Complementary Foods: Guidelines and Practices

Merryn J. Netting and Maria Makrides

Complementary feeding, the transition from a breast milk-based diet to inclusion of other sources of nutrition in an infant’s diet, is a major milestone in infant development. Complementary feeding usually begins at around 6 months of age when an infant’s requirements for energy, protein and other nutrients (particularly iron) cannot be met by breast milk alone. The complementary feeding period extends from the early initiation phase to establishing meal and food habits that will move into early childhood and beyond.

Many countries are now faced with the issue of malnutrition presenting as overweight or obesity, i.e. risk factors for the development of noncommunicable diseases in later life. As under- and overnutrition may coexist in children from the same country, it is important that the advice provided by complementary feeding guidelines meets the needs of all children helping them to grow and develop into healthy adults.

Many consistent and important themes emerge when comparing complementary feeding guidelines from different countries:

- **Timing of Complementary Foods.** Introduction of complementary foods is recommended at (or around) 6 months of age. Most guidelines include the importance of waiting for developmental cues pertaining to ‘readiness’ for complementary foods, and some include guidelines related to responsive feeding, where the infant’s feeding cues are observed and followed by the parent or caregiver. Developmental cues rather than a specific age may be the best indicator of ‘readiness’ to accept complementary foods.

- **Continued Breast Feeding.** Breast feeding is universally recommended during the complementary feeding period because of its nutrient profile, protection from infection and longer-term benefits to maternal health.

- **Nutrient-Dense Complementary Foods.** Iron deficiency disorders are a major health issue in both high-income and low-/middle-income countries. Nutrient-dense, iron-rich foods are universally encouraged,
although specific foods vary slightly from country to country. In many countries, this takes the form of iron-fortified cereals, although many countries encourage early inclusion of meat, eggs and legumes in the infant’s diet. A nonnutritional strategy – delayed cord clamping after birth – has been identified as a strategy for increasing early hemoglobin concentrations and infant’s iron stores, thus preventing this nutritional issue.

• Hygienic Food Practises. Food-borne illness is an important public health issue and is important in both developed and developing countries.

• Development of Feeding Skills and Fostering Long-Term Eating Habits. Progression from thick spoon foods to mashed foods and finger foods, and consuming nutritious family foods are highlighted in many infant feeding guidelines. Caregivers are encouraged to follow the child’s feeding cues to foster independent eating skills.

• Prevention of Noncommunicable Diseases. Many aspects of complementary feeding including food type and feeding styles have the potential to influence the development of early obesity and therefore potentially increase the risk of noncommunicable diseases later in life. Guidance to avoid added salt, sugar and fats, and avoidance of energy-dense drinks such as juice is included in many infant feeding guidelines. Likewise, delayed introduction to common food allergens may influence the risk of sensitization and later development of allergy, and many industrialized countries now include specific advice related to the development of allergy in their guidelines.

Complementary feeding guidelines that promote good eating during the first year and beyond recognize that nutrition, particularly during the first 1,000 days, has an important influence on immediate growth and development, but also plays an important role in programming an infant’s susceptibility to the development of noncommunicable diseases later in life.
The period of complementary feeding (from 6 to 24 months of age) can be a challenging and vulnerable time for infant nutrition, with a high incidence of malnutrition and nutrient-specific deficiencies [1]. Infant nutritional requirements are high due to their metabolic rate, rapid developmental processes and limited gastric capacity. Additional foods supplement breast milk provisions to meet the increasing needs of the infant. However, barriers to adequate foods include lack of access to nutritious complementary foods, such as due to poverty or environmental availability, and poor infant feeding practices, such as early or late introduction of complementary foods or replacement of breast milk feeds [1].

The 6- to 24-month period is a time of genetically preprogrammed rapid growth and development. An infant's brain will grow from 25 to 80% of its adult size, and a dependent immobile newborn will grow into an active, mobile toddler capable of basic memory, speaking two-word sentences and feeding themselves [2]. These abilities emerge as the relevant areas of the brain that undergo intense periods of rapid myelination (creation of the myelin sheath around neuronal axons to increase the speed of electrical impulses travelling along it) and synaptogenesis (creation of communication channels between neurons) [2]. Nutrition is considered the most influential nongenetic determinant of growth and development during the 6- to 24-month period. Developmental processes such as myelination and synaptogenesis have high energy and nutrient requirements, and once formed, synapses need energy for maintenance. Key nutrients needed for infant brain development include iron (required for oxygen provision to metabolize energy), fatty acids (to make cellular membranes and myelin) and protein (for structural support, such as in myelin).

Inadequate nutrition during infancy can result in deficits that can be difficult to compensate for later in childhood, even when nutritional status
is corrected [3]. Observational studies have consistently demonstrated links between nutrient deficiencies and impairments in intellectual abilities, work capacity, behavioral functioning and even delayed mental and motor development [3]. Yet, results from a number of interventions using food, individual nutrients or multiple micronutrients with child development assessments are mixed [3]. Many of these studies included infants with deficiencies or poor growth, with some reports of improvements after interventions. Limitations of the current evidence around nutritional interventions during the complementary feeding period and child development outcomes include the broad intervention periods of many studies extending from pregnancy to mid-childhood (with a lack of interventions specifically targeting the 6- to 24-month period). Sample sizes in many studies were small (n < 150), attrition was high, and there was a mix of nutrient-sufficient and -deficient conditions between and within studies. Additionally, blinding was unlikely in many studies, and, as reported by a recent Cochrane review of food supplements in early childhood, there was evidence of leakage (when the child does not consume the prescribed amount of the intervention) when the intervention was supplied at the home, as opposed to at a child care center [4]. Importantly, child development outcomes were not the primary outcome of the majority of studies but rather a secondary outcome, and, as with a Cochrane review of multiple micronutrient powders for infants under 2 years, there are many trials that did not assess cognitive or motor development [5]. As with the observational studies, most of the randomized controlled studies were conducted in developing countries where food security is often poor and nutritional deficiencies are common. Given the perceived importance of adequate nutrition between 6 and 24 months of age for both early development and long-term outcomes, further high-quality intervention studies are warranted in the complementary period.

References

A child’s transition to independent eating is a protracted process that progresses over the course of many years. Although major health agencies, such as the World Health Organization (WHO), now offer clear guidance when to begin introducing solids, advice about how to safely transition to progressively challenging foods is varied and comes from a staggering number of sources. The varying, and often conflicting advice has resulted in parental confusion and anxiety about what foods are appropriate and when to advance to new textures. Common parental concerns include risks of choking, allergies, nutrition and food refusal/neophobia.

Research on early child feeding is bringing to light the delicate balance in pediatric feeding between providing textures that are challenging but safe. Introducing solids too soon increases the risks of choking, sudden infant syndrome and chronic diseases such as diabetes, obesity, asthma and celiac disease as well as food hypersensitivity [1]. In contrast, introducing solids too late increases the likelihood that a child may not learn to eat solid foods properly, become malnourished, develop iron deficiency anemia and not follow the normal growth curve. Despite these known risks, however, many children are being offered solids too early [1] while some are being offered them too late.

One challenge to developing a rigid, age-based timeline for advancing complementary feeding is the well-known differences among children in their rates of development. For this reason, many guidelines promote the conventional wisdom that food textures should be gradually upgraded based on infants’ abilities. From a motor development perspective, a child’s readiness for a given food will depend on the match between the developmental status of their oromotor system and the demands required to macerate and safely transport the food into the esophagus. Additional research is needed, however, to begin to stratify different foods along the continuum from easy to challenging to chew
taking the physical properties of the food and the oromotor readiness of the child into consideration.

To better understand oromotor readiness for different textures, we have begun to investigate the development of chewing biomechanics to evaluate the age appropriateness of solid foods that vary in texture [2–4]. The broad goals of this research include improving our understanding of (1) the development of chewing motor skills, (2) the factors that influence chewing development, such as the emergence of dentition, and (3) the interaction between a child’s oromotor readiness and the physical properties of the food. In this work, we are recording jaw movement and muscle activity as young children (9–36 months) chew several commercially available products that vary in texture – Cheerios (General Mills), an oat-based cereal, and Rice Rusks (Hipp), a puffed rice-based cracker. Our preliminary findings suggest that chewing behavior varies among the two foods. Overall, a more mature chewing pattern was observed for the Cheerios than for the Rice Rusks, suggesting that Rice Rusks biscuits were mechanically challenging for beginning chewers. Additional studies are required that test a larger number of textures that vary in their physical properties. The information from these studies will be essential for providing caregivers science-based guidance regarding the safety and appropriateness of new foods, identifying children at risk for choking or feeding impairments, designing new developmentally appropriate foods, and redesigning foods that pose a high risk [5].

References
With increasing incidence, severity and persistence of food allergies in many communities, effective prevention strategies are needed. The question of when in infancy to introduce any solid food, or specific ‘more allergenic’ foods (including peanuts and eggs), has been the focus of several randomized controlled trials (RCTs) over recent years. The Enquiring About Tolerance (EAT) RCT compared the commencement of solid foods in exclusively breastfed infants from 3 months of age to solid food avoidance with continued exclusive breastfeeding until around 6 months of age [1]. No differences between the groups were found, with 7.1% of infants developing food allergies in the group avoiding solids until 6 months compared to 5.6% of infants in the group receiving solids from 3 months (relative risk 0.80; 95% CI 0.51–1.25; p = 0.32). Thus the EAT trial results do not support the need to change the existing current consensus in allergy prevention guidelines [2], based on evidence from previous observational studies, that recommend the introduction of any solid food into infant diets should commence after 4 months of age.

In the year 2000, the American Academy of Pediatrics Committee on Nutrition recommended that for infants at higher risk of allergy (based on family history) the introduction of ‘more allergenic’ foods should be delayed in their diet, including that eggs be avoided until 2 years and nuts until 3 years of age. Then, in contrast, over the next decade, observational studies found delayed introduction, beyond 6–10 months of age, of some specific foods (including oats, wheat, dairy foods, fish and egg) to be associated with an increased risk of allergic disease. At least six RCTs have been conducted in recent years to investigate whether the timing of introduction of specific food allergens into the infant diet reduces the risk of developing a food allergy. To date, the results from the EAT, Learning Early About Peanut Allergy (LEAP) and Solids Timing for Allergy Reduction (STAR) RCTs have been published, and these trials are summarized in figure 1.
The EAT RCT investigated the sequential introduction of cow’s milk protein, egg, peanut, fish, sesame and wheat from 3 months compared to exclusive breastfeeding until around 6 months of age, and no differences in food allergy outcomes were found between the groups [1]. The LEAP RCT found that the introduction and regular dietary intake of peanuts commencing between 4 and 11 months of age significantly reduced the incidence of peanut allergy when compared to the avoidance of peanuts in the child’s diet until 5 years of age (1.9 vs 13.7%; p < 0.001) [3]. It is important to note that 9% of infants initially screened were excluded due to peanut sensitization and were recommended to continue to avoid peanut. Hence, both the safety, as well as the effect, of the introduction of peanuts during infancy for previously peanut-sensitized infants remains unknown.

The STAR RCT [4], investigating regular egg ingestion compared to egg avoidance from 4 to 8 months of age, found 33% of infants introduced to eggs from 4 months developed an egg allergy compared to 51% of infants who avoided eggs until 8 months of age (relative risk 0.65; 95% CI 0.38–1.11; p = 0.11). Thus, to date, the results from three RCTs have determined that there is no reason to delay the introduction of the ‘more allergenic’ foods into the infant’s diet after solid foods have commenced. The results from three other RCTs evaluating egg introduction timing are anticipated within the next year, and the availability of these results will

Figure 1. Timing of intervention and type of food allergens introduced during infancy.
add greater clarity and contribute additional dimensions to the compos-ite picture of available evidence to this area of food allergy prevention research.

References

Flavor and Taste Development in the First Years of Life

Erin Sundseth Ross

Across the first 4 years of life, infants transition from a liquid diet to solid foods. Infants and young children experience sensory inputs differently than adults, and eating is a multisensory experience. Flavor preferences affect the acceptance of novel foods, and infants and young children may require multiple tastes before they accept a food into their repertoire. Experiences prior to birth, as well as the flavors with fluids, influence the newborn’s flavor development. With the introduction of complementary foods, infants develop preferences for foods. These flavor experiences influence the diet of the young child and set the stage for later eating habits.

Fetuses experience flavors in the uterine environment, and some preferences appear to be innate. Sweet and salty flavors tend to be accepted by most newborns, while bitter tastes are rejected [1]. These preferences appear to continue through the early years, as slightly salted vegetables appear to be more readily accepted during the transition to complementary foods, and sweetened foods are chosen over more bitter foods (e.g. vegetables) when preschoolers are allowed to self-select. Breastfed infants appear to have an advantage over formula-fed infants, as they are exposed to a varying flavor profile provided by the mother’s diet. There are data to suggest breastfed infants are more accepting of novel foods, although the number and variety of food experiences appear to be more powerful predictors of taste acceptance [2]. Formula-fed infants demonstrate a preference for flavor profiles similar to those underlying their formula, and even become brand specific in their preferences. The preference for similar profiles (e.g. bitter, sour profiles from specialized formulas) can influence the foods preferred by the infant during complementary food introduction.

Infants are fairly accepting of novel foods, but rejection of new foods increases across the initial years of life. Infants may demonstrate facial behaviors that indicate a ‘dislike’ but still eat the offered food. Taste exposure is a powerful intervention to improve acceptance of novel foods.
Allowing the child to spit out the food increases their willingness to taste the food. Children exposed to more tastes are more likely to integrate that food into their food repertoire. A greater variety of taste exposures also appears to increase generalized acceptance [3].

Despite a wealth of knowledge regarding the development of taste preferences in young children, improving the quality of children’s diets continues as a major focus of countries as well as the World Health Organization. While repeated exposures are an effective way to teach children to eat more nutritious foods (e.g. fruits and vegetables), parents typically offer foods only 2–3 times before stopping because they feel their child does not like the food. Some children are more accepting of various sensory inputs present during mealtimes. Parents report a greater challenge getting multiple taste exposures when their child exhibits less sensory adaptability [4]. Parents may use appropriate behaviors with a child who accepts most sensory inputs easily and may resort to ineffective strategies with children who are less tolerant. Research is just beginning to evaluate the child characteristics that influence parental behaviors. Based upon the child’s response, the parent may resort to ineffective strategies, and in some cases, their strategies may actually compound the problem of food rejection. A model of this interactional relationship during mealtimes is presented, highlighting the need to identify and educate caregivers on situationally effective strategies to be used during the complementary feeding period (fig. 1). Strategies to help parents be more successful in achieving taste exposures in a positive social environment need to be identified.

Fig. 1. Responsive feeding model for situationally effective strategies.
References


Patterns of Growth in Early Childhood and Infectious Disease and Nutritional Determinants

Robert E. Black

The physical growth of young children in low- and middle-income countries (LMIC) is generally reduced compared to that expected in the World Health Organization Child Growth Standards (fig. 1) [1]. Children in these countries have a height for age that from birth starts slightly below the standard and then declines steeply to nearly two standard deviations below by 24 months of age [2]. This decline is greatest for children in South Asia and sub-Saharan Africa. The pattern for weight for length differs markedly by region. Children in Africa dip below the standard in the first 24 months and then go back to the expected level for the remainder of their childhood. Children in South Asia start life at three quarters of a standard deviation below the standard and decline to more than one standard deviation below standard, where they remain for the remainder of their childhood. Children in Latin America have a higher weight for length compared to the standard, indicating more overweight and obesity.

The deviations in growth as reflected by both height for age and weight for length have serious consequences for child mortality, development, adult stature and health [3]. The determinants of these patterns of growth faltering include intergenerational factors, such as maternal height (<160 cm), short birth interval (<2 years) and conditions in pregnancy, including maternal underweight (body mass index <18.5) and anemia (hemoglobin <110 g/l). These factors contribute to fetal growth restriction and premature delivery, which put many infants on a different growth trajectory. Fetal growth restriction as assessed by the newborn being small for gestational age (SGA) is particularly important [3]. Babies who are SGA have an elevated risk of death and surviving children an increased risk of stunted linear growth. It has been estimated that a fifth of stunted growth (reduced length for age compared to the growth standard) in children can be attributed to being born SGA. In some regions this may be more than a third.
Dietary factors, especially consumption of complementary foods of insufficient quality, have a paramount role in growth faltering in the critical period of infancy. Diets that are inadequate in calories, protein, essential fatty acids and micronutrients (essential vitamins and minerals) can result in poor growth. Breast milk is an important source of nutrients in the first months and years of life. Current recommendations are that babies be fed only breast milk for the first 6 months of life and that breastfeeding be continued along with complementary foods to at least the second birthday. Introduction of liquids or foods in the first 6 months can lead to a diet of reduced nutritional quality and exposure to microbes, which can cause diarrhea and possibly environmental dysfunction. Failure to continue to provide breast milk in the second half of infancy and feeding complementary foods of poor energy density and quality contribute to the faltering of both linear growth and weight gain in LMIC from 6 to about 24 months of age.

Observational studies of the determinants of stunting have shown significant relationships with reported food intake, as well as other indicators such as dietary diversity, reflecting the adequacy of intake of vitamins and minerals. Of particular importance among these is zinc because a zinc-deficient diet is associated with reduced linear growth.

**Fig. 1.** Mean anthropometric z-scores according to age (1–59 months) for all 54 studies relative to the WHO standard. Reproduced with permission from *Pediatrics* [2] by the American Academy of Pediatrics.
Exposure to microbes after birth resulting in diarrhea and febrile infectious diseases and poor quality diet further compromise growth. Diarrhea episodes have been estimated to cause 20% of linear growth faltering [4]. Determinants of growth faltering after birth vary by setting and are not independent of each other. For example, the adverse effects of diarrhea on growth may be mitigated by a high-quality diet. In addition to the effects of infectious diseases, subclinical enteric infections can result in intestinal dysfunction with adverse effects on nutrition and growth [5].

References

The publication of the WHO infant and young child feeding (IYCF) indicators in 2008 [1] equipped the nutrition and broader development community with an invaluable tool for measuring, documenting and advocating for faster progress in improving these practices in low- and middle-income countries (LMICs). The indicators, with 5 of them focusing on complementary feeding (CF) practices (box 1), were originally designed for population level assessment, targeting, monitoring and evaluation.

Box 1

List of WHO indicators of CF and the key dimensions they are meant to measure

1 Introduction of solid, semisolid and soft foods: optimal timing of introduction of complementary foods
2 Minimum dietary diversity: micronutrient adequacy of the diet (diet quality)
3 Minimum meal frequency: energy adequacy of the diet
4 Minimum acceptable diet: composite indicator combining breastfeeding and CF indicators 2 and 3
5 Consumption of iron-rich and iron-fortified foods: adequacy of iron intake

This chapter takes stock of where we are with the existing CF indicators; it reviews how they have been used, what we have learned, and what their strengths and limitations are, and suggests a way forward. We find that the indicators have been used extensively for population level assessments, country comparisons and to track progress. They have also been adopted by researchers for impact evaluations of programs aimed at improving CF practices, and in research seeking to understand the
determinants and consequences of poor CF practices for child growth and development outcomes. By helping generate knowledge and unveiling the severity of the global problem of poor CF practices in LMICs, the indicators have been an invaluable tool for raising awareness and to call for urgent action on improving CF practices at scale.

The indicators have several strengths. They are simple and practical, and therefore suitable for use in large national surveys. They also measure 4 key dimensions of CF practices: (1) timing of introduction of complementary foods, (2) dietary diversity, (3) meal frequency and (4) intake of iron-rich foods. We identified some limitations, however, which include the following:

- **Lack of Validation against the Gold Standard.** With the exception of the minimum dietary diversity indicator, none of the indicators have been validated to test whether or not they reflect the underlying construct they are meant to measure.

- **Subject to Recall Error and Bias.** The indicators rely on maternal recall of child feeding in the previous 24 h; this can result in recall error (due to memory failure) or recall bias (mothers respond based on what they know to be the desired answers, rather than reporting their real practices; this problem can be particularly severe if mothers have been exposed to an education intervention aimed at improving CF practices).

- **Other Measurement Errors and Misclassification.** These relate to the fact that the indicators do not quantitatively measure the child’s intake of complementary foods, and mothers may report a meal or the child having consumed certain foods even if the amounts were very small (and nutritionally insignificant).

- **Assessment of CF Practices in the Previous 24 h.** Therefore, assessments do not capture usual or long-term practice; this is particularly problematic for CF practices because consumption of complementary foods in young infants is a dynamic process that changes rapidly within short time frames.

- **Focus Is Set on Preventing and Reducing Child Undernutrition, and Indicators for the Prevention of Childhood Overweight and Obesity Are Not Included.**

The CF indicators were originally designed to serve as rough proxies for a few selected CF behaviors that are amenable to being measured in large-scale data collection exercises; they were not designed to reflect the intricacies and complexities of the multiple dimensions of CF practices or to describe usual practices at different ages. However, given the interest and demand for more performance indicators, the time has come to revisit how we can improve and enhance our set of indicators. The chapter provides some recommendations for the way forward, including to revisit the indicators and carry out validation studies and develop approaches to
reduce measurement error; to work on the development of new indicators to reflect some of the dimensions of CF practices that are not represented in the current set of indicators; to develop a simplified, technology-smart 24-hour dietary assessment method to quantitatively measure nutrient intake in children 6–24 months of age for use in research and small data collection exercises, and to include new indicators focused on the prevention of childhood overweight and obesity.

Enormous progress has been achieved since the WHO CF indicators were released in 2008. In the 8 years of their existence, the indicators have made tremendous contributions to enhancing awareness and knowledge about the status of CF practices nationally and globally. This has stimulated unprecedented interest and commitment among nutritionists and the wider development community to renew efforts to tackle the neglected area of CF as one of the critical inputs to accelerate progress in improving child nutrition. More can be done, and we suggest that it is time to reflect and revisit the CF indicators, improve them, develop new ones and promote their appropriate use. Better indicators are critically important to stimulate action and investments in improving CF practices at scale.

Reference

Complementary feeding interventions, which aim to improve dietary intake of children 6–23 months of age, were ranked among the top 10 effective interventions to address child undernutrition in low- and middle-income countries (LMIC) by the Lancet Nutrition series [1]. Given the implications for strategic planning and resource allocation by governments, donors and researchers, it is important that the underlying evidence base be continuously synthesized and clearly articulated.

Three recent systematic reviews provide pooled estimates for two categories of complementary feeding interventions on length and weight gain of children aged 6–23 months in LMIC [2–4]. Meta-analyses have recognized limitations but remain our primary tool for synthesizing evidence across intervention trials. To account for the heterogeneity in measurement approaches, continuous outcomes may be reported as relative standardized mean differences (SMD) rather than absolute mean differences (MD). Generally, an SMD of 0.2 SD is considered a small, of 0.5 SD a medium and of 0.8 SD a large effect [5].

**Education-Only Interventions.** Complementary feeding education interventions promote optimal caregiver practices related to continued breastfeeding, age-appropriate food choice, food preparation methods as well as frequency and style of feeding. The two most recent systematic reviews examining the impact of complementary feeding education alone on growth of children in LMIC are published by Lassi et al. [3] in 2013 and Imdad et al. [2] in 2011. Lassi et al. identified 10 trials of education-only interventions meeting inclusion criteria compared to 8 by Imdad et al.; 7 studies are included in both reviews. Both reviews limited study inclusion to controlled intervention trials among children under 23 months of age.
in LMIC with available data on change in weight and/or length. They further restricted their analyses to trials with a 6-month minimum intervention duration that did not selectively enroll malnourished children. Using CHERG methods, both reviews graded the quality of evidence for each outcome as ‘moderate’.

The 2 reviews reported similar pooled effect sizes for length and weight gain (table 1) compared to no intervention controls. Imdad et al. [2] also reported the absolute difference (MD) in length gain [0.49 cm (95% CI 0.00–0.999); 7 studies] and weight gain [0.30 kg (95% CI 0.05–0.54); 8 studies]. Lassi et al. [3] reported pooled estimates for several additional growth metrics including weight-for-age and length-for-age z-scores and stunting (not shown).

Lassi et al. presented a subanalysis by food security status in which trials were classified as food secure or food insecure based on a country level per capita income cutoff of USD 1.25/day. In the subanalysis (table 1), significant differences were only observed in food-secure populations. The differences are consistent with the rationale that food-secure populations have more resources to implement promoted feeding practices and therefore a higher potential to benefit from education-only interventions than food-insecure populations. Neither review attempted to pool by delivery platform, intensity, age group, duration or other implementation-related factors.

Provision of Foods or Specially Formulated Supplements with or without Nutrition Education. In pooling estimates for this second category of complementary feeding interventions, it is assumed that the nutritional supplement drives all of the observed effect on growth (not the optional educational component). Lassi et al. identified a total of 7 trials compared to 11 in the study by Imdad et al. for interventions providing food or

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<tr>
<td></td>
<td>SMD (95% CI)</td>
<td>studies, n</td>
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<tr>
<td>Length gain</td>
<td>0.23 SD (–0.00, 0.45)</td>
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<tr>
<td>Food secure</td>
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<tr>
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<tr>
<td>Weight gain</td>
<td>0.26 SD (–0.00, 0.52)</td>
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<tr>
<td>Food secure</td>
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<td>0.21 SD (0.01-0.41)</td>
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<td>0.30 SD (0.05-0.54)</td>
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nutrient supplements with or without education. A third more recent systematic review by Kristjansson et al. [4] examined growth outcomes for food supplementation interventions among children aged 3–59 months, with 23 studies in LMIC included in their meta-analysis. Pooled estimates for RCTs and controlled before and after studies (CBA) were reported separately. The majority of the subjects across the 23 studies were 6–23 months old. Across the 3 reviews, the quality of evidence for each pooled outcome was categorized as ‘moderate’ based on GRADE/CHERG criteria [6] except for those reported by Kristjansson et al. using CBA trials, which were all rated ‘very low’.

Despite the variability in the studies included, pooled effect sizes for height gain and weight gain are consistent across the analyses (table 2). Relative effect sizes (SMD) are small (<0.5) and significant only in the study by Imdad et al. The absolute effects on length (MD) reported by Imdad et al. include both RCTs and CBAs, and fall consistently between the independent pooled estimates for RCTs and CBAs reported by Kristjansson et al. Among the RCTs of the latter study, the effects of interventions providing high-energy supplements (>60% DRI) on height compared to control were large and statically significant [MD 0.62 cm (95% CI 0.13–1.11); 2 studies] in comparison to those providing medium (30–59% DRI) [MD 0.16 cm (95% CI –0.09 to 0.41); 5 studies] or low energy (0–29% DRI) supplements [MD 0.25 cm (95% CI –0.05 to 0.55); 1 study]. There were no statistically significant differences in weight gain across subgroups. Additional subanalyses presented by Kristjansson et al. suggest trends towards improved growth outcomes for younger and/or more malnourished children, for interventions involving center-based

Table 2. Summary of findings from three recent meta-analysis of growth effects of complementary feeding interventions that provide food or nutrient supplements with or without education to children 6–23 months of age in LMIC

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<th>Study</th>
<th>RCT (SMD)</th>
<th>CBA (SMD)</th>
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<td>Imdad et al. [2] (2011)</td>
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<td>0.34 (–0.09, 0.78)</td>
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<tr>
<td>Lassi et al. [3] (2013)</td>
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<td>0.27 (0.07, 0.48)</td>
</tr>
<tr>
<td>Kristjansson et al. [4] (2015)</td>
<td>0.52 (–0.07, 1.1)</td>
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<th>Effect</th>
<th>SMD (95% CI)</th>
<th>MD (95% CI)</th>
<th>n</th>
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<td><strong>Height gain, cm</strong></td>
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<tr>
<td>SMD</td>
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<td>0.34 (–0.09, 0.78)</td>
<td>10</td>
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<tr>
<td>MD</td>
<td>0.43 (0.19, 0.65)</td>
<td>0.27 (0.07, 0.48)</td>
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<tr>
<td><strong>Weight gain, kg</strong></td>
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<tr>
<td>SMD</td>
<td>0.22 (0.06, 0.38)</td>
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<tr>
<td>MD</td>
<td>0.14 (0.05, 0.24)</td>
<td>0.12 (0.05, 0.18)</td>
<td>9</td>
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compared to home-based feeding and for multifaceted interventions compared to single-strategy interventions. However, small sample sizes limit the ability to draw conclusions.

**Conclusion.** Evidence from controlled trials consistently points to complementary feeding interventions making a small but significant impact on growth of children 6–23 months of age in certain LMIC contexts (e.g. education-only in food-secure populations). However, at present, there is not a sufficient evidence base (in terms of number and variety of large-scale controlled trials) to support meaningful categorization and comparison of growth effects across intervention designs (e.g. facility- vs. community-based education), delivery factors (e.g. duration and intensity of supervision) and/or contextual variables (e.g. age, food security and baseline nutritional status).

**References**

Results with Complementary Food Using Local Food Ingredients

Tahmeed Ahmed, Munirul Islam, Nuzhat Choudhury, Iqbal Hossain, Sayeeda Huq, Mustafa Mahfuz and Shafiqul Alam Sarker

Up to 6 months, an infant should be fed only mother’s breast milk. After 6 months, breast milk alone is not enough, and complementary food should be given in addition to breast milk up to at least 2 years. When the child is 6 months old, the supply of energy and iron, among other nutrients, can be limited in breast milk, which can supply only 60–70 and 6–7% of the required intake of energy and iron, respectively [1]. Existing infant and young child feeding (IYCF) guidelines provide a robust guidance on complementary feeding of infants and young children. IYCF guidelines categorize food for children into seven groups which include: grains, roots, tubers; legumes and nuts; milk, yogurt, and cheese; meat and fish; eggs; vitamin A-rich fruits and vegetables, and other fruits and vegetables. Children after 6 months of age daily require food from at least four food groups in order not to become nutrient deficient (minimum dietary diversity). The minimally accepted diet is an important metric for assessing dietary intake of children. It is a composite of taking food from at least four food groups including milk and a daily feeding frequency of 2–4 times depending on age. In Bangladesh, only 23% of children under 2 years receive the minimally accepted diet. These figures are 26.5 and 11% for Nepal and Uganda, respectively.

Children receive inappropriate complementary diet for various reasons. Principal reasons include poverty, food insecurity and lack of awareness regarding appropriate child feeding practice. Globally, 21% of the population lived in poverty on less than USD 1.25 per day in 2010, while 15% are food insecure. In Bangladesh, 29% of the population lives below the poverty line. Food insecurity, assessed on the basis of consumption of less than 1,805 kcal per capita per day, affects 16% of the Bangladeshi population. In a study done in rural Bangladesh, we found that the prevalence of adequate intakes ranged from a mean of 0 for calcium to 95% for vitamin B₆ and was <50% for iron, calcium, riboflavin, folate and vitamin B₁₂ [2]. This level of inadequacy of micronutrient status
among children in Bangladesh was explained by diets low in energy and little diversity in foods. In the same study, we observed that almost all women consumed less than the recommended intake levels for total fat, total polyunsaturated fatty acids, α-linolenic acid and docosahexaenoic acid. Median breast milk linoleic acid (8.5% weight) and α-linolenic acid (0.2%) concentrations were among the lowest reported in the literature [3]. More than 95% of the children had fat intakes <30% of total energy. An estimated 80% of all of the children consumed <4% of total energy as linoleic acid, and 99% consumed <1% of energy as α-linolenic acid, implying an acute lack of essential fatty acids in the diet. These factors are important for the huge burden of childhood malnutrition in Bangladesh – 36% of children under 5 years of age suffer from linear growth retardation or stunting, 14% suffer from acute malnutrition while 33% are underweight.

Since inadequate energy and micronutrient intake during childhood is a major public health problem in developing countries which are plagued with food insecurity, we developed ready-to-use complementary food (RUCF) made of locally available food ingredients [4]. One was based on rice-lentil and the other on chickpea. Linear programming was used to determine possible combinations of ingredients and micronutrient premixes. The total energy contents obtained from 50 g of rice-lentil-/chickpea-based RUCFs were 264 and 267 kcal, respectively, which also supplied ~70% of the micronutrient needs of a child. The RUCFs were found to be well accepted by children and their mothers through an acceptability trial done in the community where the primary outcome variable was to see the acceptability of RUCFs versus another local food (Pushthi packet) by measuring the amount of food consumed by children. The secondary outcome variable was to measure children's mothers’ opinion on the food color, flavor, mouth feel and overall acceptability by using a seven-point hedonic scale.

We tested the efficacy of the local RUCFs by a cluster-randomized controlled trial in rural Bangladesh where the effect of the two RUCFs and a fortified blended food (wheat-soy blend++, WSB++) was compared with a commercial lipid-based nutritional supplement called Plumpy’doz, all with nutrition counselling versus nutrition counselling alone (control) on outcomes of linear growth (length and length-for-age z-score, LAZ), stunting (LAZ ≤2), weight-for-length z-score (WLZ) and wasting (WLZ ≤2) in children 6–18 months of age [5]. Children (n = 5,536) were enrolled at 6 months of age and provided with one of the allocated supplements daily for 1 year. Deceleration in LAZ was significantly lower (by 0.02–0.04/month) in the rice-lentil, Plumpy’doz and chickpea groups compared to control at 18 months of age. WLZ decline was lower only in Plumpy’doz and chickpea groups. WSB++ was not different from the
control. In children who received chickpea RUCF or Plumpy’doz, the prevalence of stunting was lower by 5–6% at 18 months.

Poor-quality complementary food is a risk factor for growth retardation. UCFs made of locally available food ingredients and conforming to standard specifications can be used to improve child growth particularly among those living in conditions of food insecurity and under social safety net mechanisms.

References

Fortification of Complementary Foods: A Review of Products and Program Delivery

Lynnette M. Neufeld, Saskia Osendarp and Wendy Gonzalez

Although there is great potential to improve the quality of complementary foods through the use of local ingredients, there are many populations in which limitations of availability and/or affordability of diverse nutrient-rich foods, particularly foods of animal source, may be a barrier to this. Fortified complementary foods (FCF) and home fortification – single-sachet micronutrient powders (MNP) or small-quantity lipid-based nutrient supplements (SQ-LNS) to be added to a child’s food immediately before consumption – have been shown to be efficacious to improve the micronutrient status and some functional outcomes in children 6–23 months of age. A number of programs have sought to increase their availability and/or affordability in the market by working directly with industry (from small to large scale) or public-private partnerships, but a number of challenges remain to create viable business models for the production and marketing of complementary feeding products [1].

Many public programs target populations at high risk of inadequate dietary nutrient intake in infants with free or subsidized distribution of complementary feeding products. The free distribution of FCF is common across Latin America, and many countries around the world are now distributing MNP. At this time, the use of SQ-LNS in programs is still very limited.

There is ample guidance to ensure that products can be produced safely and aligned with recommended nutrient intakes, such as recommendations on product composition [2], CODEX Alimentarius and guidelines from the World Health Organization. The Home Fortification Technical Advisory Group (HFTAG; www.hftag.org) has developed guidance for MNP formulation and production, as well as for the implementation and monitoring of programs. The latter two guidance documents can be easily applied to programs distributing any complementary feeding product.

The selection and development of the product itself is critical, but impact on nutritional status and functional outcomes will be achieved
Fig. 1. WHO/CDC logic model for micronutrient interventions in public health (reproduced with permission from De-Regil et al. [3]).
only if adequate attention is paid to program design and implementation. In this chapter, we use the WHO/CDC generic logic model for programs (fig. 1) [3] to guide a review of critical program components, particularly the choice of the delivery platform, availability, accessibility, acceptability, coverage and utilization by the target population with illustrations from published literature. Well-targeted programs such as social protection programs, community health workers and sales forces, health facilities, child health weeks, and rations in emergency settings and refugee camps have all been used as delivery platforms for FCF or MNP.

For FCF and MNP, there are a number of demand-related challenges that must be overcome, including lack of the perceived need for the products and sharing of products in the home that limit utilization by the child. Ensuring that there is an in-depth understanding of the local context and culture and the design and implementation of program components including behavior change interventions that respond to those can increase program coverage and product utilization. This highlights the need for formative research to be used to guide the design of all programs [4].

Process evaluation and implementation research are tools that should also be used in all programs to track performance, i.e. the quality of implementation in comparison to design, and provide specific recommendations to improve the quality of study design and implementation [5]. Using rigorous designs and ensuring high-quality research would strengthen the evidence related to how programs work and permit the development of improved program guidance to increase effective implementation.

References

Ying Yang Bao: Improving Complementary Feeding for Chinese Infants in Poor Regions

Junsheng Huo

Ying Yang Bao (YYB, a Chinese translation of nutrient sachets) is a soy bean powder-based complementary food supplement containing vitamins A, D, B₁, B₂, B₆, and B₁₂, folic acid, calcium, iron and zinc. YYB can be used as a home fortification product and added to porridge, noodles and other homemade complementary foods.

Development of YYB

YYB could be traced back to a home fortification intervention study on complementary feeding of infants which was organized by the Chinese Centers for Disease Control and Prevention (CDC) and ILSI during 2001–2003. The results showed that YYB improved nutrition status and cognitive scores of the test group. Nestlé developed the YYB product and donated the product for the intervention [1]. In 2008, the Chinese CDC implemented the project 'Infants Nutrition Intervention Project in Wenchuan Earthquake Regions'. The project supplied infants with YYB in 11 counties from 2008 to 2011. The survey data showed that the anemia rate decreased and z-scores increased remarkably. The national standard of complimentary food supplements was proven by the Ministry of Health in 2008. There have been 15 national or regional intervention projects carried out in rural China so far. The Ministry of Health launched a national project aiming to improve child nutrition in poor regions in 2012.

Nutrition Effects of YYB

Results of the Gansu study suggested that the YYB group had lower anemia rates, higher length-for-age and weight-for-age z-scores, and better cognitive scores [2–4]. Zhang et al. [5] systematically reviewed the studies of different YYB projects. Thirteen groups of qualified data from 9 YYB intervention studies were used. The results showed that
YYB significantly increased the level of hemoglobin, reduced the prevalence of anemia, and increased weight-for-height and weight-for-age z-scores.

**Improving Child Nutrition in Poor Regions**

The project ‘Improving Child Nutrition in Poor Regions’ aimed to supply all the 6- to 24-month-old infants with YYB in poor rural counties combined with the distribution of nutrition knowledge to the guardians. In 2015, the fund amounted to 500 million CNY and 341 counties covered. It is expected that the coverage will extend to all the 834 poverty counties mainly located in west and middle regions. The Chinese government has continuously purchased YYB products and distributed them to families in 341 poor counties and thus to more than 4 million infants.

In conclusion, the YYB studies indicate the effectiveness of this fortification method, and YYB might also be beneficial for malnourished infants in other developing countries to improve nutrition and health. To strengthen the scientific observations and research on YYB, further studies aiming to improve the formula, randomized controlled trials and cost-benefit analyses are warranted. The working system for YYB project implementation should also be studied in terms of sustainability and feasibility.

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Healthy Growth and Development

Ken K. Ong

There is a remarkably consistent association between rapid infancy weight gain and higher risks for obesity in later childhood and adult life. Most recently, 45 of 46 studies reported positive associations in settings across the world [1]. The shape of this association shows a continuous influence of rising infancy weight gain on the risk of childhood obesity, plus a substantially higher risk in those infants who crossed upwards by >1.33 z-scores [2]. Those findings indicate potential benefits for both population-wide and targeted high-risk preventive strategies.

Feeding for Healthy Infancy Weight Gain

The (typical) slower trajectory of weight gain in breastfed infants underlies the rationale for the WHO 2006 Growth Standards. Adoption of these WHO growth charts has substantial (and likely beneficial) impact on the classification of more young children being in overweight and obese categories, and far fewer having underweight.

Within formula milk-fed infants, higher protein composition promotes faster infancy weight gain. There has been significant lowering of protein contents of most formula milks [3]. Recent observational studies of the (substantially more variable) nutrient composition of human breast milk supports a positive effect of milk protein on infant weight and suggests a weight-limiting role of milk fat content [4].

There is a linear relationship between total energy intake and infancy weight gain. Effective shifting downwards of the widespread excessive infant calorie intakes requires a sensitive understanding of parental attitudes and aspirations for their infant's growth, which are often higher than optimal.

There is an inconsistent association between age at the introduction of solid foods ('weaning') and the risk of obesity [1]. A recent review shed doubt on the underlying premise that early weaning promotes faster infant weight gain. Conversely, early age at weaning may be a parental response to larger infant size, rapid growth and weight gain, or even higher infant hunger signals [5].
Infant Control of Infant Weight Gain

Infant feeding is the result of complex interaction and signaling between mother and infant. Monogenic studies of severe early-onset obesity have identified rare mutations that delineate the ‘central’ regulation of appetite and satiety. Affected children have extremely high and insatiable appetites (‘hyperphagia’) from infancy.

The heritability of BMI is high even in young children. Longitudinal studies show that common ‘obesity susceptibility genetic variants’ affect weight gain during infancy and childhood – the higher attained weight persists through life with adverse consequences such as diabetes and other obesity-related metabolic disorders [6]. These obesity susceptibility variants also support a predominantly ‘central’ genetic regulation of weight gain and BMI. Furthermore, they act across the spectrum of infancy weight gain, being protective against ‘inadequate’ levels of weight gain while also predisposing to overweight and obesity.

Llewellyn and Wardle [7] identified distinct infant appetitive constructs relating to food responsiveness (appetite) or satiety responsiveness. These traits are influenced by obesity susceptibility variants and are predictive of infant weight gain. Therefore, it appears that centrally acting obesity susceptibility variants contribute to the wide interindividual differences in infant appetite, satiety, food intake and weight gain, and they provide a biological link between early growth and feeding behaviors and later childhood pubertal timing and adult metabolic disease risks (fig. 1).

Future Perspectives

The long-term relevance of infant body composition and fat distribution (and also other detailed measures of infant metabolism) are yet unknown. While we await longer-term follow-up studies, research studies that categorize the infant phenotypes associated with low versus high
genetic obesity susceptibility might inform which infant profiles are indicative of future health. Recent findings indicate that, in infants with rapid weight gain, rapid gains in lean body mass are not necessarily protective for future obesity and that the emergence of higher percent body fat may be a relatively late occurrence [6].

References

Responsive Feeding: Strategies to Promote Healthy Mealtime Interactions

Maureen M. Black and Kristen M. Hurley

Feeding is a major developmental task in the first years of life as infants and young children progress from an exclusively liquid diet to pureed foods, and finally to the family diet [1]. Progression in feeding is influenced by: (1) advances in digestive and oral motor skills, (2) internal regulatory cues of hunger and satiety, and (3) advances in cognitive, fine motor and social-emotional development that facilitate interest in food, self-regulation and self-feeding. Infants and young children signal hunger and satiety through actions such as hand sucking, leaning forward for food, opening and closing of the mouth, turning and crying/fussing. These behaviors vary in form and intensity across infants, often contributing to interpretation confusion.

Responsive feeding, a derivative of responsive parenting [2], refers to the reciprocity between the parent and child during feeding, whereby parent and child behaviors vary in a back-and-forth or serve-and-return pattern [3]. Early in life, this reciprocal process influences the emotional bonding or attachment between infants and parents that forms the basis for healthy social-emotional functioning [4], as children are acquiring feeding skills.

Feeding problems occur among up to 50% of typically developing infants and young children throughout the world, and they frequently include food refusal, food selectivity (pickiness) or disruptive mealtime behavior [5]. In many cases, feeding problems represent typical toddler development of neophobia (hesitancy to try new foods) or autonomy (food refusal and desire for independence). Food refusal can be confusing to parents because it may be unclear whether children are signaling satiety, requesting an alternative or exhibiting a behavioral problem. Early feeding problems are often transient and resolve over time, particularly when parents are sensitive to their child’s signals of satiety and emerging autonomy, and adhere to regularly scheduled mealtime routines. However, when feeding problems are associated with family stress, they can
result in weight-related problems (either under- or overweight) and long-term behavioral problems.

As children progress to the family diet, strategies to promote healthy mealtime interactions include: (1) assurance that the feeding context is pleasant with few distractions, that the child is seated comfortably ideally facing others, that expectations are communicated clearly, and that foods are healthy, tasty, developmentally appropriate and offered on a predictable schedule so the child is likely to be hungry; (2) an emotional climate whereby the parent models eating, offers encouragement as needed, promotes self-feeding and attends to the child's signals of hunger and satiety, and (3) the parent responds in a prompt, emotionally supportive, contingent and developmentally appropriate manner. With parent patience and adherence to a regular mealtime routine (2–3 h between meals, 20–30 min/meal), transient feeding problems resolve. Responsive feeding promotes children's attentiveness and interest in feeding, attention to their internal cues of hunger and satiety, ability to communicate needs to their parent with distinct and meaningful signals and successful progression to independent self-feeding.

Responsive feeding acknowledges children's feelings and allows them to determine how much they eat, while parents decide what, when and where food is offered. Embedded within the domain of responsive parenting, responsive feeding emphasizes the interactive nature of feeding, whereby parents set guidelines, with their reactions gaged to the signals they read from their children, ideally resulting in a respectful give-and-take relationship around feeding.

Complementary feeding typically begins during the second 6 months of life, a period of rapid growth that includes multiple developmental changes along with nutritional and health risks. Responsive feeding provides the guidelines that enable parents to avoid and manage transitional feeding problems and promote the successful transition to the family meal and self-feeding.

References
Complementary Feeding in an Obesogenic Environment: Behavioral and Dietary Quality Outcomes and Interventions

Lynne A. Daniels

The WHO infant feeding guidelines are prescriptive, largely based on the outcomes of exclusive breastfeeding and have a bias to undernutrition [1]. Little attention has been paid to outcomes (independent of exclusive breastfeeding) of complementary feeding (CF) practices relevant to food preferences and eating behaviors/patterns that are potentially protective in the excess food environment of affluent countries [1].

Complementary feeding comprises a number of interrelated exposures: timing (initiation and rate of progression); type of food (nutrients, taste and texture); process (repeated exposure, variety and self-feeding), and parent feeding practices [control, (non)responsive feeding and structure] [2]. To date, the focus has been on the exposures of timing (when) and nutrients (what) and relatively short-term outcomes (growth rate, infection, micronutrient status, atopy and infant mortality). However, in the context of an obesogenic environment, it is important to consider longer-term outcomes that potentially mediate the associations between infant feeding and life-long eating patterns and obesity and chronic disease risk [3, 4]. These ‘intermediate’ outcomes do not only include rapid growth but also taste preferences, food acceptance and texture tolerance, which are key determinants of early dietary variety and hence quality. However, studies examining the independent impact of the ‘when, what and how’ of CF are scarce.

Many correlational studies have suggested that infant feeding practices ‘program’ taste preferences, texture tolerance and appetite regulation at a time when both behavior and biology are plastic. A seminal 2008 review [5] of studies examining the role of feeding practices in child eating behavior and weight status reported there were only 6/67 longitudinal studies, 2 small interventions and no studies that commenced in infancy. The NOURISH intervention and trial were designed around this time to address this gap [6].
The NOURISH trial [6, 7] evaluated a CF intervention for first-time mothers commencing at infant age 3–6 months. The overall research question was *Can anticipatory guidance increase ‘protective’ feeding practices that support development of healthy child eating behaviors, food intake and growth?*. The trial allocated 698 mothers with healthy term infants. Outcome assessment occurred at ages 4 months (baseline), 14 and 24 months, and 3.5 and 5 years (3.5 years after intervention). The intervention comprised two modules, each of six fortnightly group sessions, that commenced at child age 4 and 14 months. Messages emphasized healthy growth and eating behaviors rather than obesity prevention. Overall, NOURISH demonstrates that anticipatory guidance on the process of CF increased protective maternal feeding practices and was associated with trends (p = 0.06) in obesity risk reduction >3 years after intervention. The impact on dietary quality, food preferences and child eating behavior was limited. NOURISH was a universal intervention with participants enrolled regardless of obesity risk. Targeting infants with genetic or phenotypic risk may enhance the impact of anticipatory guidance during CF [7]. The Early Prevention of Obesity in Childhood (EPOCH) collaboration provides an individual participant data prospective meta-analysis of individual data from four feeding trials commencing before 6 months age, including NOURISH [8]. Analysis (n = 2,196) showed a significant intervention effect at 2 years of age on BMI z-score (–0.12, p = 0.017, adjusted for baseline) [9].

There is a clear need for better evidence to inform affluent country guidelines on the ‘when, what and how’ of CF based on outcomes relevant to obesity and chronic disease risk. Mothers, most of whom do not exclusively breastfeed to 6 months, need clear and consistent advice on continuing any breastfeeding for as long as possible, safe and appropriate bottle feeding (e.g. avoiding encouragement to empty the bottle) and introducing solids in a way that promotes increased acceptance of a wide range of foods and textures (e.g. repeated, varied exposure and early texture progression). There needs to be less political correctness related to exclusive breastfeeding and more research on optimizing the timing and process of CF.

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Modifiable Risk Factors and Interventions for Childhood Obesity Prevention within the First 1,000 Days

Anne M. Dattilo

Worldwide, the prevalence of childhood obesity has increased to 42 million and there is increasing evidence that the origins are within the first 1,000 days, the period of conception through 2 years. Antecedents of early childhood obesity are multifactorial, and associations of varying strength have been documented for genetic/epigenetic, biologic, dietary, environmental, social and behavioral influences. Primary modifiable factors in pregnancy and early infancy that have been associated with childhood obesity include maternal overweight/obesity, maternal smoking, gestational weight gain, infant and young child feeding (IYCF), caregiver responsive feeding practices, as well as sleep duration and physical activity. Promising obesity prevention interventions include those beginning during the first 1,000 days, using a multicomponent approach, with roots in nutrition education theories or behavior change communication that can continue over time. However, the limited number of completed interventions to date within pediatric clinics, home-based or community-based settings may not be scalable to the magnitude needed for sustainable obesity prevention. Scale-up interventions that can be maintained for durations needed, addressing IYCF and other modifiable risk factors associated with childhood obesity, such as using digital technologies as enablers to extend the reach of such programs globally, and within early childhood education, are needed.

Recent evidence indicates that the genesis of childhood obesity may be rooted to the environment within the first 1,000 days, the time period from conception until age 2 years, in which nutritional, metabolic and diet-related behavioral ‘programming’ may be established. As many overweight infants remain overweight through their childhood years, and childhood obesity has long been recognized as a strong predictor of adult obesity, attention to overweight status during infancy is warranted.
Multiple genetic, economic, and societal factors have been proposed to explain the global prevalence of childhood obesity. However, several modifiable factors have been identified at the individual level, as maternal and caregiver behaviors, that can be potentially adopted or changed. Although the majority of risk factors associated with childhood obesity have been identified in pregnant women and their young children from high-income countries, they are potentially applicable to all global regions.

Three recent systematic reviews and meta-analyses [1–3] have identified significant associations among early childhood overweight, obesity or measures of adiposity and modifiable factors that occur both in utero and during early childhood. In general, these factors can be categorized as either food- and diet-related behaviors, or feeding and associated lifestyle behaviors.

Modifiable in utero exposures, such as cigarette smoking, excess gestational weight gain and maternal preconception weight (considered as a proxy for the early gestation exposure), have been consistently identified to be positively associated with infant birth weight or later childhood overweight. Glucose control for women with maternal diabetes mellitus is also potentially modifiable, and most studies have indicated that gestational diabetes is an independent risk for infant or childhood overweight.

After birth, breastfeeding has been reported to be protective of rapid weight gain, a strong and consistent risk factor for childhood overweight. Introductory age to complementary foods, along with the quality and quantity of the diet, has also been associated with infant and young children's weight status. Modifiable factors that are not directly food and diet related include parental feeding practices, maternal modeling of healthy food choices and routines, such as sleep, activity and sedentary behaviors.

Understanding of the modifiable factors associated with healthy growth during infancy provides an opportunity for the design and assessment of interventions targeted to reverse trends in childhood obesity, beginning during the first 1,000 days. For behavior change, or adoption of new behaviors, interventions based within nutrition education theories or behavior change communications hold promise for effectiveness [4, 5].

A limited number of multicomponent interventions that target obesity prevention during the first 1,000 days have been employed, and some have yielded successful outcomes within a randomized, controlled, clinical trial design [6]. Two important questions remain: whether these interventions render sustainable results and whether they are potentially scalable to larger populations. Digital-based interventions are increasingly feasible for such scale-up efforts and may help avoid the limitations of prior interpersonal interventions which affect coverage, dose and fidelity.
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