10**(3)**:** 177–91.

49 Gerrish CJ, Mennella JA. *Am J Clin Nutr* 2001; **73**(6)**:** 1080–5.
50 Maier AS, Chabanet C, Schaal B, et al. *Clin Nutr* 2008; **27**(6)**:** 849–57.
51 Birch LL, McPhee L, Shoba BC, et al. *Appetite* 1987; **9**(3)**:** 171–8.
52 Guthrie CA, Rapoport L, Wardle J. *Appetite* 2000; **35**(1)**:** 73–7.
53 Birch LL. *Annales Nestle* 1998; **56**(1)**:** 11–8.
54 Forestell CA, Mennella JA. *Pediatrics* 2007; **120**(6)**:** 1247–54.
55 Harper L, Sanders K. *J Exp Child Psychol* 1975; **20:** 206–14.
56 Birch LL, Zimmerman S, Hind H. *Child Dev* 1980; **51:** 856–61.
57 Rozin P. *Dev Psychol* 1990; **26**(4)**:** 555–62.
58 Pliner P, Pelchat ML. *Appetite* 1986; **7**(4)**:** 333–42.
59 El-Sohemy A, Stewart L, Khataan N, et al. *Forum Nutr* 2007; **60:** 176–82.
60 Keskitalo K, Knaapila A, Kallela M, et al. *Am J Clin Nutr* 2007; **86**(1)**:** 55–63.
61 Rajan L. *Health Visitor* 1986; **59**(2)**:** 41–4.
62 Wardle J, Cooke L. *Br J Nutr* 2008; **99**(Suppl. 1)**:** S15–21.
63 Birch LL. *Dev Psychol* 1990; **26:** 515–9.
64 Beauchamp G, Mennella J. *Annales Nestle* 1998; **56**(1)**:** 19–31.
65 Mennella JA, Johnson A, Beauchamp GK. *Chem Senses* 1995; **20**(2)**:** 207–9.
66 Mennella JA. *J Hum Lact* 1995 Mar; **11**(1)**:** 39–45.
67 Cowart BJ. *Psychol Bull* 1981; **90**(1)**:** 43–73.
68 Green J, Moore C, Ruark J, et al. *J Neurophysiol* 1997; **77:** 2704–16.
69 Rapley G, Murkett T. 1st edn. Vermillion; 2008. ISBN: 978-0-09-192380-8.
70 Illingworth R, Lister J. *J Pediatr* 1964; **65:** 839–49.
71 Skuse D. *Arch Dis Child* 1993; **69**(5)**:** 604–8.
72 Northstone K, Emmett P, Nethersole F. *J Hum Nutr Diet* 2001 Feb; **14**(1)**:** 43–54.
73 Coulthard H, Harris G, Emmett P. *Matern Child Nutr* 2009; **5**(1)**:** 75–85.
74 Macknin ML, Medendorp SV, Maier MC. *Am J Dis Child* 1989; **143**(9)**:** 1066–8.
75 Morgan JB, Lucas A, Fewtrell MS. *Arch Dis Child* 2004; **89**(8)**:** 728–33.
76 Roberton DM, Paganelli R, Dinwiddie R, et al. *Arch Dis Child* 1982; **57**(5)**:** 369–72.
77 van Elburg RM, Fetter WP, Bunkers CM, et al. *Arch Dis Child Fetal Neonatal Edn* 2003; **88**(1)**:** F52–5.
78 Martinez-Augustin O, Boza- JJ, Del-Pino J, et al. *Biol Neonate* 1997; **71**(4)**:** 215–23.
79 Axelsson I, Jakobsson I, Lindberg T, et al. *Acta Paediatr Scand* 1989; **78:** 532–7.
80 Pang KY, Newman AP, Udall JN, et al. *Am J Physiol* 1985; **249**(1 Pt 1)**:** G85–91.
81 Shulman RJ, Schanler RJ, Lau C, et al. *Pediatr Res* 1998 Oct; **44**(4)**:** 519–23.
82 Schanler RJ, Schulman RJ, Lau C. *Pediatr Res* 1995; **37:** 319A.
83 Senterre J. *Acta Paediatr Scand* 1980; **69**(5)**:** 653–7.
84 Lebenthal E, Lee PC. *Pediatrics* 1980; **66**(4)**:** 556–60.
85 Kolacek S, Puntis JW, Lloyd DR, et al. *Arch Dis Child* 1990; **65**(2)**:** 178–81.
86 Nissler K, Von Katte I, Huebner A, et al. *J Pediatr Gastroenterol Nutr* 2001; **33**(1)**:** 28–31.
87 Kori M, Maayan-Metzger A, Shamir R, et al. *Arch Dis Child Fetal Neonatal Ed* 2003 Mar; **88**(2)**:** F106–8.
88 Yahav J, Carrion V, Lee PC, et al. *J Pediatr* 1987; **110**(6)**:** 949–51.
89 Hyman PE, Clarke DD, Everett SL, et al. *J Pediatr* 1985 Mar; **106**(3)**:** 467–71.
90 Kelly EJ, Newell SJ, Brownlee KG, et al. *Early Hum Dev* 1993 Dec 31; **35**(3)**:** 215–20.
91 Hamosh M. Digestion in the newborn. *Clin Perinatol* 1996 Jun; **23**(2)**:** 191–209.
92 Rings E, Minich D, Fetter W, et al. *Pediatr Res* 1999; **45:** 290A.
93 Deenamamode J, Nicholl R, Sherwood R, et al. *Pediatr Res* 1998; **44:** 435A.
94 Forget P, Van den Neucker A, Degraeuwe P, et al. *Pediatr Res* 1995; **37:** 307A.
95 Pereira G, Barsky D, Hamosh M, et al. *Pediatr Res* 1995; **37:** 316A.
96 Hamosh M. A review. *Pediatr Res* 1979; **13**(5 Pt 1)**:** 615–22.
97 Lindberg T, Skude G. *Pediatrics* 1982; **70**(2)**:** 235–8.
98 Heitlinger LA, Lee PC, Dillon WP, et al. *Pediatr Res* 1983; **17**(1)**:** 15–8.
99 Shulman RJ, Schanler RJ, Lau C. *Pediatr Res* 1996; **39:** 320A.
100 Shulman RJ, Wong WW, Smith EO. *Am J Clin Nutr* 2005 Feb; **81**(2)**:** 472–9.
101 Bissett WM, Watt J, Rivers RPA, et al. *Arch Dis Child* 1989; **64:** 1356–61.
102 Berseth CL. *J Pediatr* 1992 Jun; **120**(6)**:** 947–53.
103 Mulvihill SJ, Stone MM, Fonkalsrud EW, et al. *J Surg Res* 1986; **40**(4)**:** 291–6.
104 Lucas A, Bloom SR, Aynsley Green A. *Acta Paediatr Scand* 1986; **75**(5)**:** 719–23.
105 Lucas A, Bloom SR, Aynsley Green A. *Acta Paediatr Scand* 1983; **72**(2)**:** 245–9.
106 Newell S. *Semin Neonatol* 1996; **1:** 59–66.
107 Newell SJ. *Clin Perinatol* 2000 Mar; **27**(1)**:** 221–34. viii.
108 Aperia A, Zetterstrom R. *Clin Perinatol* 1982; **9**(3)**:** 523–33.
109 David TJ, Ewing CI. *Arch Dis Child* 1988; **63**(4)**:** 435–6.
110 Buhrer C, Grimmer I, Niggemann B, et al. *Lancet* 1999 May 15; **353**(9165)**:** 1674.
111 Siltanen M, Kajosaari M, Pohjavuori M, et al. *J Allergy Clin Immunol* 2001 Feb; **107**(2)**:** 229–34.
112 Agosti M, Vegni C, Gangi S, et al. *Acta Paediatr Suppl* 2003; **91**(441)**:** 44–7.
113 Klebanoff MA, Berendes HW. *Arch Dis Child* 1988; **63**(12)**:** 1519–20.
114 de Martino M, Donzelli GP, Galli L, et al. *Biol Neonate* 1989; **56**(6)**:** 301–5.
115 Lucas A, Brooke OG, Morley R, et al. *BMJ* 1990; **300**(6728)**:** 837–40.
116 Kvenshagen B, Jacobsen M, Halvorsen R. *Arch Dis Child* 2009; **94**(3)**:** 202–5.
117 Steffensen FH, Sorensen HT, Gillman MW, et al. *Epidemiology* 2000 Mar; **11**(2)**:** 185–8.
118 Helms I, Rieger C. *Eur J Pediatr* 1987; **146:** 131.
119 Siltanen M, Kajosaari M, Savilahti EM, et al. *J Allergy Clin* 2002; **110**(4)**:** 658–63.
120 Szajewska H, Mrukowicz JZ, Stoinska B, et al. *Acta Paediatr* 2004; **93**(9)**:** 1159–65.
121 Norris F, Williams P, Larkin M, et al. *Ped Asthma Allergy Immunol* 1999; **13**(4)**:** 169–75.
122 Savilahti E, Tuomikoski JP, Jarvenpaa AL, et al. *Acta Paediatr* 1993 Apr; **82**(4)**:** 340–4.
123 Forster J, Dungs M, Wais U, et al. *Klin Padiatr* 1990; **202**(3)**:** 136–40.
124 Morgan J, Williams P, Norris F, et al. *Arch Dis Child* 2004; **89**(4)**:** 309–14.
125 Khakoo GA, Lack G. *Arch Dis Child* 2004; **89**(4)**:** 295.

126 Siltanen M, Savilahti E, Pohjavuori M, et al. *Pediatr Pulmonol* 2004 Jan; **37**(1)**:** 43–9.

127 Grischkan J, Storfer-Isser A, Rosen CL, et al. *J Pediatr* 2004; **144**(3)**:** 321–6.

128 Paediatric Group of the British Dietetic Association. Weaning infants onto solid foods. Position paper. Available at: http://www bda uk com/resources/statements/PositionStatementWeaning pdf; 2009.

129 Food Allergy & Intolerance Specialist Group of the British Dietetic Association. Practical dietary prevention strategies for infants at risk of developing allergic diseases. Professional consensus statement. www bda uk com.

130 van Haastert I, de Vries LS, Helders PJ, et al. *J Pediatr* 2006; **149**(5)**:** 617–22.

131 Wachs T. *Monogr Soc Res Child Dev* 1993; **83**(7)**:** 100–10.

132 Fomon SJ, Filer Jr LJ, Anderson TA, et al. *Pediatrics* 1979; **63**(1)**:** 52–9.

133 Satter E. *J Pediatr* 1990; **117**(2 Pt 2)**:** S181–9.

134 Burdette HL, Whitaker RC, Hall WC, et al. *Am J Clin Nutr* 2006; **83**(3)**:** 550–8.

135 Brown KH, Sanchez-Grinan M, Perez F, et al. *Am J Clin Nutr* 1995 Jul; **62**(1)**:** 13–8.

136 Douglas JE, Bryon M. *Arch Dis Child* 1996; **75**(4)**:** 304–8.

137 Martin M, Shaw NJ. *J Human Nutr* 1997; **10:** 271–5.

138 Hawdon JM, Beauregard N, Slattery J, et al. *Dev Med Child Neurol* 2000; **42**(4)**:** 235–9.

139 Rommel N, De Meyer AM, Feenstra L, et al. *J Pediatr Gastroenterol Nutr* 2003; **37**(1)**:** 75–84.

140 Schadler G, Suss-Burghart H, Toschke AM, et al. *Eur J Pediatr* 2007; **166**(8)**:** 803–8.

141 Bazyk S. *Am J Occup Ther* 1990; **44**(12)**:** 1070–8.

142 Burklow KA, McGrath AM, Valerius KS, et al. *Nutr Clin Pract* 2002; **17**(6)**:** 373–8.

143 King C, Marriott L, Foote KD. Weaning your premature baby. London: BLISS. Available at: www.bliss.org.uk; 2008. 5th.

144 Field D, Garland M, Williams K. *J Paediatr Child Health* 2003; **39**(4)**:** 299–304.

145 Mathisen B, Worrall L, Masel J, et al. *J Paediatr Child Health* 1999; **35**(2)**:** 163–9.

146 veerman-wauters G, Palmer M, Goeleven D, et al. *Gastroenterol* 1999; **108**(4)**:** A760.

147 Pelchat ML, Rozin P. *Appetite* 1982; **3**(4)**:** 341–51.

148 Hyman PE. *J Pediatr* 1994; **125**(6 Pt 2)**:** S103–9.

149 Johnson R, Harris G. *J Reprod Inf Psychol* 2004; **22**(3)**:** 183–8.

150 Garb JL, Stunkard AJ. *Am J Psychiatry* 1974; **131**(11)**:** 1204–7.

151 Blaymore-Bier JA, Ferguson A, Cho C, et al. *Am J Dis Child* 1993; **147**(8)**:** 858–62.

152 Singer L, Martin RJ, Hawkins SW, et al. *Pediatr* 1992; **90:** 380–4.

153 Blackman JA, Nelson CL. *Clin Pediatr Phila* 1985 Aug; **24**(8)**:** 434–8.

154 Senez C, Guys JM, Mancini J, et al. *Childs Nerv Syst* 1996 Oct; **12**(10)**:** 590–4.

155 Mason SJ, Harris G, Blissett J. *Dysphagia* 2005; **20**(1)**:** 46–61.

156 Dodrill P, McMahon S, Ward E, et al. *Early Hum Dev* 2004; **76**(1)**:** 23–37.

157 Scarborough DR, Boyce S, McCain G, et al. *Dev Med Child Neurol* 2006; **48**(6)**:** 460–4.

158 Askari A, Long CL, Blakemore WS. *J Parenter Enteral Nutr* 1979; **3**(3)**:** 151–6.

159 Venkataraman P, Luthar HK, Neylan M. *Pediatr Res* 1990; **27:** 293A.

160 Chan GM. *J Pediatr* 1993; **123:** 439–43.

161 Bishop NJ, King FJ, Lucas A. *Arch Dis Child* 1993; **68:** 573–8.

162 Congdon P, Horsman A, Ryan SW, et al. *Arch Dis Child* 1990; **65:** 1038–42.

163 Schanler R, Burns PA, Abrams SA, et al. *Pediatr Res* 1992; **31:** 583–6.

164 Bishop NJ, Dahlenburg SL, Fewtrell MS, et al. *Acta Paediatr* 1996; **85:** 230–6.

165 Fewtrell MS, Williams JE, Singhal A, et al. Bone 2009; uncorrected proof.

166 Pierrehumbert B, Nicole A, Muller-Nix C, et al. *Arch Dis Child Fetal Neonatal Edn* 2003; **88**(5)**:** F400–4.

167 Lindberg L, Bohlin G, Hagekull B. *Infant Ment Health J* 1994; **15**(3)**:** 262–77.

168 Birch LL, Fisher JO. *Pediatrics* 1998; **101**(3 Pt 2)**:** 539–49.

Acknowledgements

Many thanks to Annie Aloysius, Chris Jarvis, Gillian weaver and Trak Davis for very helpful comments and corrections.

