Nurturing a Healthy Generation of Children: Research Gaps and Opportunities

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Preface

Optimal growth is a central theme in human nutrition. Growth is a proxy indicator of health and well-being. Adequate food intake is crucial for growth. Nurturing a healthy generation of children is a social imperative. This formed the title of the workshop. Much remains to be learned on the factors that limit and enhance food intake in children. Hence, the workshop focused on research gaps and opportunities. The workshop covered 3 sessions that involved an excellent array of presentations. The first session was entitled “Early Eating Behavior and Taste Development Influence in Children.”

According to the World Health Organization (WHO), the global number of children aged from 0 to 5 years with overweight or obesity has increased from 32 million in 1990 to 41 million in 2016. This trend concerns most countries around the globe, although we may see obesity rates stabilizing in some countries, such as in northwestern Europe [NCD Risk Factor Collaboration: Lancet 2017;390:2627–2642]. Obesity is associated with comorbidities, placing children at a greater risk of developing type 2 diabetes, cardiovascular disease, and even psychological disorders such as low self-esteem. In this context, the WHO has developed a framework to prioritize 6 actions that could help put an end to childhood obesity [Commission on Ending Childhood Obesity: Report of the Commission on Ending Childhood Obesity, 2016]. The importance of nutrition for children is present in 3 of these actions, which relate to the content of this workshop: (1) the promotion of healthy food intake, (2) early childhood diet and physical activity, and (3) health, nutrition, and physical activity for school-age children. In this context, it is more topical than ever to ensure children receive the best nutrition from the start of life, and even before, and develop healthy eating habits which could be maintained throughout life. In relation to these issues, in the first session of the workshop entitled Nurturing a Healthy Generation of Children: Research Gaps and Opportunities, the development of eating behaviors in the early years of life has been addressed from the very early months of postnatal life according to several themes related to modifiable
factors: the role of sensory inputs, the role of dietary experience, and the effect of parental feeding practices.

Sophie Nicklaus et al. focused on the development of taste and flavor preferences and its consequences on children’s eating behaviors. After birth, when foods are orally exposed, infants discover the intrinsic properties of foods, with a variety of tastes, flavors, textures, as well as energy densities. Here, the focus was on deciphering the involvement of taste and olfaction in the early establishment of eating behavior based on data collected in the OPALINE birth cohort (Observatory of Food Preferences in Infants and Children), which was followed up in the area of Dijon (France). Taste and flavor preferences were studied in those children in relation to food acceptance over the first 2 years of life. The data show that both taste and flavor preferences evolve during this period: for instance, saltiness acceptance increased sharply between 3 and 12 months, while rejection of unpleasant food odors developed between 8 and 22 months. At the beginning of the complementary feeding period, a higher preference for some basic tastes (sweet, sour, and umami tastes) was associated with a higher acceptance of foods with similar tastes (sweet, sour, and umami, respectively); and, similarly, rejection of the odor of trimethylamine and dimethyl disulfide were related to the rejection of fish and sulfurous cheeses, respectively. Further in development, at 20 months, food neophobia was associated with flavor differential reactivity (within-subject variability across flavors) but not to taste differential reactivity (within-subject variability across tastes), underlying the importance of olfaction in the development of neophobic reactions. Altogether, these data highlighted the sensitivity of infants and toddlers to the sensory inputs from foods, which also contribute to the pleasure of eating.

Andrea Maier-Nöth highlighted some mechanisms by which infants and toddlers learn to like vegetables, which is a critical issue given that children’s vegetable consumption falls below current recommendations in many countries. The first approach to increase acceptance of vegetables was based on offering infants a variety of vegetables (purée changed every day for 10 days vs. 3 days and no change) at the beginning of weaning. Such an experience with a variety of foods as of the beginning of weaning is associated with a higher acceptance of new vegetables and new foods from other groups, which persisted for several weeks, and to a higher liking and a higher consumption of new vegetables up to the age of 6 years. The acceptance of new vegetables was also higher in infants who had been breastfed, i.e., who had been likely exposed to a variety of flavors in breast milk. The second approach to increase acceptance is based on repeated exposures to an initially disliked vegetable. This experience markedly increases the acceptance of this vegetable, which becomes as liked as an initially liked vegetable. This presentation revealed the plasticity of young children to the food
experience they receive in their first years and the long-term effect of this experience in shaping healthy eating habits.

Kimberley Mallan and Narissa Miller addressed another facet of the parent-child interaction in terms of feeding, focusing in particular on eating behaviors related to appetite regulation and obesity risk, and on parental feeding practices likely to alter appetite regulation, namely nonresponsive feeding practices, which can be of many types. In this area, most of the previous research has been cross-sectional, whereas a bidirectional relationship between parent feeding and child eating has been proposed more recently. The aspects of child eating behaviors discussed in relation to obesity risk were eating in the absence of hunger (which can be measured experimentally), food responsiveness, or satiety responsiveness (which can be measured with an instrument such as the Child Eating Behavior Questionnaire). The presented review summarized findings related to feeding practices that may support (e.g., being responsive to a child’s cues or providing mealtime structure) or undermine (e.g., pressure to eat, instrumental emotional feeding, or restriction) children’s eating behaviors. In summary, this review confirmed that parents’ feeding practices do impact on children’s eating behaviors, but also that children’s eating behaviors influence the feeding practices parents use. Moreover, the presentation was ended by useful tips for responsive feeding practices that were successfully tested in the frame of the NOURISH study conducted in Australia.

The session was concluded by Lisa Fries and Klazie van der Horst who addressed “picky eating” in children, and how it is likely to be modified by parental feeding practices. Picky eating is a broad construct that relates to the perception of a limited diet or food refusals. A recent review of the literature found that picky eaters display several different types of behaviors, among which the most common are neophobia, lower fruit and vegetable intake, food refusals, less enjoyment of eating, and sensory sensitivities. Parental feeding practices may be usefully applied to overcome picky eating behavior in children. For instance, parents could be encouraged to keep trying after a food is refused, as children may need to be exposed to a food several times before it is accepted. Varying the preparation changes a food’s taste, texture, and appearance, and this may help identifying a child’s preferred variants. Conversely, coercive feeding practices such as the use of pressure to eat or using food as rewards should be avoided, as these can create negative associations with the food or meals and lead to food refusals. Instead, caregivers can model eating and enjoying the food. Nonfood rewards, such as praise or stickers, can also be used to encourage children to taste a food without negative outcomes. The presentation of casual reports from social media highlighted how food refusals may be an important matter of concern for parents. Finally, useful tips to avoid or cope with food pickiness were presented, which could apply in a variety of cultural contexts.
The second session focused on *What Children Eat*. The session compared and contrasted what children eat in both advanced and developing nations. Unlike other regions of the world, economic growth in Asia appears to have not kept pace with the eradication of undernutrition. Christiani Jeyakumar Henry articulated the etiology and causes of undernutrition in Asia and other emerging nations. He articulated that undernutrition was due to the poor access to weaning foods with adequate energy and sufficient palatability. Using human growth during the first 6 months of life, he illustrated that, in many instances, it was not the inadequate protein content in the diet that restricted growth but the poor energy density of the meal. The presentation also focused on the provision of simple diet formulations to meet the energy and palatability of infant foods.

In their presentation, Ciarán Forde, Anna Fogel, and Keri McCrickerd focused on how early life risk factors during the first 1,000 days of life can influence the development of childhood obesity. They focused their presentation on emphasizing the major role that caregivers and the food environment can play in the behavioral transition from the early life risk to the development of obesity. Several examples were highlighted. For example, children who ate their meal at a faster rate (g/min) consumed more energy than those that ate at a slower pace. How children’s food intake can be influenced by the availability of palatable foods was also further emphasized. The authors concluded that a holistic intervention was necessary to combat the escalating prevalence of childhood obesity.

Alison L. Eldridge described the history and background to the FITS (Feeding Infants and Toddlers Study) and KNHS (Kids Nutrition and Health Study) program. The FITS/KNHS are cross-sectional surveys designed to investigate nutrient intakes and eating patterns in infants and children. On most occasions, data from national surveys were used for the analysis. These surveys have been conducted in Australia, China, Mexico, the Philippines, Russia, and the USA. Country presentations on the FITS/KNHS program were made for the following countries: China (Danton Wang), Mexico (Salvador Villalpando-Carrion and Alison L. Eldridge), Philippines (Imelda Angeles-Agdeppa et al.), and the USA (Regan Bailey et al.).

Norimah A. Karim and Nurliyana Abdul Razak drew on 2 nationwide studies conducted in Malaysia, SEANUTS Malaysia (the Southeast Asian Nutrition Survey) and the MyBreakfast Study, to make their presentation. They demonstrated that 13–17% of children aged between 6 and 12 years were either overweight or obese. A majority of children attained the Malaysian recommended nutrient intake (RNI) for energy and protein. However, RNI for calcium and vitamin D was not met by more than half of the children. They also showed that only 13.4 and 9.5% met the Malaysian Dietary Guideline (MDG) for fruit and vegetable intake per day, respectively. The MyBreakfast Study showed that approximately 18% of the children consumed ready-to-eat cereal at breakfast. Milk, dairy products,
and fruits and vegetables were not daily eaten; only 1 in 20 children met the MDG for milk while 1 in 10 achieved the MDG for fruits and vegetables. It was concluded that there is considerable scope for improving the fruit/vegetable and milk consumption in this age group.

The third and final session focused on revisiting the *Importance of Breakfast for Children’s Health and Development.* Breakfast has long been promoted as the most important meal of the day. However, the lack of standard definitions of breakfast, breakfast consumers, and breakfast skippers, and the lack of a description of how the meal is important, especially compared with other meals, have hampered the ability to confirm this long-held belief. All of the inconsistencies in these definitions can affect how researchers, nutrition educators, and policy makers interpret data and make recommendations. Mike Gibney and Irina Uzhova’s presentation focused on dietary guidelines for breakfast intakes. Whilst there is consistent evidence on the nutritional benefits of a regular breakfast, there are few guidelines to help policy makers issue specific targets on optimal nutrient intake at breakfast or selection of foods to possibly include in the development of a nutritious breakfast. However, there is a lack of consistency in the definition of recommended food categories. Collectively, government recommendations that are currently being used highlight the need for a more scientifically rigorous approach to recommend optimal food and nutrient intakes at breakfast. Cluster analysis is one approach in determining optimal nutrient and food intake. However, there are major limitations in setting out gradations in optimal nutrient intakes for breakfast. Ultimately, meal-based advice may become the basic building block for digitally based personalized dietary analysis and guidelines.

Leonidas Karagounis discussed the importance of dietary protein at breakfast in childhood. Proteins are the major functional and structural components of all the cells of the body and participate in virtually all biological processes occurring in the body. Dietary protein is essential in child nutrition because children are in a state of ongoing growth and development. In terms of nutrient availability, current research supports the concept of nutrient timing intake. For example, the diurnal turnover of whole body protein which in turn impacts whole body protein balance may to some extent be dictated by specific need states where macronutrient intake, such as proteins and carbohydrates, may be imperative to support healthy physical growth and development. Specifically, a typically observed overnight fast in children has recently been shown to result in a physiological state of increased catabolism as measured by increased rates of whole body protein breakdown. It is, therefore, important that specific amounts of macronutrients be consumed at breakfast in order to attenuate such losses in whole body protein and, therefore, to provide an environment that supports healthy physical growth and development.
Theresa A. Nicklas presented 3 studies looking at breakfast skipping and body weight, breakfast patterns, and breakfast cognition. Twenty percent of US children and 32% of US adolescents skipped breakfast. Breakfast skippers had the lowest mean adequacy ratio for micronutrients compared to those who consumed breakfast. Moreover, breakfast skippers had the highest body mass index. They acknowledged a limitation of this study, which, among other similar studies, has been based on the incorrect premise that breakfast meals are homogeneous. A separate study found 12 distinct breakfast patterns in a US nationally representative sample of children. Results suggest that simply consuming breakfast was not associated with better diet quality when compared to breakfast skippers. More importantly, the specific foods/food groups consumed at breakfast influenced nutrient intake and overall diet quality. Thus, the nutrient profiles varied considerably depending on the type of breakfast pattern. The association of the breakfast patterns was not consistently associated with lower body mass index as seen in breakfast skippers. The third study was designed to address inconsistencies observed in previous studies by examining the short-term effects of breakfast consumption and fasting on neuropsychological functioning using a robust set of psychological measures of multiple domains of cognitive functioning in healthy, low- and medium-income school-age children. Breakfast consumption had no effect on neuropsychological functioning in children. More studies are needed regarding habitual breakfast consumption and its effect on neuropsychological functioning in healthy children and those with marginal or subnormal nutritional status.

The session was concluded by Sandra I. Sünram-Lea, who reviewed the impact of breakfast-based glycemic response on cognition in children. The data suggest that a more stable blood glucose profile which avoids greater peaks and troughs in circulating glucose is associated with better cognitive function across the morning. Although the evidence to date is promising, it is currently insufficient to allow firm and evidence-based recommendations. What limits our ability to draw conclusions from previous findings is that the studies have differed widely with respect to subject characteristics, cognitive tests used, and timing of cognitive assessment. In addition, few studies have profiled glycemic response in children specifically.

Christiani J. Henry
Theresa A. Nicklas
Sophie Nicklaus
Infant and childhood nutrition is the basis of an individual’s health in later life. Multiple lines of evidence – from experimental to epidemiological – are converging to highlight the importance of this early period for metabolic programming, physiological growth, and cognition. This is the cornerstone of the “developmental origin of health and disease” (DOHAD) paradigm, underscoring the significance of infancy and early childhood for setting the foundation for health. Any public health intervention that seeks to improve the general health of a population or combat disease should, therefore, target infants and children in order to reap the greatest benefits.

Yet, there is little mechanistic evidence to reveal how. Some of the answers can be found in studying diet and eating behavior: food choices and dietary habits go hand in hand with nutrition. Eating is a key skill that develops during early life. Between conception and childhood, the mode of feeding drastically evolves, from amniotic fluid, to breastfeeding, weaning, and independent feeding. Not only does the child learn how to eat, but also what to eat, how much, and in what context. During this time, infants discover the intrinsic properties of foods, along with the variety of tastes, flavors, and textures. These earliest sensations pave the way for food choice, steering an individual towards a lifetime of healthy (or unhealthy) eating patterns.

The 91st Nestlé Nutrition Institute Workshop on Nurturing a Healthy Generation of Children: Research Gaps and Opportunities, which took place in Manila (Philippines) in March 2018, highlighted the importance of childhood diets, eating behaviors, and potential impacts on development and health. The first session chaired by Dr. Sophie Nicklaus (INRA, French National Institute for Agricultural Research, France) examined the development of taste in infants, revealing how taste preferences are shaped in utero and throughout weaning, and guide the individual’s later food choices. The theme of the second session, led by Dr. Christiani Jeyakumar Henry (National University of Singapore), focused on what do children really eat in different parts of the world. FITS (Feed-
ing Infants and Toddlers Study) and KNHS (Kids Nutrition and Health Study) provided a glimpse into the diets of children around the world, identifying nutrition gaps and potential areas for intervention. The workshop ended with a final session on the most important meal of the day: breakfast. This session chaired by Prof. Theresa A. Nicklas (Baylor College of Medicine, Houston, TX, USA) concluded the 3 days of the fascinating scientific forum.

The key learnings from this workshop provide valuable insight for policy makers, researchers, and health care professionals on how diet and feeding behavior during each of these stages can influence health and disease.

We would like to thank the three chairpersons Sophie Nicklaus, Christiani Jeyakumar Henry, and Theresa A. Nicklas for putting the scientific program together.

We would also like to thank all speakers and scientific experts in the audience, who contributed to the workshop content and scientific discussions. Finally, we thank Dr. Josephine Yuson-Sunga, her team in the Philippines, and the NNI team in Switzerland for their support and nice hospitality.

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Early Eating Behavior and Taste Development Influence in Children

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Abstract
The first 1,000 days of life constitute an important period for the development of health and eating behavior. While the feeding mode drastically evolves, the child learns “how”, “what,” and “how much” food to eat. When orally exposed, infants discover food properties, with a variety of tastes, flavors, textures, as well as energy densities. Here, we focus on deciphering the involvement of taste and olfaction in the early establishment of eating behavior. In the OPALINE French birth cohort (Observatory of Food Preferences in Infants and Children), taste and flavor preferences were studied in relation to food preferences over the first 2 years. Both taste and flavor preferences evolved during this period. At weaning, a higher preference for sweet, sour, and umami tastes was associated with a higher acceptance of sweet-, sour- and umami-tasting foods, respectively. At 12 months, rejection of the odor of trimethylamine and dimethyl disulfide was related to the rejection of fish and sulfurous cheeses, respectively. Further, at 20 months, food neophobia was associated with odor but not taste differential reactivity, revealing the importance of olfaction in neophobic reactions. Further studies are ongoing to examine the long-term effect of early taste and flavor exposure on food preferences.

Introduction
Early childhood is an important period for the development of health. Recent researches using different approaches (experimental or epidemiological) have shown the importance of this early period for metabolic programming [1]. This
general concept of the “Developmental Origin of Health and Disease” (DOHAD) has been refined in humans to highlight the importance of the first 1,000 days for the development of health status [2]. In this context, our specific focus is on understanding how eating behavior is programmed during this period of the first 1,000 days. As a first observation, eating behavior undergoes a strong development during this period, in particular because the mode of feeding drastically evolves from conception until the age of 2 years. This implies that the child has to learn “how” to eat but also “what” to eat, “how much food” to eat, and “in which context” meals take place. After birth, when orally exposed to foods, infants discover their intrinsic properties, with a variety of tastes, flavors, textures, as well as energy densities, and all these aspects become even more salient at the onset of complementary feeding. By the end of the second year, food neophobia, i.e., the refusal of new food, develops [3–5]. We have previously observed that eating behavior established at the end of this period tracks on later into childhood and up to early adulthood [6–9]. Altogether, this calls for a better understanding of the driving factors and the key periods for the establishment of eating behavior during the first 2 years of postnatal life.

Here, we report several works in which we focused on deciphering the involvement of taste and olfaction in the early establishment of eating behavior over the first 2 years of postnatal life. We focused on both senses because they both strongly relate to the oral phase of feeding and because the chemosensory environment evolves strongly during this early period of life [10, 11]. In the frame of the OPALINE French birth cohort (Observatory of Food Preferences in Infants and Children), taste and flavor preferences were studied independently in children, as well as food acceptance and food neophobia over the course of the first 2 years of life.

**Evolution of Taste and Odor Preferences in Early Life**

At birth, previous works revealed evidence of differential preferences across tastes, with a preference for sweet taste, a rejection of bitter taste [12], and very little evidence of inborn flavor preferences (but rather of avoidance of smell of rotten foods [13]), except when infants had been previously exposed to specific flavors from the maternal diet [10, 11]. Thus, inborn taste and flavor preferences are not numerous although marked food preferences exist in adults and even in young children. It is then much needed to understand the factors contributing to the building of food preferences. The evolution of taste and flavor preferences at later stages in early childhood has received little attention. Within the OPALINE cohort, we studied longitudinally in a group of 285 infants the
evolution of taste preferences from 3 to 20 months [14, 15] and the evolution of flavor preferences from 8 to 22 months [16].

Acceptance of each taste (sweet, salty, bitter, sour, and umami) and of a fat emulsion relative to water was defined based on ingestion or liking at 3, 6, 12, and 20 months of age [14, 15]. For each taste, 4 bottles were presented (water, tastant, tastant, water). The acceptance of each taste relative to water was defined using proportional variables that are ratios of ingestion or liking evaluated by the experimenter. These data were analyzed with mixed models that accounted for age and subject effects. Taste acceptance trajectories for all primary tastes and for a fat emulsion were modeled. For saltiness, acceptance increased sharply between the ages of 3 and 12 months. The trajectories of acceptance were parallel for sweetness, sourness, and the umami taste between 3 and 20 months, with sweetness being preferred. Between 12 and 20 months, the acceptance of all tastes, except bitterness, decreased, and at 20 months, only sweetness was not rejected. The acceptance of bitterness remained stable. For the fat emulsion, acceptance evolved from indifference to rejection. Moreover, more rejections were reported based on the judgment of the experimenter than of the infant’s liking. Ingestion and liking ratios are rather complementary, and this result highlights that a grimace is not necessarily associated with reduced ingestion.

Similarly, acceptance of each food odor was defined using proportional variables based on behavioral analysis [16]. Four control stimuli and 8 odors (4 rated by adults as a priori pleasant and 4 as a priori unpleasant) were presented in bottles to infants at 8, 12, and 22 months of age. The infant’s exploratory behavior towards odorized and control bottles was measured in terms of mouthing defined as a direct contact with perioral and/or perinasal areas. For each odorized bottle, durations of mouthing were calculated relative to the control bottles. In this age range, shorter durations of mouthing were found for unpleasantly scented bottles (trimethylamine, dimethyl disulfide, and butyric acid) than pleasantly scented bottles. So, between 8 and 22 months, unpleasant food odors lead to avoidance behavior in infants, but pleasant food odors did not elicit specific behaviors.

In these studies, we noted that developmental changes were dependent on taste and odor. We will now examine to which extent these developmental changes also depend on the taste and flavor experiences the infant receives during this period.

**Effect of Early Taste and Flavor Experiences on Taste and Food Preferences**

Several pieces of work have shown that the flavors of the foods consumed by the mother may be transferred into the amniotic fluid and the milk [17–19], but this phenomenon is variable and not yet fully known [10, 11].
Nevertheless, the exposure to specific flavors in utero is associated to a higher attraction for the specific food odor at birth [17], to a higher acceptance of the specific food the infant was exposed to in utero when this food is offered at the beginning of complementary feeding [20], as well as to a higher acceptance of a similarly flavored food later in childhood [21].

In a similar fashion, the exposure to flavors in mother’s milk is associated to a higher acceptance of the specific food the infant was exposed to in mother’s milk when this food is offered at the beginning of complementary feeding [20] and to a positive effect of breastfeeding on acceptance of a new food, even in the absence of a specific flavor exposure [22]. This work suggests that the variety of flavor exposure in breast milk may be key and not only the specific exposure to a given flavor.

To expand this building knowledge on the effect of early taste and flavor exposure (i.e., dietary exposure to a variety of tastes in foods), in the OPALINE cohort we wondered about the effect of exposure to specific tastes in the context of milk feeding. It has been described that breast milk contains much more glutamate than formula milk, a compound that is associated with the umami taste. In this context, we observed that infants who were breastfed longer had a higher preference for the umami taste at the age of 6 months [23]. Moreover, concomitant with the introduction of complementary foods which are characterized by a variety of tastes, taste differential reactivity (within-subject variability across tastes; the higher the score, the greater is the difference in reaction of the infant to the tastes) clearly increased [14].

In order to develop our understanding of infant dietary taste exposure, we developed a method to evaluate the taste properties of the diet by describing extensively the intensities of the tastes of all the foods consumed monthly by infants relying on data from “food taste databases” [24]. The application of this method showed that the exposure of French infants to tastes was dominated by exposure to sweet taste over the first year, as illustrated in Figure 1 (in relation to the sweet taste of milk and a number of foods introduced after the initiation of complementary feeding) [25]. We expanded these findings by comparing the dietary exposure to sweet taste and fattiness [26]. They both increased during the first year in relation to the introduction of complementary foods in the child’s diet, but exposure to sweetness increases more rapidly than exposure to fattiness.

However, we have not shown any specific associations between dietary exposure to each taste and acceptance of each taste measured in water, as explained above [27]. The longer-term associations between early exposure to taste and further taste preferences are currently being explored in the OPALINE cohort.

Concerning olfactory exposure, we have found that at 8 months of age only, positive correlations were found between liking of some unpleasant odors and
Early exposure to these odors through the mother’s diet. However, no correlations were found between infants’ liking of the pleasant odors and early exposure to the foods bearing these odors. This study highlights that early exposure to unpleasant food odors may increase subsequent liking (or reduce subsequent dislike) of these food odors at least until the age of 8 months [28].

The originality of the OPALINE study was to evaluate the effect of early odor exposure on the infant through the mother’s spontaneous consumption of a wide spectrum of foods without asking mothers to consume one target food bearing a specific odor quality in sizeable amounts. Such “ecological” research regarding the influence of prenatal and dietary taste and flavor exposure on the establishment of preferences for foods with similar tastes and flavors is still in its beginning. More studies in different cultural contexts were the flavor experience is likely to be contrasted are needed to more completely understand these early imprinting phenomena.

**The Influence of Taste and Odor Preferences on Infants’ Eating Behavior**

To further explore the question of the association between taste or flavor preferences and food preferences, we further explored data from the OPALINE cohort. This was evaluated separately for taste and flavor.

Concerning taste, we characterized the taste intensities of all foods introduced at the beginning of the complementary feeding period. In parallel, mothers were asked to report their infant’s acceptance of these first foods. We applied...
classification methods to the taste profiles of the foods, which showed that 15 groups of foods with similar taste profiles had been given to children (e.g., salty foods, sour foods, and sour and sweet fruits) [29]. Then, we compared the average acceptance of all food groups and showed that the acceptance of new foods varied according to their taste profiles. More specifically, we showed that the acceptance of salty vegetables was higher than the acceptance of bitter vegetables, or of sweet and bitter vegetables [29]. Furthermore, we showed that a higher preference for sweet, sour, and umami tastes was associated to a higher acceptance of some sweet-, sour- and umami-tasting foods, respectively [29]. This supports the hypothesis that the preference for some foods was partly related to the specific preference for their taste properties. Finally, an exploration of the factors related to vegetable acceptance along the first 2 years showed that a higher bitterness acceptance was associated with a higher acceptance of vegetables at the age of 1 year [30].

Concerning flavors, we similarly explored the acceptance of foods bearing specific odors and evaluated whether their acceptance was related to the acceptance of the corresponding odors (presented alone in scented bottles). We found that at 12 months rejection of the odor of trimethylamine and dimethyl disulfide was related to the rejection of fish and sulfurous cheeses between 12 and 15 months, respectively [31]. Therefore, in the case of olfaction, the flavor-food acceptance associations concerned foods with strong, unpleasant flavors at 12 months only, suggesting that the olfactory system acts as an “alarm” system during this period of food transition.

Eating behavior in children is characterized by its evolution as far as food neophobia is concerned. By the end of the second year, neophobic reactions start happening and can also be designated as picky eating behavior. This developmental phase concerns most children, but we were interested in evaluating whether neophobic reactions could be related to differences in taste and smell acceptance. To evaluate this aspect, we considered taste differential reactivity by computing within-subject variability across tastes as well as flavor differential reactivity by computing within-subject variability across flavors. We found that at 20 months, food neophobia was associated to flavor differential reactivity but not to taste differential reactivity [32], stressing the importance of olfaction in the development of neophobic reactions.

Finally, we have developed a working model of chemosensory, experiential, and environmental factors likely to influence food likes at the age of 2 years (Fig. 2). In this model, we included parental feeding practices and feeding style in the environmental and experiential factors likely to influence likes. The evaluation of this model showed that most of the factors hypothesized to influence liking for vegetables at the age of 2 years had a
Early Development of Taste and Flavor Preferences

significant influence, but not the variety of early flavor exposure (in utero and in mother’s milk), when all factors are taken into account in the same model [30].

Conclusions

It was shown that children are born with the ability to taste, smell, and discriminate foods, and also to learn to like a new food and its sensory properties. However, marked reactions to taste and olfactory inputs may hinder the learning processes and may be associated with the rejection of specific foods with pro-

Fig. 2. Working model of the various early factors which are likely to influence the development of food likes at the age of 2 years. Among the putative factors, it was previously shown that exposure to food-related flavors (in utero or in breast milk) may impact acceptance of new foods at the time of onset of complementary feeding (CF), because the amniotic fluid or breast milk may be flavored by the flavors from the mother’s diet. The reactivity of the infant to sensory stimuli, in particular food-related tastes and odors, is also likely to modulate his/her acceptance of new foods. At the onset of CF, repeated exposure to a given food was shown to strongly impact its acceptance; moreover, exposure to a variety of foods within a given category impacts the acceptance of other new foods from this category. Tracking of eating habits was previously shown but did not necessarily cover well the very early period. Finally, beyond the impact of the family feeding practices, it was previously shown that parental feeding style is also likely to impact food likes in young children.
nounced tastes and/or flavors. Through the effect of eating experience, taste and olfactory cues acquire a biological significance in relation to the foods they are associated with. Observation of the development of taste and flavor preferences in children shows that learning abilities are high between the onset of complementary feeding and the age of 2 years. This period clearly appears as a window of opportunity to introduce foods from the family diet, particularly vegetables. Learning processes also happen in interaction with parental feeding style and practices, which have to be taken into account to fully understand the development of children’s eating behavior. The research on the early development of food preferences in relation to taste and flavor exposure is still in its infancy. Much more has to be learned: the type of exposure that is more likely to alter food preferences further, the most important periods for this chemosensory exposure, and the conditions under which they may resist to the influence of other factors which are also likely to influence the development of eating behavior and food preferences.

**Practical Implications**

The present results may have practical implications in terms of child feeding in the early years. Encouraging mothers to eat a variety of foods during pregnancy may help to imprint their child’s liking of healthy foods through the exposure to the flavors of such foods in utero. Similarly, breastfeeding until the start of complementary feeding may enhance the acceptance of new foods offered at this transitional stage in child feeding. Parents should also be aware that when tasting or smelling new foods, children are more likely to display negative facial expressions than positive ones, but they may also continue eating. Thus, parents should be encouraged to continue offering new foods to their children for sensory learning to take place, even if they feel that their child’s initial reactions to these foods are not very positive. Such advices should be particularly enforced in parents of children who are very sensitive to taste and odors, and who may be more likely to display neophobic reactions. Parents should be patient and ready to persist in their willingness to offer new foods without forcing their child to eat.

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Abstract
Children’s vegetable consumption falls below current recommendations, highlighting the need to identify strategies that can successfully promote better acceptance of vegetables. Recently, we described two promising approaches to increase the acceptance of vegetables: (a) offering infants a variety of vegetables (purée changed every day for 10 days vs. 3 days and no change) at the beginning of weaning increases acceptance of new foods, including vegetables, and (b) offering 7-month-old infants an initially disliked vegetable at 8 subsequent meals markedly increases acceptance for that vegetable. The first stage of the study showed that these different effects persisted for several weeks. In a follow-up study, at 6 years, observations in an experimental setting showed that children who had been breastfed and who had experienced high vegetable variety at the start of weaning ate more new vegetables and liked them more. They were also more willing to taste vegetables than formula-fed children or the no- or low-variety groups. The initially disliked vegetable was still liked by 57% of children. This brief review shows that experience with sensory variety in the context of breastfeeding, early experiences with vegetable variety during complementary feeding, and repeated experience with an initially disliked vegetable can influence food preferences and healthy eating habits into childhood.

Introduction
The first smile, the first step, the first word... We never learn as much as in our earliest childhood, and: What children learn in their first 1,000 days characterizes them for the rest of their lives. This period is a sensitive one for the develop-
ment of healthy eating habits, and, for this reason, interventions are likely to have a strong impact on health outcomes later during childhood and adulthood. Anyone setting the right course here lays the foundation for a healthy life. Be it growth, the immune system, or mental development, all benefit from a healthy diet.

The early development of taste and food pleasure plays an important role for children and has long-lasting influences on subsequent food preferences and choices [1, 2]. Eating a variety of foods is essential to achieve adequate coverage of macro- and micronutrients. However, children’s vegetable consumption often falls below current recommendations, highlighting the need to identify strategies that promote better acceptance of vegetables [3]. Apart from our innate liking for sweet foods and disliking for very bitter foods, sensory pleasure for foods is mostly acquired through our early eating experiences. Infants have a fine palate and more taste buds than adults when they are born. They have about 10,000 taste buds all around their tongue, including the roof, back, and sides of their mouth [4]. The flavors of what a mother eats while pregnant can reach the fetus and help set up flavor preferences later on [5, 6]. From birth, infants can taste and smell foods, an experience that can take place through human milk as the food eaten by the mother influences the flavor of her milk and, thereby, the child’s preference [7, 8]. Thus, preferences for specific flavors develop early through milk-related flavor exposure or even during pregnancy, allowing an easier acceptance of new flavors and textures. Breastfeeding favors the taste acquisition of a variety of foods [2, 9, 10]. This early experience serves as the foundation for the continuing development of food preferences across the lifespan and is shaped by the interplay of biological, social, and environmental factors.

At weaning, food preferences develop due to repeated exposure to a variety of foods, especially vegetables and fruits [10–13]. The persistence of these early influences seems to be long-lasting [1]. Factors favoring the development of food acceptance at the beginning of complementary feeding include, in particular, the role of early variety, repeated exposure, timing of food introduction, and sensory properties (texture, taste, and flavors).

With increasing age, the influence of a number of factors, such as peers, personal experience, family, and food availability, continue to mold food preferences and eating behaviors. During the 3rd year of life, most children enter a neophobic phase, during which the introduction of new foods becomes difficult [14]. However, habits of eating a variety of vegetables and foods acquired early in weaning appear to attenuate this neophobia [1].
A Spoon of Culture and Tradition

Young infants are far less fussy than the experience might suggest at the dining table. This shows the diversity of the various complementary food traditions around the globe. Eating habits and attitudes towards eating can be considered one of the most important aspects of a culture. Because of different cultural traditions, attitudes, and systems [15], the reasons for introducing complementary food may vary widely. The literature shows large differences in practice across the world in the timing of the onset of complementary feeding, and even within European cultures, practices are surprisingly varied [16].

When parents in Germany think of the first weaning food, they all think first about allergies. Does my child eat the carrot or is it better to start with the low-allergen parsnip? To be on the safe side, there is often a whole week then of parsnip until a new vegetable will be introduced. In the neighboring country France, the mothers are much more courageous. Almost every day there is a new vegetable introduced during weaning, even fish is introduced quite early and regularly [17]. The wider the perspective, the more confusing is the variety of complementary feeding traditions. While worried parents may be looking for the best solution for their child, experts advise one thing above all: relaxation. A baby’s nutritional needs can be met in many different ways. To provide guidance for parents, it makes sense for each country to develop its own recommendations on how children can grow up healthy with available resources, systems, and traditions. Whether it is fermented corn sorghum paste like in Nigeria, millet porridge with sour milk like in Senegal, or Thai rice porridge with bananas: infants can learn to like almost anything as long as their parents set a good example and demonstrate it to them.

Early Development of Sensory Experience

There is considerable evidence from controlled animal and human studies that sensory experiences early in life can influence flavor preferences and food acceptance [7, 18, 19]. This critical period starts with feeding through the umbilical cord during gestation, continues via oral feeding with milk, and then the complementary feeding begins, and the infant discovers a variety of foods and flavors. Humans generally have inborn positive responses to sugar and salt, and negative responses to bitter taste [20]. Genetically determined individual differences also exist and interact with experience to ensure that children are not genetically restricted to a narrow range of foodstuffs [21]. Children are also predisposed to prefer high-energy foods, to reject new foods, and to learn as-
associations between food flavors and the postingestive consequences of eating [22].

Previous research showed that breastfed infants more rapidly accepted a new vegetable than formula-fed infants [9, 10, 23]. Breastfeeding is also associated with positive effects on later eating patterns and willingness to accept vegetables [1, 2, 24]. A longitudinal study was conducted in Germany and France to evaluate if children who had had been breastfed liked a new vegetable more readily and were also more willing to taste vegetables than formula-fed children at the start of complementary feeding but also at the age of 6 years. It showed that at both time frames children who had been breastfed consumed more of the new vegetables and were more willing to taste vegetables [1, 10]. This positive effect of breastfeeding on food acceptance may be associated with the more varied flavor variety in breast milk, linked to the transfer of flavor compounds. Thus, in contrast to infant formula, mother’s milk provides a potentially rich and complex sensory experience for the infant, reflecting in part the mother’s eating habits and food culture [20]. The early flavor experience of formula-fed infants is markedly different from that of breastfed infants. Exclusively formula-fed children do not benefit from the ever-changing flavor profile of breast milk. Their flavor experience is more monotone and lacks the flavors of the foods of the mother’s diet. There are striking differences in flavors among the different types and brands of formulas, and formula-fed infants learn to prefer the flavors of the formula they are fed and foods containing these flavors [20]. This is indicated by a study on a milk substitute containing hydrolyzed proteins (hypoallergenic nutrition). This milk substitute for infants with a severe milk protein allergy has an unmistakably sour and bitter “burnt” taste. Infants who were fed this milk substitute for the first time at the age of 2 or 3 months accepted it even at the age of 7 months. However, if infants were offered this milk for the first time when they were 6 or 7 months old, they rejected it entirely [25]. Moreover, infants who were fed hydrolyzed baby milk for several months at a very early age were more willing to accept sour-tasting beverages when they were 4 or 5 years old [26].

A Spoon of Variety at Complementary Feeding – A Window of Opportunity

The complementary feeding period is a “window of opportunity” for acclimatizing infants to the taste of a wide variety of foods. Early learning about flavors continues during the complementary feeding period through the introduction of solids and changing exposures to a variety of new foods. In this particular time of the child’s life, there is the transition from breastfeeding/formula feeding to a complementary solid diet, and infants discover the sensory (taste, flavor, and texture) and nutritional properties (energy density) of the foods that willulti-
mately compose their adult diet [27]. Infant acceptance of new tastes and flavors develops during the so-called “sensitive period” between 4 and 6 months [28]. This period is crucial in influencing the development of later food preferences. The period from 6 to 10 months is favorable for the introduction of more complex textures [28]. The early and easy acceptance of new foods at a slightly younger age in the period of the introduction of complementary foods (4–6 months) has been observed in many studies. It has been shown that the earlier fruits and vegetables were introduced, the better their acceptance both in infancy and at a later age in childhood. This possibly reflects the difficult nature in terms of texture and tastes shared by many fruits and vegetables, both properties which children find aversive. The only texture the infant has experienced before complementary feeding is thin, liquid, warm milk, and thus new textures like soft-cooked vegetables and even thick yogurt will feel wildly different. The oral motor skills are usually learnt between 6 and 12 months of age (the period in which the tongue learns to move solid food around the mouth in preparation for swallowing), and this ability is dependent upon the experience of textured food within the mouth rather than on any particular age or developmental stage [28]. It has been observed that if 12-month-old infants were given pureed and chopped carrots, they consumed more of the pureed carrots, but there was variability in the infants’ willingness to take the chopped carrots. The strongest predictor of the acceptance of chopped carrots at 12 months – other than the presence of teeth – was earlier experience with textured foods [29]. In addition, children who were used to a high variety of different foods in their diet ate more of the pureed carrots, but there was variability in the infants’ willingness to take the chopped carrots. The strongest predictor of the acceptance of chopped carrots at 12 months – other than the presence of teeth – was earlier experience with textured foods [29]. In addition, children who were used to a high variety of different foods in their diet ate more of the chopped carrots; this again reflects the generalization effect, the greater the experience, the greater the willingness to try. Furthermore, infants who are introduced earlier to lumpy foods tend to be easier to feed by their mothers than children introduced to lumpy solids after the age of 10 months. Children introduced to lumpy solids after the age of 10 months were reported as having more feeding problems at 7 years. They were also reported as eating fewer portions of fruits and vegetables at 7 years [30].

At the onset of complementary feeding, many infants dislike vegetables, and there are various reasons for this, including the taste, appearance, and texture, often influenced by how they are prepared. Being exposed to a variety of foods during the complementary feeding period helps modulate the acceptance of new foods, especially vegetables, in the first year of life and later on [1, 10, 11]. It has been shown that experience with a variety of vegetables (changing the vegetable offered each day) at the very onset of weaning increased intake of new foods a few weeks later [10] but also a few years later [1]. Breastfeeding and early experience with variety interacted, in that infants who had been breastfed and had then experienced a high variety of vegetables at weaning showed the most marked
acceptance of new foods [10]. In a follow-up study, it has been shown that the benefit of introducing a variety of vegetables maintains at least up to the age of 6 years [1]. At 6 years, children who had been exposed to a high level of variety consumed more of the new and known vegetables, were more willing to taste vegetables, and had higher liking scores for new or familiar vegetables [1].

At present, the first weaning food in many European countries (e.g., Germany), such as vegetables, potatoes, and meat, is thus increasingly competing with the variety and, following the Mediterranean model, also fatty sea fish. The long-held view that only 1 or 2 vegetables per week should be fed has become obsolete. Monotonous nutrition offers no protection against allergies and better food intake. On the contrary, infants who receive a varied complementary diet are also better and less complicated eaters later in life. Parents should, therefore, pay attention to a variety of fruits and vegetables at the beginning of the complementary feeding. Offering the infant a variety of flavors and textures from the start of complementary feeding is the best way to help them to enjoy a variety of foods as they grow up.

In conclusion, a preference for varied flavors should ultimately increase the range of nutrients consumed and the likelihood that a well-balanced diet is achieved. In other words, the variety effect may reflect an important adaptive mechanism in the regulation of food intake among omnivores.

**Repeated Exposure**

Despite the new freedom to introduce a variety of foods, many infants and young children are still unable to find the optimal nutritional mix. Vegetables may be rejected for a number of different reasons, from their bitter taste, unfamiliar texture, their relatively low energy content to simple lack of access in many families. Infants are born with about 10,000 taste buds and are, so to speak, real supersmarters at birth. Although they have a genetic preference for sweets, they also have an aversion to bitterness. Whether fennel, broccoli, or artichoke – even the smallest trace of bitter substances often does not escape the highly sensitive child’s palate. Thus, the following question emerges: Can children learn to like vegetables? What the infant tastes or does not taste is a question of training. Many parents give up here too soon. So, what to do when gourmet babies stubbornly resist something new? The most successful strategy to promote vegetable intake is repeated exposure [1, 12–14]. Repeated exposure to the pure/distinct taste of a vegetable during complementary feeding (on at least 8 occasions) can help infants learn to accept vegetables both immediately and in later childhood [1, 12]. So, if the baby does not eat a certain type of vegetable, it does not auto-
matically mean that they do not like it. At first, they only reject them because they do not know them. This is often misinterpreted. So, patience, patience – parents should not blame the child. It is a fundamental survival instinct that warns the little ones against new things. Patient repetition pays off. Parents should offer a new type of vegetable at least 8 times in a row. So, the baby gets used to its taste and learns to like the disliked vegetable.

Several research groups have observed that repeated exposure to a new vegetable, even one that is initially disliked, can lead to acceptance of that vegetable [12, 13]. For example, when a well-liked vegetable and an initially disliked vegetable were given to 7-month-old infants on alternate days over 16 days, by the 8th exposure to each, intake and liking of the 2 were similar [12]. In this study, mothers were asked to specify which vegetable purée their infants especially liked during the first months of taking solid foods or rejected so adamantly that the mothers no longer offered these foods to them. The mothers were then asked to offer their infants one vegetable daily – alternating between a vegetable the infants had initially rejected and one they had preferred – for 16 consecutive days. By the 8th exposure, the infants’ liking and intake of both vegetables was almost identical. Nine months later, 63% of the infants were still consuming and liking the previously disliked vegetable [12]. This persistence of increased acceptance was confirmed in children aged 6 years since 57% of the children continued to eat and like the initially disliked vegetable [1]. The importance of this effect has considerable practical implications. In the same regions in Germany and France where the repeated exposure study was conducted, if infants initially disliked a vegetable, most mothers (85%) offered it at no more than 2–3 subsequent meals before giving up and deciding not to offer it again [17]. Among the mothers reporting refusal, 6% said they immediately decided their infant definitively disliked the vegetable, 33% after 2 meals, 57% after 3–5 meals, and only 4% continued trying for longer. The results of those studies suggest that, rather than giving up after 2–3 tries, it is well worth offering an initially disliked vegetable up to 8–10 times without pressuring the child to eat it, because it is likely to be followed by adequate acceptance well into childhood.

Methods which mothers use to promote the intake of vegetables in their children are numerous. Strategies include seasoning, adding sauces or other liked foods, or even hiding vegetables. There is a lot of literature whether mixing or “masking” vegetables with other foods, a common way of preparing infant meals, enhances or reduces the positive effects of exposure on the development of acceptance for the masked vegetable [13]. Further research is required to explore whether specific combinations of foods and the prominence of the individual vegetable flavors (and visual characteristics) produce different outcomes for preference and intake. There is some evidence from a small sample of moth-
ers that mixing vegetable flavors (purées of cooked vegetable) with milk or baby rice can increase infants’ initial acceptance of vegetables and help bridge the transition from a diet of milk to the introduction of pure vegetable flavors [21].

Discussion and Conclusion

The prevalence of childhood obesity is rising, and multiple studies indicate that most of the risk factors develop during the early phases of life. These factors may range from the prenatal to the postnatal period. This brief review shows the importance of complementary feeding as a window of opportunity for the development of eating behaviors that can be maintained throughout childhood. The complementary feeding period is a “window of opportunity” to familiarize infants with a wide variety of foods because at this stage infants’ openness to trying new foods is at its peak, and familiar foods are likely to become preferred foods, and these acquired preferences tend to persist in later childhood.

Many children do not eat the currently recommended amounts of vegetables, and parents are frequently searching for practical ways to increase vegetable acceptance. The lack of the sweet flavor and the low energy density of many vegetables and some fruits mean that these foods may be rejected by children, and extra efforts may need to be put in place to help them accept these foods. Within this context, strategies to successfully promote better acceptance of vegetables should be identified. In spite of a huge body of literature, practical aspects and the results of their application are still poorly understood. This is due to the high complexity related to physiological mechanisms underlying early sensory experiences and the development of sensory preferences.

This review shows the effectiveness of breastfeeding, early experiences with vegetable variety during complementary feeding, and repeated experience with an initially disliked vegetable in promoting vegetable acceptance into childhood. The effects are long-lasting and provide the foundation for evidence-based recommendations to help parents promote healthy eating habits to their children. Current infant feeding guidance and practices suggest that this type of approach is not typical in many countries and that there is scope to provide parents and health care professionals with practical advice on encouraging vegetable acceptance during complementary feeding. The findings addressed in this review should be used in the design of future interventions targeting the prevention of childhood obesity.

Disclosure Statement

The author has no conflict of interest.
Early Development of Food Preferences and Healthy Eating

References


Abstract
Child eating behaviors contribute to individual variability in weight status and are influenced by a combination of genetic and environmental factors. Feeding practices have been identified as a potentially modifiable factor that can influence children’s dietary intake and eating behaviors. However, the majority of research in the field has been cross-sectional whereas more recently a bidirectional relationship between parent feeding and child eating has been proposed. The purpose of this review is to provide a summary of patterns of findings related to feeding practices that may support or undermine children’s eating behaviors. The focus is specifically on eating behaviors related to appetite regulation and obesity risk. Evidence for the potential effect of nonresponsive feeding practices as well as structure-related practices is presented. In sum, there is evidence that parents’ feeding practices do impact on children’s eating behaviors, but children’s eating behaviors also influence the feeding practices parents use. Suggestions for future research in terms of design, measures, and research questions are proposed. Future work in this area will serve to build the evidence base for targeted intervention strategies that can guide parents to feed their children in a way that optimizes child health.

Introduction
Child eating behaviors, food preferences, and dietary intake patterns develop early in life and become the foundation for eating behaviors that track into later life [1]. The development of healthy eating behaviors assists children to achieve
and maintain a healthy weight status through the effective self-regulation of energy intake whereby children develop the ability to recognize and respond appropriately to internal cues of satiety and hunger [1]. Eating behaviors characterized by high responsiveness to external food cues, eating in response to negative emotions, or poor recognition of satiety cues have consistently shown to correlate with higher BMI and increased obesity risk in children [2, 3]. Worldwide it is estimated that 42 million children under the age of 5 years are overweight. These children are at increased risk of a wide range of health problems, including chronic diseases such as diabetes, cardiovascular disease, cancer, and psychosocial problems [4]. Whilst genetic factors play a role in obesity risk, environmental factors related to nutrition and sedentary/physical activity also influence susceptibility to the development of obesity [5]. Thus, there has been a strong research focus on identifying modifiable factors that may influence the development of children’s eating behaviors to reduce obesity risk.

Parents play a pivotal role in children’s early food environment and eating experiences through food selection, portion size, timing, frequency, structure, and social context of the eating environment [6]. Parental feeding practices have been of interest to researchers and clinicians alike because they constitute modifiable risk factors for problematic child diet-related outcomes and appear to be amenable to intervention [7]. However, evidence from child obesity interventions targeting maternal feeding practices has indicated that whilst significant changes in feeding practices due to intervention can be maintained over a number of years, differences in child eating behaviors and BMI are limited [7, 8]. Furthermore, evidence from twin studies suggests that in childhood some eating behaviors have a significant genetic component [9]; thus, how readily these can be influenced by environmental factors may be less than anticipated. The purpose of this review is to examine current evidence for a causal relationship between feeding practices and child eating behaviors related to obesity risk. The aim will be to further understand the etiology of children’s eating behaviors by considering the relationship with responsive and nonresponsive feeding practices.

Child Eating Behaviors

Eating behaviors have been found to influence energy intake and weight status through the individual child’s choice of the amount and type of food they consume [3]. Child eating behaviors have been measured using both observational and questionnaire-based methods. An observational method that has been used is the eating in the absence of hunger (EAH) paradigm. Eating in the absence of
hunger is defined as a heightened response to food cues (even after a meal has just been eaten). It is characterized by the inability of the child to self-regulate their energy intake, and hence the child’s propensity to eat will be reinstated in the presence of palatable foods [10, 11]. Cross-sectional and prospective research has indicated that overweight children eat significantly more than children of normal weight in the EAH paradigm [12].

One of the most commonly used questionnaire methods to measure child eating behavior is the Children’s Eating Behavior Questionnaire (CEBQ) [2]. The CEBQ was developed to aid the investigation of how individual differences in eating style contribute to the development of underweight and overweight in children. The CEBQ assesses 2 main dimensions of children’s eating behaviors: food approach and food avoidance behavior. Food approach behaviors include: food responsiveness (child is always asking for food or eats too much if allowed), emotional overeating (child consumes more food when annoyed, anxious, worried, or bored), enjoyment of food (child loves food or enjoyment of eating), and desire to drink (child always wants a drink or constantly asks for one). Food avoidance behaviors include: satiety responsiveness (child gets full easily or cannot eat a meal if a snack has been consumed prior), slowness in eating (child takes longer than 30 min to eat a meal), emotional undereating (child consumes less food when tired, angry, upset, or happy), and food fussiness (child is highly selective about the range of foods they will accept) [2]. The CEBQ has been shown to have good reliability and validity [2, 9, 13].

Research using the CEBQ has shown that food approach traits correlate positively with BMI in children, and food avoidance (except food fussiness) traits negatively correlate with BMI [2]. A longitudinal study of children from the Twins Early Development Study found that the characteristic ways in which children interact with their food environment may be moderately stable over time [13]. However, it was also noted that eating behavior traits may vary with age: food avoidance behaviors decrease over time, whereas food responsiveness behaviors increase over time [13]. These variations may be reflective of changes in children’s food environments or as a result of children eating in environments that are less controlled by family members as they get older.

Some eating behaviors measured via the CEBQ have been shown to have a strong genetic underpinning. Low satiety responsiveness and high food responsiveness, for instance, appear to have a substantive genetic basis in childhood that contributes to a higher rate of weight gain [14, 15]. In contrast, both emotional overeating and emotional undereating were found to have minimal genetic basis and are likely to be learned responses to negative affect [16]. Thus, variations in children’s eating behaviors are, in part or predominantly, influ-
enced by environmental factors. Culture, social and economic status, accessibility to food resources, family practices, and environmental factors, all contribute to obesity-related behaviors [5]. One specific environmental factor may be the feeding practices parents use with their children [6].

**Feeding Practices**

Feeding practices are defined as content-specific goal-directed strategies or behaviors used by parents in an attempt to control or modify their child’s diet and eating behaviors [6]. Historically, in times of famine, foods were often low in nutrients, energy, and palatability. As such, the use of feeding practices that aimed to increase children’s food intake was likely to be adaptive for survival. However, in the current obesogenic environment of many developed and developing countries where there is an abundance of energy-dense, palatable, inexpensive foods that are conveniently available for consumption [1], the use of “coercive” or “controlling” feeding practices that aim to encourage consumption of food are potentially problematic and may contribute to the development of child obesity. One of the most widely used self-report instruments to measure maternal feeding practices is the Child Feeding Questionnaire (CFQ) [17]. The CFQ assesses parental beliefs, attitudes, and controlling practices (monitoring, restriction, and pressure to eat) with a focus on the risk of obesity.

More recently, many of the feeding practices referred to as controlling have been similarly described in the literature as nonresponsive and include pressure to eat (pressuring a child to eat), instrumental feeding (using food to reward children’s behavior), and emotional feeding (using food to soothe or calm children). Restriction is another feeding practice that was originally conceptualized as controlling [17] and is often grouped with these nonresponsive practices; however, rather than encouraging food intake, this practice involves the parent attempting to limit the child’s access to “unhealthy” foods.

DiSantis et al. [18] proposed that nonresponsive feeding practices may interfere with a child’s ability to self-regulate their energy intake, i.e., to adjust their eating in response to internal feelings of fullness or satiety. It is proposed that when parents fail to recognize or respond appropriately to children’s internal cues of hunger or fullness, the child’s ability to self-regulate may be disrupted [18]. Thus, the way in which feeding is responsive to the child is an important element of the caregiver-child interaction. Similarly, Black and Aboud [19, p. 492] proposed that responsive feeding can be conceptualized as a component of responsive parenting which is a process that reflects “reciprocity between the child and caregiver.” Within the context of child weight, responsive feeding has
been defined as developmentally appropriate (not intrusive or controlling), prompt, and contingent responses to infant and child hunger and satiety. Also integral to responsive feeding are: establishing routines around mealtimes (eating at the same place and times), modeling appropriate behavior (making healthy choices), and ensuring children are seated [19].

**Evidence for Associations between Feeding Practices and Child Eating Behaviors**

**Pressure to Eat**
Pressure to eat is a nonresponsive feeding practice whereby the child is coerced to eat particular foods or to eat more. However, associations between pressure to eat and child outcomes including eating behaviors and BMI are mixed. In line with predicted deleterious effects of this practice on child eating behavior, a cross-sectional Australian study (\(n = 560\)) of 5- to 6-year-old children found pressure to eat was associated with higher estimated daily energy intake and higher consumption of both sweet and savory snack foods [20]. However, cross-sectional and longitudinal studies have reported higher pressure to eat to be associated with lower child BMI [21, 22] and positively associated with food avoidance eating behaviors, such as food fussiness, slowness in eating, and child satiety responsiveness, and negatively associated with food enjoyment [23]. Together, these findings suggest that pressure to eat may be associated with higher consumption of discretionary/snack foods but may be a practice that is used in response to parental concerns about the child being/becoming underweight or displaying food-avoidant eating behaviors such as food fussiness.

**Instrumental and Emotional Feeding Practices**
Feeding practices such as instrumental feeding and emotional feeding that promote the use of food as a reward or as a source of comfort have been suggested to influence child BMI via their potential to teach children to eat for reasons other than hunger. Findings from Rogers et al. [22] study of mother-child dyads (\(n = 222\)) reported maternal instrumental feeding to be associated cross-sectionally with emotional eating and a tendency to overeat in children (mean age = 2.03 ± 0.37 years). Instrumental feeding was also found to be prospectively associated with higher child BMI. Rogers et al. [22] suggested when parents use food as a reward to decrease negative affect in children, dysfunctional eating patterns and weight gain may occur. Another cross-sectional study of children aged 6–7 years (\(n = 135\)) [24] also found instrumental and emotional feeding to be positively associated with the snacking behavior of children. In a longitudinal
study \((n = 623)\) [25], it was shown that use of food as a reward (instrumental feeding) in children 6 years of age predicted higher food responsiveness at age 8 years. While these feeding practices may provide short-term solutions to manage children’s behavior or mood, evidence indicates poor outcomes for children’s eating behaviors in the longer term.

**Restriction**

Restrictive feeding practices have been thought to result in greater preference for restricted food and poor self-regulation of eating [26]. Restrictive feeding practices have been positively associated with increased intake of restricted foods when these are made available and heightened food responsiveness [23, 27]. A longitudinal study of maternal feeding practices found that girls of overweight mothers who reported restricting their daughter’s food intake at 5 years of age showed greater EAH across the age of 5–9 years [26]. However, this finding did not apply to girls with mothers who were not overweight; rather, restriction had no effect on EAH [26]. Similarly, another longitudinal study with mother-child dyads \((n = 323)\) found restriction of child’s food for the purpose of weight control to be prospectively associated with food approach behaviors and overeating [22]. Nevertheless, these studies do not address the issue of whether mothers who are concerned about their child’s risk of overweight/obesity or who perceive their child as being overweight/obese are prompted to more rigorously attempt to restrict their child’s access to unhealthy food. Further research is needed to better understand the effects of restrictive feeding practices and what factors may moderate these effects (such as child gender and obesity risk). Furthermore, how restriction may be used in conjunction with other feeding practices needs to be considered given that the foods most likely to be restricted may also be used in instrumental or emotional feeding as rewards or comfort foods, respectively.

**Structure of the Mealtime Environment**

Although the provision of structure in terms of the timing and setting of meals is central to Black and Aboud’s [19] concept of responsive feeding, limited research has considered the role of the structure of the mealtime environment until recently. The emerging evidence supports structure as integral to positive child feeding. In a recent report by Powell et al. [28], the structure of a typical mealtime was studied within the family setting of 75 mothers of children aged 2–4 years. The children of mothers who ate the same foods as their children (at the same time as their children) were found to be easier to feed and refused less food than children of mothers who did not. Children displayed less fussy eating behaviors when mealtimes were free of distractions (television and
toys), and when children were allowed to have input into portion size and food choice.

The Feeding Practices and Structure Questionnaire [29] was developed specifically to expand the measurement of child feeding to include structure-related practices. Initial validation of the questionnaire included examination of cross-sectional associations with child eating behaviors. Three practices related to the timing of meals, setting of meals, and eating meals as a family were associated with less food fussiness, more enjoyment of food, and less emotional (over- and under)eating in a sample of 2-year-old children of first-time mothers. These initial studies into the influence of structure on the mealtime environment suggest that it may contribute to promoting healthier eating behaviors of children and is of interest to consider in future research.

**The Reciprocal Relationship between Child Eating Behavior and Maternal Feeding Practices**

To date, the vast majority of research investigating the relationship between maternal and child eating behaviors is cross-sectional in nature, and, therefore, inferences about causality cannot be made. Furthermore, until recently, longitudinal studies have assumed feeding practices as the independent variable and child eating as the dependent variable. However, some recent studies in the field have moved toward considering the parent-child feeding relationship as reciprocal and have tested bidirectional parent → child and child → parent effects. A study by Steinsbekk et al. [25] tested for bidirectional relationships between nonresponsive feeding practices (instrumental feeding, encouragement to eat, and control over eating) and a range of child eating behaviors but only identified a parent → child effect (instrumental feeding leading to increased food responsiveness). None of the child → parent effects were significant. However, other similar studies have produced evidence of bidirectional effects.

The study by Rogers et al. [22] (n = 323) of mothers and their 2-year-old children assessed parental feeding practices and child eating behaviors at baseline and again 1 year later. Controlling for baseline feeding practices, a child’s tendency to overeat at baseline predicted greater maternal instrumental feeding 1 year later, and emotional eating of a child at baseline predicted greater maternal emotional feeding 1 year later. Another longitudinal study [30] that used concurrent assessments of child eating behavior (satiety responsiveness and food responsiveness) and parental nonresponsive and structure-related feeding practices tested for bidirectional effects across child ages of 2, 3.7, and 5 years. Covert restriction and use of food as a reward for behavior (instrumental feeding) at 2
years predicted greater food responsiveness at 3.7 years. However, other nonresponsive feeding practices (persuasive feeding and reward for eating – conceptually similar to pressure to eat) were not predictive of child eating behaviors. Interestingly, child food responsiveness did not influence parental feeding whereas higher satiety responsiveness was predictive of an increase in (overt and covert) restriction and more structured timing of meals [30].

Limitations, Future Research Directions, and Conclusions

This review provides a snapshot of the state of the field with regard to feeding practices and their potential effects on children’s eating behaviors. The primary limitations within the field include the over-reliance on cross-sectional designs, often with small samples of highly educated, Caucasian mothers. The use of various self-report measurement tools in many studies is also a limitation due to potential reporting bias as well as limited validity testing of self-reported practices against observed feeding practices. The CFQ [17] is one of the most widely used tools for measuring feeding practices. However, it does not consider potentially key nonresponsive feeding practices such as instrumental and emotional feeding nor the role of structure in the mealtime environment (such as family management, timing, and setting) which may assist in understanding the relationship between feeding practices, child eating behavior, and obesity risk [30].

Future research in this field that utilizes a longitudinal design, assesses feeding practices and child eating concurrently, and attempts to ensure the validity of such measures is needed. Validation of questionnaire measures is critical to the accurate interpretation of study findings and has generally been limited to statistical validation of questionnaires in this field of research. Observational data that can complement self-report measures of both feeding practices and child eating behavior are one option for ensuring the validity of study findings.

In conclusion, it is anticipated that greater understanding of the complex associations between these child eating-parental feeding constructs can assist in improving our knowledge of the modifiable factors that contribute to the development of childhood obesity. These findings may be used in the design of future interventions targeting the prevention of childhood obesity.

Disclosure Statement

There is no conflict of interest.
References


Early Eating Behavior and Taste Development Influence in Children

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Abstract
Picky eating, which includes behaviors such as limited dietary variety, neophobia, food refusals, and sensory sensitivities, can be a source of stress for families. Parents can influence their children’s mealt ime behavior through the feeding practices they use when offering foods. Some practices are counterproductive to establishing healthy eating habits and should be avoided, but caregivers need alternative behaviors to replace them. Parents should be encouraged to keep trying after a food is refused, as children may need to be exposed to a food several times before it is accepted. Varying the preparation changes the taste, texture, and appearance of food, and children may prefer some variants to others. Some children refuse foods to express independence; thus, providing choices between two healthy options may allow children to express a preference without saying “no” altogether. Coercive feeding practices such as the use of pressure to eat or using food as rewards should be avoided, as these can create negative associations with the food or meals and lead to food refusals. Instead, caregivers can model eating and enjoying the food. Nonfood rewards, such as praise or stickers, can also be used to encourage children to taste a food without negative outcomes.

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Introduction
Picky eating can be frustrating to parents who worry about their children’s growth and development, but many children go through a picky eating phase in early childhood and then their eating behavior improves [1]. The first years of
life are an important period of dietary diversification when children develop eating habits that continue into later life. Foods introduced in early childhood tend to be better accepted than those first encountered later in childhood or adulthood, making the toddler years a sensitive window for expanding the range of foods an individual consumes.

Picky eating is a broad construct that has been defined in a variety of ways by different researchers and likely is comprised of several types of behaviors that contribute to a perception of a limited diet or food refusals. Some of the most common behaviors of picky eaters include limited dietary variety, neophobia, food refusals, less enjoyment of eating, and sensory sensitivities [Fries et al., unpubl. data].

Picky eaters have been reported to consume less of certain food groups, such as vegetables [2], and may have lower intakes of some macro- and micronutrients [3]. Due to their low intake of fiber-rich foods such as whole grains and vegetables, picky eaters may be at increased risk for digestive troubles such as constipation [4, 5], but there is little evidence that picky eaters are at increased risk of underweight or malnutrition [6]. Beyond the potential impact on children’s diet, picky eating can have a negative impact on the family, causing stress or conflicts at mealtimes and causing parents to worry about their child’s health [7]. Therefore, it is valuable to understand the relationship between feeding practices and children’s food acceptance, their potential consequences on dietary intake, and promising solutions to help parents manage the challenges of a picky eating phase.

Parents influence their children’s diet and mealtime behavior through the foods offered, as well as through the feeding practices they use when offering them [8, 9]. The feeding relationship is a two-way interaction, with parents influencing their children’s eating behaviors and children’s behaviors affecting the parents’ feeding practices [10, 11]. Parents’ feeding practices influence children’s intake and acceptance of foods, and a recent study found that picky eaters may be particularly sensitive to feeding practices [12]; thus, it is important for parents of picky eaters to apply positive feeding behaviors such as eating together as a family, modeling eating nutritious foods, and continuing to offer food variety.

Parents may also adapt their feeding behaviors in response to a child that is perceived to be picky [12, 13]. Parents’ assumptions about what children will or will not eat may keep them from offering a wider variety of foods, and fear of rejection and food waste may lead them to not offer foods that were previously rejected [10]. Parents may also change the foods they offer and their feeding practices based on the child’s perceived weight, or what (or how much) the parent believes the child should be eating. Parents’ beliefs about how much
children need to eat may influence their perception of picky eating and may lead them to use specific practices like pressure to eat and asking the child to clean their plate. A recent longitudinal analysis suggests that the relationship indeed goes in both directions: parents respond to picky eating by increasing pressure on the child to eat, and this in turn predicts further picky eating, which can result in a vicious cycle [11]. It is, therefore, important to evaluate how parents can effectively intervene when encountering difficult eating behaviors in their children and to give them useful alternatives to parenting practices that have been shown to be counterproductive in establishing healthy eating habits.

Parents might benefit from education about why children may be acting picky to help them to understand, and potentially address, the causes. However, they are also likely to benefit from advice on feeding practices that can help reduce or avoid food refusals, unpredictable food preferences, and requests for special meals, as well as information about which behaviors or facial expressions constitute a “surprise” rather than a “rejection” when trying a new food. It is also important for parents to remember that their child is an individual with preferences and needs, which may not always correspond to those of the parents, and that it is normal to dislike some foods and express preferences for other foods [14]. Educating parents on these topics might change their perception about their child’s eating behaviors and provide some practical guidelines and ideas to appropriately address picky eating behaviors.

In general, mealtime structure, routines, and regular eating times [15] help ensure that children are expecting to eat and feeling hungry at mealtimes. Caregivers can also reduce between-meal eating occasions and avoid offering snacks or energy-containing beverages such as milk or juice shortly before meals. Similarly, oral nutritional supplements taken too close to mealtimes can be disruptive to children’s appetites and may take away opportunities to learn and try foods. Children are most receptive to eating at mealtime when they are hungry. In addition, when meals are consumed at a table and without distractions from other activities such as toys or television, children will be more focused on the meal. When food is competing with more attractive playtime activities, children may get up from the table before they are full. Clear and consistent parenting practices or rules on when, how often, and which foods can be consumed will also help children know what to expect and what is expected of them at mealtimes.

Parents and other caregivers may use a variety of different feeding practices when trying to convince their children to eat healthy foods, but some have better success rates and long-term outcomes than others. It is important when giving guidance on feeding children that not to simply provide a list of “don’ts,” which
will leave parents uncertain of what they should do. When possible, an alternative, positive behavior should be presented that parents can adopt in its place. For this reason, we have provided our own recommendations below, following a similar format: first a behavior or situation that should be avoided or changed, followed by a suggested alternative.

**Do Not Give Up if the Child Does Not Like Something the First Time**

When introducing a new food to a child, parents typically give up after approximately 3 tries if the child rejects the food [16, 17]. However, children’s taste preferences change with time, and they can also be influenced by the child’s previous experience with foods. If parents stop offering a food after just a few refusals, they will not be able to observe this evolution, and the child’s diet will remain limited.

**Instead, Use Repeated Exposure, Vary Preparations, and Cook Together**

Repeated exposure is when an individual tastes a food on several occasions. This has been shown to lead to improved acceptance of the target foods, and it has been frequently used to promote vegetable consumption in young children [18]. The process is easiest in infants, as the caregiver can control which foods are offered on a spoon, and a baby will usually take at least one bite of what is offered. Older children may require more exposures, and children may be less willing to taste novel or previously rejected foods [19]. As children’s dietary variety grows, they may become more willing to taste and accept future unfamiliar foods [20].

Repeated exposure does not necessarily mean that the food has to be prepared or served in exactly the same way each time; in fact, to the contrary, by varying the cooking method, visual appearance, texture, and combinations of flavors, caregivers may be able to discover a version of the target food that is accepted by the child. For example, mixing flavors, such as by adding dips, sauces, or seasonings, can also help to make new foods seem more familiar and encourage children to taste them [21]. Like taste, texture can have a large impact on children’s food acceptance [22]. Longitudinal studies have found that previous texture exposure and the timing of introduction of textures during complementary feeding may predict children’s future food acceptance [23]. Some texture avoidances, particularly to foods that need to be chewed more, may be due to children’s mastication skills not being fully mature, as children...
continue to develop strength and coordination in their jaws over the first few years of life [24]. If children seem to reject foods due to the texture, caregivers can try using other preparation methods such as boiling and steaming, which have been shown to be better accepted by children than other cooking styles [25, 26]. Crunchiness and a uniform appearance can also contribute to acceptance. Sliced vegetables, whether prepared as sticks or fun shapes (like stars), may also be better accepted than whole vegetables, potentially due to both being easier to bite and its visual appearance [27]. Other examples of simple texture modifications include freezing squishy fruits or cutting foods into more manageable pieces [28].

In addition to repeated taste exposures, there are other ways that children can become familiar with a novel food. One way is through sensory play with food, in which children use various senses, such as smell, vision, and touch, to explore food objects [29] and sensory education, teaching children about the sensory properties of foods, as these methods can improve the children’s willingness to try a food and their expectations to like it [30]. Involving the child in meal preparation is also an effective way to improve eating behaviors in children, both through the additional hands-on experience with the foods and through the child’s pride from helping create the meal [31, 32]. Visual exposure, either directly to foods or through books about food [33], especially if the book contains positive messaging about the food, can also create familiarity. Asking questions and making the activity more interactive can help build positive associations with the food.

**Do Not Pressure the Child to Eat**

There are many strategies that parents can use to encourage a child to eat a particular food [28]. In some scenarios, such as when a child is resistant to eating something, parents may use more coercive techniques such as pressuring the child to eat more or demanding that they finish all of the food on the plate. The use of pressure could range from insisting that children eat a particular food to telling them that they cannot leave the table until they finish or to physically feeding the children. Caregivers should avoid pressuring the child to eat, as this can create a stressful context, which can lead to negative associations with the target food or even general mealtime avoidance [34]. For the same reason, negative interactions such as arguments among family members should be avoided at mealtimes so that the child does not create negative associations with the dining experience. In contrast, an optimal mealt ime environment in terms of parenting style and feeding practices,
mealtime structure, and a positive nutrition climate can all contribute to children’s eating behaviors and intake; that is to say if the mealtime environment is pleasant, children will be more willing to sit at the table and to eat the foods they are offered.

As many caregivers pressure children to finish the food on their plate as a way of avoiding food waste, an alternative solution is to offer children small portions at the beginning of the meal and then to give additional small servings if the child is still hungry. This will not only help the child to not feel overwhelmed by the amount of food on the plate but can also reduce plate waste.

**Use Modeling and Reasoning Instead**

One of the most successful ways to convince a child to try a food is for another person to model eating and enjoying it [28]. The model can be a parent, teacher, sibling, or peer. When families eat meals together and consume the same foods, this provides an excellent opportunity for modeling. There may be some barriers to caregivers modeling eating certain foods, such as that adults are less likely to model eating or to serve foods that they themselves dislike, and that they may not consider offering “exotic” foods to children with the expectation that these will be rejected. Further, parents of picky eaters may not offer foods they expect their child to refuse or that the child previously rejected [10]. Recent reviews of interventions to increase vegetable consumption showed that increasing the amount and variety of vegetables available in the home as well as their accessibility (e.g., preslicing fruit) both improve intake [32, 35].

Parents who give a reason why the child should taste something, such as by talking about the good taste of the food or its nutritional value, rather than simply telling them to eat it, may also help children be willing to taste a new food [36, 37]. This practice can also create intrinsic motivation for the child to eat the food in the future, as they will appreciate the food for its own properties (e.g., taste and health benefits) rather than only eating it when they expect an external reward.

**Do Not Use Food Rewards**

Some feeding practices have negative associations with food acceptance. For example, parents should avoid using one food as a reward for eating another food, as this can have negative short- [28] and long-term [38] consequences, such as
food refusals and decreased liking of the target food. Using foods as rewards or to modify child affect (e.g., to cheer her up when sad) has also been shown to be associated with later emotional eating [39], as children learn to associate foods with certain emotional states.

**Use Nonfood Rewards or Praise Instead**

In contrast, nonfood rewards, such as praise or stickers, can be used to encourage children to taste a food without creating these negative outcomes [40]. It should be noted that such rewards should be reserved for encouraging children to *taste* a food, but the child should not be required to finish the food. Using any kind of extrinsic rewards for plate cleaning can override children’s internal satiety cues and lead to eventual overeating.

**Do Not Cook Separate Meals for Your Child**

In general, parents should be encouraged not to give up when a child refuses a food a few times and continue to offer it while avoiding preparing separate meals for picky eaters. Providing an alternative meal for a child who refuses the food initially offered reinforces the food refusal behavior. Further, if children are regularly provided with a limited range of “accepted” foods, this reduces opportunities for the child to experience new tastes or to have additional exposures to foods that they have not previously accepted. Thus, this behavior can perpetuate the child’s limited diet.

**Provide Choices among Healthy Options Instead**

Some children may refuse to eat a food simply as a way of asserting independence. In general, young children are not able to control many aspects of their environment, and they may seek to capitalize on opportunities to influence certain situations where they can exert some control, such as mealtimes. Often, when parents tell their child to eat something, the options that the child has are either to obey the parent or to refuse. However, if parents give children choices between preselected healthy options, such as two different kinds of vegetables to have as a side dish, this may allow children independence in expressing a preference without saying “no” altogether [41].
Conclusions

Picky eaters display several different types of behaviors. Although caregivers of picky eaters should avoid some feeding practices, they should be provided with alternative behaviors with more positive outcomes. Some key behaviors to promote include: repeated exposure, modeling healthy eating, providing mealtime structure, and providing choice.

Disclosure Statement

L.R.F. is an employee of Nestlé Research. K.H. is a former employee of Nestlé Research.

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Parental Feeding Practices and Associations with Children’s Food Acceptance and Picky Eating


The different presentations of this session were followed by a vivid exchange between the audience and the speakers regarding many aspects that had been raised by the speakers, for instance:

- How to make sure that the advice that can be provided to parents is culturally relevant?
- Can social media be used to disseminate tips for parental feeding practices?
- How to help parents to differentiate between thirst and hunger, in particular during the period when infants still receive some milk or formula?
- What is the place of oral nutrition supplements in the child’s diet?
- How to make sure that some tips to avoid undereating do not lead to overeating, and vice versa?

Overall during this session, it was exposed that infants need to learn about foods, and that they need guidance from their parents to learn what and how to eat from the very early stages of oral feeding on. Learning what to eat can start in the context of breastfeeding, which may be a medium for learning about the flavors from the foods from the mother’s diet. Learning “what” to eat can further happen during the very first steps of complementary feeding. The period of weaning is a window of opportunity to educate infants to eat and like a variety of healthy foods. For instance, early sensory experiences and the variety of foods offered at the start of complementary feeding can influence food acceptance for several years. It was also observed that when tasting/smelling new foods, chil-
Children may make faces, but parents should continue offering new foods for learning to take place, because infants learn to like new foods through experience. Thus, parents should keep trying to introduce foods in their child’s food repertoire by introducing a variety of foods with a variety of tastes, flavors, and textures.

The period of complementary feeding is also a window of opportunity to educate infants about “how” to eat in terms of appetite regulation. Some tips can be formulated to help parents provide support for their child. It has long been established that parents should provide foods, and the child should decide if they eat or not. Parents should listen to and trust their child; they should encourage autonomy and self-feeding during timely developmental stages while accepting some mess around eating during a transitional phase during which the child learns oral feeding skills. Parents should also avoid emotional feeding and praise for eating, and they should remember to be a role model for their child!

Most of these tips may appear simple to apply in daily routine, but many studies help identifying deviations from these feeding practices; thus, it is important to ensure their wide dissemination.

Furthermore, many areas for future research were identified during the workshop to develop appropriate tools to define and qualify target feeding practices and eating behavior, and to better understand the circumstances under which feeding practices may successfully result in healthy eating habits.

Sophie Nicklaus
What Children Eat in Developing Countries: Diet in the Etiology of Undernutrition?

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Abstract
We live in a world of paradoxes: one half of the world is overweight or obese with abundant access to food and the other half undernourished due to poor food access. It has been estimated that nearly 36% of children in Asia are stunted. Worldwide, approximately 1 in 4 children under the age of 5 years shows stunted growth, making the number of stunted children to 155 million; 52 million children under 5 years are wasted, of which 17 million are severely wasted. Given the wide-scale nature of global malnutrition and its long-term consequences, why has this scar in our consciousness not being addressed systematically? The Asian enigma underscores the observation that unlike other regions of the world, economic growth does not appear to keep pace with the eradication of undernutrition. Exclusive breastfeeding is capable of maintaining adequate growth in infants in the first 3–6 months of life. Human breast milk contains the lowest protein content than any other homoeothermic animal. Despite the very low protein content of the breast milk, the protein content is sufficient for adequate infant growth. Protein deficiency is, therefore, not the cause of undernutrition in children. Most weaning foods in developing countries are of very low energy density, high viscosity, and poor palatability. This paper suggests that it is the poor energy density of weaning food that is in part responsible for the stunting and wasting pandemic seen in developing countries. Using the concept of developing ready-to-use therapeutic food, the paper proposes an urgent need to develop high energy, low viscosity, and palatable foods. Processed foods at the village community level or on a large scale will remain one of the solutions to produce palatable and energy-dense foods. Without this intervention, our world will continue to see the ravage of malnutrition which plagues our conscience.

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Diet in the Etiology of Undernutrition

We live in a world of paradoxes: one half of the world is overweight or obese with abundant access to food and the other half undernourished due to poor food access. Today, most discussions on infant nutrition focus on overweight and obesity. Whilst not diminishing the importance of this topic, the magnitude and the scale of global undernutrition in children are even stronger. This disparity starts very early in life. An examination of the infant mortality rate (IMR) in various countries illustrates this point. In many advanced countries, IMR is as low as 2–5/1,000 and in emerging countries as high as 90/1,000 (Central African Republic) [1]: a 45-fold difference! IMR is a proxy indicator of a variety of factors that include sanitation, health, public health, and governance. A high IMR is usually associated with childhood undernutrition.

Prevalence of Stunting and Wasting

Growth is an increase in weight, height, length, and girth that occurs when humans are provided with adequate food, water, and sustenance. One of the earliest attempts to define undernutrition was described by Gomez et al. [2], who used weight for age as the classification criterion. However, this method could not distinguish between stunting and wasting. Stunting refers to a child too short for his or her age. It is the failure to grow both physically and cognitively. It results from chronic or recurrent malnutrition. The effects of stunting can last a lifetime. Wasting refers to children who are too thin for their height. Wasting or acute malnutrition is the result of recent rapid weight loss or the failure to gain weight. A child who is undernourished has an increased risk of death, morbidity, and cognitive impairment. To address these two forms of undernutrition, Waterlow [3] developed a classification method that is still widely used — even today.

It has been estimated that nearly 36% of children in South Asia and approximately 34% of children in West, Central, Southern, and Eastern Africa are stunted. Similarly, the number of wasted children represents 16% in South Asia and 7–9% in Africa. In 2016, 22.9%, approximately 1 in 4 children under the age of 5 years, had stunted growth worldwide, making the number of stunted children to 155 million. In 2016, 52 million children under 5 years were wasted, of which 17 million were severely wasted globally. This translates to a prevalence of 7.7 and 2.5%, respectively [4]. Given the wide-scale nature of global malnutrition and its long-term consequences, why has this scar in our consciousness not being addressed systematically? Secondly, could we provide a tangible explanation for the nature of this pandemic?
Why Is There Such a High Prevalence of Stunting and Wasting Worldwide?

In a commentary entitled *the Asian Enigma*, Ramalingaswami et al. [5] observed that despite rapid economic growth in Asia, childhood undernutrition still remained a major public health challenge. The Asian enigma underscores the observation that, unlike other regions of the world, economic growth does not appear to keep pace with the eradication of undernutrition.

Growth is a proxy indicator of nutritional status and well-being. A resurgence of interest in infant growth has been prompted by the observation that early growth retardation may have long-term mental and health consequences [6]. It is also an important contributor to the global burden of chronic disease. Human growth is characterized by 2 significant features. Firstly, a rapid growth velocity in the first year of life, followed by a slow growth rate until the pubertal spurt later in life (Fig. 1). Secondly, the rate of growth even in the first year of life is no more than 25–30 g/day followed by as little as 5 g/day during the subsequent years (2–9 years). This slow rate of growth continues till the child attains its pubertal spurt (Fig. 1). A closer examination of the rate of growth in the first 12 months of life demonstrates that the rate of growth is highest in the first 3 months after birth (approximately 700–900 g) per month, which then stabilizes to 500 g/month after the 6th month (Fig. 1).

Exclusive breastfeeding is capable of maintaining adequate growth in infants in the first 3–6 months of life [7–9]. Comparing the growth rate of infants in the first 3–6 months of life with the breast milk composition, we can estimate the protein and energy needs for early growth. Initial recommendations for protein and energy for normal infant growth was based on the protein and energy content of human milk [9]. This can be calculated using the nutrients present in breast milk. It is known that the stage of lactation influences the nutrient contents of human milk [10]. Field studies suggest that the macronutrient composition of human milk (notably protein, fat, and carbohydrates) does not vary significantly between populations [11].

Human breast milk contains the lowest protein content compared to any other homeothermic animal [12, 13] (Table 1). This is a significant observation and further corroborates the view that the protein needs for human growth, even during the maximum growth period, is extremely small.

For over 3 decades, protein deficiency was labelled as the root cause of undernutrition in children [14]. This major focus in correcting the “protein gap” diverted attention and policies away from the real cause of undernutrition, notably an energy deficiency in infant foods [15].

Using the protein and energy content of breast milk, the amount of protein (in gram) may be converted into the percentage of protein energy by multiply-
ing the amount of protein by the metabolizable energy conversion factor of 4 kcal or 16.7 kJ per gram of protein. This calculation is elaborated in the box below.

**Protein: Energy Percent of Breast Milk**

- Protein content: 1.2 g/100 mL
- Energy content: 70 kcal (293 kJ)/100 mL
- Protein as energy = $1.2 \times 4 \text{ kcal (16.7 kJ)} = 4.8 \text{ kcal (20 kJ)}$

\[
\text{Percentage protein energy in breast milk} = \frac{4.8 \text{ kcal (20 kJ)}}{70 \text{ kcal (293 kJ)}} \times 100 = 6.86\% \approx 7\%.
\]

**Fig. 1.** Growth velocity in humans. **a** Growth velocity and weight. **b** Growth velocity in the first 12 months.
A mere 7% of total protein energy is all that is needed to meet the growth requirement of the infant during the first 0–6 months of life. Similarly, we can convert the protein content of any food as a percentage of total protein energy using the calculation model above.

Such a calculation on the percentage energy from protein in cereals and tubers widely used as weaning foods may be computed as illustrated in Table 2.

What is clear is that even with foods that are quantitatively low in protein, e.g., potatoes (g/100 g), the percentage protein energy is higher than the requirements for infants (7% protein energy). This is even during the time of maximum

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**Table 1. Milk composition of humans and other animals (adapted from Jensen [12])**

<table>
<thead>
<tr>
<th>Species</th>
<th>Milk composition</th>
<th>Total energy, kcal</th>
<th>Energy from protein, %</th>
<th>Energy from fat, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camel</td>
<td>4.9 3.7 5.1</td>
<td>79</td>
<td>18.7</td>
<td>55.6</td>
</tr>
<tr>
<td>Cow</td>
<td>4.1 3.6 4.7</td>
<td>70</td>
<td>20.5</td>
<td>52.6</td>
</tr>
<tr>
<td>Deer</td>
<td>19.7 10.4 2.6</td>
<td>229</td>
<td>18.1</td>
<td>77.3</td>
</tr>
<tr>
<td>Dog</td>
<td>8.3 9.5 3.7</td>
<td>128</td>
<td>29.8</td>
<td>58.6</td>
</tr>
<tr>
<td>Elephant</td>
<td>15.1 4.9 3.4</td>
<td>169</td>
<td>11.6</td>
<td>80.4</td>
</tr>
<tr>
<td>Goat</td>
<td>3.5 3.1 4.6</td>
<td>62</td>
<td>19.9</td>
<td>50.6</td>
</tr>
<tr>
<td>Horse</td>
<td>1.6 2.7 6.1</td>
<td>50</td>
<td>21.8</td>
<td>29.0</td>
</tr>
<tr>
<td>Human</td>
<td>4.5 1.1 6.8</td>
<td>72</td>
<td>6.1</td>
<td>56.2</td>
</tr>
<tr>
<td>Monkey</td>
<td>3.9 2.1 5.9</td>
<td>67</td>
<td>12.5</td>
<td>52.3</td>
</tr>
<tr>
<td>Pig</td>
<td>8.2 5.8 4.8</td>
<td>116</td>
<td>20.0</td>
<td>63.5</td>
</tr>
<tr>
<td>Reindeer</td>
<td>22.5 10.3 2.5</td>
<td>254</td>
<td>16.2</td>
<td>79.8</td>
</tr>
<tr>
<td>Sheep</td>
<td>5.3 5.5 4.6</td>
<td>88</td>
<td>25.0</td>
<td>54.1</td>
</tr>
<tr>
<td>Whale</td>
<td>34.8 13.6 1.8</td>
<td>375</td>
<td>14.5</td>
<td>83.6</td>
</tr>
</tbody>
</table>

**Table 2. Protein/energy of various staples compared to breast milk (using the National Nutrient Database of the United States Department of Agriculture)**

<table>
<thead>
<tr>
<th>Foods</th>
<th>Per 100 g</th>
<th>Percent protein energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>protein</td>
<td>energy, kcal/kJ</td>
</tr>
<tr>
<td>Egg</td>
<td>12.6</td>
<td>143/598</td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>3.15</td>
<td>61/255</td>
</tr>
<tr>
<td>Breast milk</td>
<td>1.1</td>
<td>72/300</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>10.33</td>
<td>364/1,521</td>
</tr>
<tr>
<td>Maize flour</td>
<td>6.93</td>
<td>361/1,509</td>
</tr>
<tr>
<td>Potato</td>
<td>2.05</td>
<td>77/321</td>
</tr>
<tr>
<td>Rice</td>
<td>7.13</td>
<td>365/1,526</td>
</tr>
<tr>
<td>Yam</td>
<td>1.53</td>
<td>118/493</td>
</tr>
<tr>
<td>Cassava</td>
<td>1.36</td>
<td>160/669</td>
</tr>
</tbody>
</table>
growth (0–12 months). Lack of protein in their diet is, therefore, not the real cause of undernutrition in children living in the developing world. If the protein needs for infant growth are extremely small even at the time of maximal growth, what limits the optimal growth in these children during the weaning period? It is certainly not due to an inadequate intake of protein.

**Preparation of Weaning Foods in Developing Countries**

The sense of taste is primordial. Apart from breast milk, weaning foods represent the second most widely exposed food during human growth. Weaning is the transition from breastfeeding to the introduction of semisolid food. It is also the most critical stage in the development of undernutrition [16].

Most weaning foods are made from carbohydrate-rich staples [17] such as ground rice, corn, cassava, yams, and plantain. These staples have to be cooked with the addition of water. During the cooking process and starch gelatinization, the carbohydrates absorb a considerable amount of water. This leads to the swelling of the starch granules with an increase in viscosity and lowering of energy density. A characteristic feature of such weaning foods is their high water content, high viscosity, and thick paste-like consistency. The preparation of weaning foods in developing countries thus poses several challenges.

An ideal weaning food must have an adequate energy density to meet the energy needs of the child. Nicol [18] was a pioneer who attempted to describe the role of energy density in defining the amount of food required to meet the energy needs of children. Subsequently, Mosha and Svanberg [17] proposed that the stomach capacity of a 1-year-old child is approximately 900–1,400 g/day. To meet the daily energy requirement of a 1-year-old child (4.2 MJ, 1,000 kcal), foods with very low energy density will need to be consumed in very large quantities. In order to meet (4.2 MJ, 1,000 kcal), the relationship between the energy density and the quantity of weaning foods to be consumed is illustrated in Figure 2. A 1-year-old child will require to consume 3–4 kg of the weaning food in order to meet their energy needs.

As an example, let us consider a mother preparing weaning food in rural India using ground rice. The weaning food needs to have an adequate mouth feel and viscosity that will enable the child to feed on this gruel safely. In order to accomplish this, she continues to add water to the gruel. As viscosity reduces and texture meets the child’s gustatory needs, the energy density of the weaning food dramatically declines (Fig. 3). A further disadvantage of preparing such carbohydrate-rich weaning food is that the “runny” texture of the weaning food at high cooking temperatures of 90°C changes into a thick
unpalatable blob upon cooling at 45°C. This is a temperature below which the weaning food is usually fed. In order to prepare the gruels with appropriate semisolid consistency, the mother continues to add further quantities of water, which results not only in producing a runny gruel but also further reduces the energy density of the gruel (Fig. 4). The reduced energy density

Fig. 2. Relationship between energy density (in kcal/g or kJ/g) and the amount of weaning foods to be consumed to meet 4.2 MJ/1,000 kcal.

Fig. 3. Change in energy density per 100 g of gruel when diluted with various ratios of water.
of the weaning food, whilst making it palatable, requires impossibly large quantities of foods to be consumed. A major limitation in most weaning foods consumed in developing countries lies in its inability to meet the child’s energy needs.

In summary, if a child consumes adequate energy from weaning food, the weaning food will automatically satisfy their protein needs. Therefore, the key to optimal growth during the first 2–3 years of life is to essentially meet the child’s energy requirements.

**Method to Improve the Energy Density of Weaning Foods**

Oils and fats are the richest sources of energy per gram. The addition of fat accomplishes several advantages. Firstly, it reduces the viscosity of the gruel (making it easy for the infant to consume such starchy foods), and, most importantly, it increases palatability and energy density [19]. The addition of just 20 g of oil increases the energy density 10-fold. The relationship between the increased energy density of weaning food and the quantity of food that now needs to be consumed to meet 4.2 MJ (1,000 kcal) is shown in Figure 2. This quantity is well within the stomach capacity of infants and also appropriate to the mothers’ routine feeding pattern that may be up to 4–6 times per day.
Can Ready-to-Eat Therapeutic Food Be a Model to Develop Weaning Food with High Energy Density?

Ready-to-use therapeutic food (RUTF) is a high-energy, vitamin- and mineral-fortified peanut paste mixed with dry milk products. It was first developed by Briend et al. [20] to treat severe acute malnutrition. The original recipe had 45–60% of energy derived from fat. Historically, RUTF was developed to treat severe malnutrition. Its high energy density, long shelf life in tropical conditions, and the facility to consume it without cooking made it a valuable therapeutic food in the treatment of severe undernutrition.

In an attempt to develop RUTF based on locally available cereal and oil seeds, Collins and Henry [21] produced a range of products based on rice, corn, wheat, along with soya and sesame seed (Table 3). An additional reason for developing such products was to exclude the use of peanuts that are potentially allergenic and are easily contaminated with aflatoxin. Locally developed RUTF has now been produced and expanded in the treatment of malnutrition [22]. Learning from the experience of developing locally made RUTF: can this concept be used to develop high-energy weaning foods? The induction of undernutrition in developing countries can be partly attributed to the consumption of low-energy-dense weaning foods. It is abundantly clear that undernutrition is not due to the lack of protein in the diet but the lack of energy-dense foods.

The following question arises: can we develop an appropriate weaning food based on the RUTF concept? This is a challenge that the present paper poses. Such a project will only be possible if there is close collaboration with private-public partnerships. At the present time, there is a raging debate on the consumption of ultraprocessed food and its implication in the etiology in diabetes, obesity, and other chronic diseases [23]. It is instructive to point out that in the case of producing appropriate weaning foods for use in the developing world,
processed food will remain one of the solutions to produce a palatable and energy-dense food.

Several challenges still remain in the development of local weaning foods. This includes the type of fat to be used particularly in relation to brain development. Most of the oils used in preparing energy-dense weaning foods are high in ω-6 linoleic acid but poor in essential fatty acids. They are also very low in ω-3 α-linolenic acid [24].

**Conclusion**

There is an urgent need for the development of low-cost weaning foods that have adequate energy and micronutrient content. Much remains to be investigated in the application of simple technology and alternative methods to reduce the high viscosity and improve the energy density of weaning foods. It is increasingly evident that the provision of weaning foods with sufficient energy still remains a challenge in many developing countries. This imbalance in meeting the energy needs of a child appears to be one of the major contributors in generating the vast number of stunted and wasted children globally.

Given that stunted children have a compromised brain development and cognition, the future challenge is to focus on providing nutritionally adequate weaning foods to realize the full potential of these children. This paper has identified the need to provide weaning foods with adequate energy and nutrients to optimize growth and development. In many developing countries, even today, it is not the lack of protein but the lack of energy in the diet that leads to wasting and stunting. An understanding of the nature and ethology of undernutrition is necessary before any strategy can be evolved. Stunting and wasting still remains a pervasive pandemic in most of Asia, Africa, and Latin America. Using the model of RUTF, it is proposed that further focus and attention is provided in developing a low-cost, high-energy, nutrient-rich weaning food. Without this intervention, our world will continue to see the ravages of malnutrition which plagues our conscience.

Many things can wait. Children cannot.
Today their bones are being formed, their blood is being made, their senses are being developed.
To them we cannot say “tomorrow. Their name is today.

*Gabriela Mistral*

**Disclosure Statement**

C.J.H. was a member of the FITS and KHNS Scientific Advisory Committee.
References

Abstract
The transition from risk factors in the first 1,000 days to childhood obesity occurs largely through the development of maladaptive eating behaviors that emerge early, remain stable, and support greater energy intake over time. We have examined the association between eating behaviors, energy intake, and body composition at 4.5 and 6 years of age among children from the GUSTO (Growing Up in Singapore towards Healthy Outcomes) cohort. Our findings demonstrate that when children select larger portions, eat at a faster rate, and continue to eat when sated, they consume more energy than children who do not exhibit these behaviors. We have shown that these behaviors are stable over time and independently predict higher adiposity and BMI\textsubscript{z} scores at the later time point. We observed that faster eating and greater intakes were associated with parent report measures of appetitive traits, such as the child’s satiety responsiveness, food fussiness, and enjoyment of food. Importantly, faster eating rates mediated the link between these appetitive traits and child energy intakes. In addition, within-meal parental feeding practices were linked to a faster eating rate, higher energy intakes, and higher BMI\textsubscript{z} scores in some children, suggesting that parents are aware of these eating behaviors and likely adapt their feeding practices to influence their child’s energy intake. These findings emphasize the need to consider the interaction and cumulative impact of these eating behaviors and parental feeding practices on children’s energy intake, and, consequently, the need to develop holistic intervention approaches that target the behaviors that contribute most to a child’s risk of developing overweight and obesity.

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This study was registered at clinicaltrials.gov as NCT01174875.
Introduction

Early-life risk factors within the first 1,000 days can cumulatively influence the development of childhood overweight and obesity. Risks such as parental weight status, breastfeeding duration, or the early introduction of solid foods have been associated with weight gain [1], and a recent analysis found that Singaporean children that had 4 or more of these risk factors were 11 times more likely to be overweight or obese at 4 years of age [2]. Associations between the early-life risk and the later development of overweight and obesity are well documented, yet the eating behaviors that support the sustained positive energy balance required for these unhealthy growth outcomes are less clear. The “behavioral susceptibility hypothesis” proposes that a genetic predisposition to become obese manifests through the development of “appetitive traits” linked with greater responsiveness to the food environment and poorer self-regulation that promotes increased energy intake [3]. In this regard, the transition from early-life “risk” to childhood obesity is likely to operate through the emergence of maladaptive eating behaviors that consolidate during childhood, remain stable over time, and predict weight gain and higher adiposity. These behaviors can overlap to influence food choice and energy intakes at every stage of a meal, from portion selection to eating behaviors within the meal, and postmeal appetite and responsivity to available food cues. A child’s food environment, food preferences, habitual energy intake behaviors, and growth outcomes are influenced by their caregivers through the foods they choose and the feeding practices they use [4, 5]. The association between caregiver feeding practices and children’s eating behaviors are likely bidirectional, and the feeding practices used by a caregiver to moderate food intake may also be influenced by the child’s appetitive traits and subsequent eating behaviors displayed [6]. This emphasizes the important role of caregivers and food environment in the behavioral transition from early-life risk to overweight and obesity.

The current paper provides a summary of a series of studies that investigated links between child eating behaviors and parental feeding practices, and their association with energy intake and body composition among children from the GUSTO (Growing Up in Singapore towards Healthy Outcomes) cohort. Since its inception in 2009, the GUSTO cohort has extensively profiled the growth and development of a large sample of Singaporean mother-child pairs ($n = 1,247$). Eligibility criteria and the GUSTO study profile are described in detail elsewhere [7]. The findings reported are summarized from data collected at 2 time points (4.5 and 6 years) and focus on child portion selection, oral processing behaviors, within-meal energy intake, and postmeal measures of food responsivity, as well as measures of parental feeding practices and parent reports of child appetitive traits.
Child Portion Selection and Energy Intake

The amount of food selected at the start of a meal can strongly influence the total amount consumed [8], and although the factors that influence adult portion selection have been studied extensively [9], to date much less is known about how children differentiate between foods, or which factors govern the portion they select [10]. To address this, at the 6-year time point, we asked children (n = 373: 197 boys and 193 girls) to complete a computer-based portion selection task where they made a series of judgments across a range of 8 different foods. Children were required to think about their feelings of hunger and fullness, and they were asked to make estimations of how filling different foods might be, as well as how much they liked them. After this, children estimated the portion of each food they would choose for a meal. They were then provided with one of the foods (fried rice) ad libitum and asked to serve themselves and consume as much or as little as they wanted for lunch. Using this approach, it was possible to compare the relative influence of different premeal beliefs on the portion selected and consumed during the meal [11]. Findings showed that the portions selected by children in the computer task significantly predicted the portion selected and consumed during the lunchtime meal. Children selected larger portions of the foods they liked, but they also appeared to consider the filling properties of different foods by selecting smaller portions of foods they regarded to be more filling and larger portions of foods they believed were less filling independently of how much they liked the food. The amount of food chosen during the lunchtime meal was the strongest predictor of the actual energy intake, with children who selected larger portions eating more, highlighting the tendency for children to eat in response to the portions they are served. These findings are important as they demonstrate that children at this age are not simply choosing larger portions of foods they like but are also capable of discriminating between foods based on their filling properties. The tendency to select larger portions at this age is linked with greater energy consumption, supporting the idea that guiding appropriate food portion selection is an important locus in the control of a child’s energy intake.

Eating Rate and Energy Intake at 4.5 and 6 Years

Although children’s appetitive traits are expressed through their premeal portion decisions, they can also be seen in the oral processing behaviors they exhibit within a meal. Previous research has demonstrated associations between the oral processing behaviors that promote greater energy intakes within a meal
and child BMI [12, 13]. To further investigate these links between portion selection, oral processing behaviors, and energy intake, children at both 4.5 and 6 years participated in an ad libitum lunchtime meal \((n = 263; 133 \text{ boys and 130 girls})\) as a measure of their usual energy intakes. The test meals were video recorded at both time points, and using behavioral coding we derived a series of oral processing behaviors for comparison with energy intake based on a previously published approach [14]. Figure 1 shows an exemplary screenshot of a video recording and a coding scheme used. This approach enabled a comparison of differences in the oral processing behaviors exhibited during the meal to explore whether these behaviors were associated with differences in child energy intakes and body composition at each time point.

Children who ate their meal at a faster rate \((\text{g/min})\) consumed significantly more energy than children who ate their meal slower [15] (Fig. 2). However, eating rate was specific to the time children had food in their mouth, and a comparison of the joint impact of eating rate and total meal duration \((\text{min})\) showed that the children who ate faster and for a longer duration consumed the most energy.

Closer inspection of the oral processing characteristics exhibited by faster-eating children showed that children who eat faster tend to have a larger average bite size \((\text{g})\), chewing each bite in fewer cycles and through this producing a
Children’s Eating Behaviors and Energy Intake

shorter average orosensory exposure to the food during each mouthful (Fig. 3). Comparison of microstructural patterns of eating at the 6-year time point demonstrated that the same oral processing behaviors were driving faster eating rates and greater energy intakes at both time points in what we have described as an “obesogenic” eating style that encourages greater food intake within a meal [16].

When children were median split into faster- and slower-eating groups at 4.5 years, we found that children in the faster-eating group consumed on average

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**Fig. 2.** Association between eating rate and energy intake during lunch ($r^2 = 0.38, p < 0.001; n = 386$) (adapted from Fogel et al. [16]).

**Fig. 3.** Summary of oral processing behaviors that predict greater energy intakes at 4.5 and 6 years of age (all significant at $p < 0.001$).
75% more energy within the same lunchtime meal than children in the slower group [15]. These acute differences in energy intake were also associated with differences in child body composition at 4.5 years, as children in the faster-eating group had significantly higher BMI$_z$ scores and higher skinfold adiposity indices, and a subset of children who had abdominal MRI scan ($n = 158$) had a higher volume of subcutaneous abdominal adiposity [15]. When the same children were followed to the 6-year time point, it was clear that these behaviors remained stable and again predicted greater energy intake during the lunchtime meal. Being a faster eater at 4.5 years was a significant predictor of being a faster eater at 6 years, and children who ate faster at 4.5 years had higher BMI$_z$ scores and adiposity at 6 years [17]. These findings emphasize the stability of oral processing behaviors and the importance of these behaviors in promoting greater energy intake and weight gain.

The selection of larger portions and eating at a faster rate were both significant independent predictors of higher energy intakes among children. However, these eating behaviors were also found to interact, such that children who chose larger portions and ate at a faster rate consumed the most energy within the meal [18], highlighting the combined impact of larger portions and eating quickly in promoting energy intake. Interventions focused on reducing eating rate alone may have limited success if they do not also account for the risk of increased energy intake arising from the selection of larger portions. Specific oral processing behaviors, such as a large bite size, appear to be stable over time and, when observed in children at 4.5 years, were capable of predicting changes in body composition at the later time point. Taken together, these findings are important because they suggest several loci for potential intervention, where it may be possible to reduce the impact of multiple behaviors on energy intakes both in terms of monitoring child-selected portions and potentially using meal properties, such as food textures, to target the specific oral processing behaviors that promote faster eating [19]. Considering the independent and combined impact of these overlapping behavioral risks, intervention strategies should take an integrated approach accounting for both premeal portion selection and within-meal eating behavior to control both energy selection and intake [18].

**Eating in the Absence of Hunger and Child Inhibitory Control**

Beyond main meals, children are susceptible to increase their energy intake when palatable snacks are available in their food environment even when a child is fully sated. The tendency to eat in the absence of hunger (EAH) is a measure of food cue responsivity and has previously been shown to contribute to the in-
creased energy intakes associated with overweight and obesity among children [20]. To study differences in EAH among GUSTO children, a subset (n = 255: 127 boys and 128 girls) were given free access to snacks after they reported feeling full following the lunchtime meal at both the 4.5- and 6-year time points. Children were classified into those that did or did not exhibit EAH behaviors, and the quantity of calories consumed from their snack intake during the EAH task was recorded. Results showed that children who demonstrated EAH did not differ in the energy consumed at lunch from children who did not show EAH. However, children who demonstrated EAH consumed more energy cumulatively when intake was combined from the lunch and the EAH snack test at both 4.5 and 6 years [21]. In addition, children who exhibited EAH at the earlier time point were 3 times more likely to continue this behavior at the 6-year time point, indicating consistency in this behavior and a potential sustained contribution to greater energy intakes. Despite this, there was no association between children’s tendency to EAH and their BMI or adiposity at either time point, suggesting the link between EAH and child growth outcomes might manifest at an older age.

The eating behaviors we have identified to predict higher energy intakes tend to be stable over time and often overlap within the same group of children. This may be due to common underlying mechanisms that predispose some children to be more vulnerable to increased energy intakes than others. For example, children who show EAH may be less able to control an impulse to respond to food cues even when sated. Previous research has shown that children who have higher inhibitory control are less likely to be overweight than children who do not show the same capacity for self-regulation [22]. In the context of eating behavior, inhibitory control relates to the ability to stop or suppress certain responses to food cues in the environment. A higher propensity to EAH is a good behavioral measure of a child’s responsivity to food cues and may be one of the mechanisms through which a lower inhibitory control predisposes children to increase their energy intake and eventually promote weight gain [23]. We investigated whether individual differences in inhibitory control were linked to the identified differences in child eating behaviors that promote greater intake, such as the selection of larger portions, faster eating rates, and EAH. Children at 6 years completed a measure of inhibitory control known as the stop signal task, which gauges a child’s capacity to voluntarily inhibit or regulate their attentional and behavioral responses (CANTAB; Cambridge Cognition 2017). Children that had lower inhibitory control and were more restless during the stop signal task were the same children that tended to EAH, suggesting a relationship between this trait and energy intakes from snacks [24]. Importantly, further associations were found where children with lower inhibitory control also selected larger food portions on the computer portion task and ate food at a faster rate.
during the meal [24]. These results suggest a convergence of some eating behaviors associated with greater energy intakes among children with lower inhibitory control that reflects the way they select and consume their portions and respond to food cues in their environment. This overlap in behaviors is predicted to drive weight gain, and identifying children with lower inhibitory control and the associated food intake behaviors may help in the development of strategies to mitigate this obesity risk.

**Parental Influences on Child Eating Behaviors and Energy Intake**

A wide range of eating behaviors have been shown to increase children’s energy intakes and promote weight gain, and it is important to consider that these behaviors emerge in the home food environment, where one of the strongest factors shaping their development and expression is the influence of a child’s caregivers. During the preschool years, parent’s dietary habits, portion selection, and feeding practices around mealtimes play a significant role in influencing children’s experience with foods, which in turn shapes their eating behaviors. For example, the additional energy consumed when children have the opportunity to EAH relies on these snacks being made available in the child’s food environment in the first place. Moreover, energy intake from EAH is likely to be moderated by the caregiver’s feeding practices. The foods and portions a parent or caregiver selects for their child can significantly influence energy intake, with larger portions promoting greater consumption [25]. When parents in our cohort were asked to choose portions for their child, they tended to select larger portions for meals they had chosen in large portions for themselves, and they picked larger portions for their child if they believed the child liked that food [11]. This indicates that parents may base portion choices for their child on their own beliefs about foods and rely less on adapting portions to their child’s needs. This raises concerns that parental biases towards selecting larger portions for themselves may translate into habitually selecting larger portions for their child, which in turn may influence a child’s longer-term perception of appropriate portion size [10].

In addition to selecting a child’s food and portions, parents often use feeding practices during mealtimes to encourage, modify, or restrict food intake. Research has shown that restricting energy-dense palatable foods and using more controlling feeding practices can be counterproductive and lead to higher energy intakes and weight gain over time [26]. We investigated whether parents in our cohort were aware of their child’s appetitive traits. Parents who reported their child to have higher food approach (enjoyment of food or food responsive-
ness) and lower food avoidance (i.e., satiety responsiveness and fussy eating) behaviors had children who consistently consumed greater energy and had higher BMI$_z$ and adiposity scores [27]. Faster eating rates were found to mediate the relationship between appetitive traits and higher energy intakes, such that children who had traits associated with greater energy intakes consumed more energy when they also ate at a faster rate [28]. This finding suggests that eating rate may be one of the behavioral pathways through which stronger appetitive traits manifest to promote energy intakes, and that mothers are noticing these behaviors in their children.

Finding that parents are somewhat aware of the eating behaviors linked to certain appetitive traits in their children suggests that they might use their feeding practices to try and modify them. Therefore, we investigated whether mothers’ use of feeding practices was linked with their child’s oral processing behaviors and increased energy intakes. To do this, we explored the relationship between the type and frequency of parental feeding practices (e.g., prompts, restrictions, and encouragements) and child eating behavior in a subset ($n = 155$) of child-mother pairs [29]. Children that experienced the most frequent feeding practices during the meal ate at a faster rate and consumed significantly more energy than children who experienced less-frequent feeding practices. However, this was not the same across both genders, as girls who displayed faster eating rates were more likely to experience parental feeding practices than boys who exhibited the same eating style. The frequency of parental feeding practices and child faster eating rates independently predicted greater energy intakes; however, children who ate faster and also experienced the highest frequency of feeding practices had the greatest energy intakes, suggesting that parental influence did little to reduce eating rate or energy intake within the meal. This remained the case at 6 years, where prospective analyses showed that those children who were more frequently prompted at age 4.5 years had continued to have faster eating rates at 6 years [29].

Taken together, these findings stress the importance of considering how parental influences can impact the child’s food environment and moderate the expression of eating behaviors associated with greater energy intakes. Caregivers can have a powerful short-term impact on their child’s energy consumption and the potential to exert a longer-term impact on the development of child food and portion selection, as well as the eating styles that can increase energy intake within meals [29]. Rather than selecting portions and encouraging intake based on the parent’s feeding goals, parents are encouraged to apply responsive feeding practices where appropriate foods are provided based on awareness of and sensitivity to a child’s appetite need state [10].
Conclusions: Future Opportunities for Integrated Behavioral Interventions

Our findings highlight associations between higher energy intakes and a series of overlapping and interrelated eating behaviors and parental feeding practices. We have identified behaviors such as selecting large portions, eating at a faster rate, and EAH consistently predicted greater energy intakes. An opportunity exists to moderate energy intakes by providing guidance to parents and children on the appropriate portions to select or by reducing the availability of larger portions for children in general. Insights into the oral processing behaviors that underpin faster eating rates create new opportunities to develop foods that encourage smaller bite size, increase chews per bite, and result in a natural slowing of eating rates in response to the food textures experienced during consumption [30, 31]. Future research should consider combining approaches in the design of food portions and textures for children with appetitive traits and eating behaviors that increase their risk of increased energy intakes over time.

The eating behaviors identified have been shown to independently predict higher energy intakes, but when combined they often increase the risk of energy overconsumption and subsequent weight gain. Each risk in isolation may periodically lead to a positive energy balance, but, cumulatively, these risks combine to sustain a positive energy balance and promote increased weight gain throughout childhood. The interplay between eating behaviors and feeding practices is important to consider, and it highlights the potential for aberrant eating behaviors to be exacerbated when energy intake is informed by factors unrelated to a child’s appetite need state. Understanding how portion selection and eating behavior is moderated by parental feeding practices can help improve our ability to identify children at risk of developing obesity and advance the development of integrated approaches that target specific elements of a child’s behavior, their food environment, and their parent’s feeding practices.

The eating behaviors and feeding practices discussed in the current chapter can each contribute to increases in energy intakes, but in combination they are likely to have the greatest impact on energy intake, e.g., to consume quickly larger portions of higher-energy-dense foods. Attempts to modify a child’s eating rate are likely to be unsuccessful if they do not also consider the portion selection or parental feeding practices that also encourage greater energy intake within meals. These findings underscore the need to go beyond targeting individual eating behaviors and to consider holistic interventions that focus on the cumulative impact of energy selection, eating styles, and feeding practices that moderate these behavioral outcomes in the child.
Acknowledgments


Disclosure Statement

C.G.F. has received reimbursements for speaking at conferences sponsored by companies selling food ingredients and nutritional products, and currently serves on the scientific advisory council of a commercial ingredient manufacturer. None of these organizations had any influence on the research presented in the current chapter. All other authors declare no conflicts of interest.

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References

Abstract
The FITS (Feeding Infants and Toddlers Study) and KNHS (Kids Nutrition and Health Study) are large-scale cross-sectional surveys designed to explore eating patterns, nutrient intakes, and food sources of nutrients among infants and children. FITS and KNHS use data from national surveys when available, but when data are not available for age groups of interest, we collect data using similar methods. So far, we have applied a common analysis approach in Australia, China, Mexico, the Philippines, Russia, and the United States. Although dietary data collection methods shared similarities, other aspects of the survey methodology differed considerably. Food composition tables varied, limiting accurate intake estimates to a short list of nutrients in some countries. Age groups and food grouping systems were not consistent, and the level of detail varied. Not all surveys recorded details about the meals or times when foods were consumed. Nonetheless, the FITS and KNHS have standardized age categories and food groupings, so comparisons can be made, and we have imputed missing values to complete data sets for nutrients of interest. We have also supported primary data collection to fill gaps. This manuscript provides an overview of the individual studies and country data that comprise the current FITS and KNHS.
Introduction to FITS and KNHS

The FITS (Feeding Infants and Toddlers Study) began in 2002 as a large-scale national telephone survey to study the eating patterns and nutrient intakes of infants and young children in the USA [1]. It was followed in 2008 by a second FITS, which surveyed 3,273 infants, toddlers, and preschool children from birth to the age of 4 years [2]. Both studies helped to fill a gap in knowledge of young child eating behaviors and confirmed Nestlé’s commitment to understanding dietary patterns among infants and children during these nutritionally important life stages.

Building on the FITS model, Nestlé expanded this research program to include older children and launched the KNHS (Kids Nutrition and Health Study) in 2014. Together, FITS and KNHS investigate nutrient intakes, food groups consumed, food sources of nutrients, meal patterns, feeding practices, household demographic factors, and key behaviors related to energy intake and expenditure in infants and children in different countries around the world. To date, we have conducted studies in Australia, China, Mexico, the Philippines, Russia, and the USA and plan to continue to expand this research initiative.

Scientific Approach

The FITS and KNHS research program uses a 3-tiered scientific approach (Fig. 1). The first step begins with an understanding of the currently available data in a country or region, informed by a literature review or from other data sources such as data briefs or summary data tables from national surveys. This “nutritional landscaping” helps to identify potential data sources for further analysis and clarify research gaps, but it may also be used to explore topics relevant to the FITS and KNHS research program. An example is the systematic review performed on parenting styles, feeding styles, and feeding practices of children [3]. The second approach we use is to conduct further analysis of national nutrition survey data when available. National nutrition and health surveys are a rich source of information on dietary intakes, and many countries have comprehensive survey data that can be used to further investigate eating patterns and dietary intakes of infants and children. The third approach is to conduct studies in countries where national nutrition surveys do not include age groups of our interest.

National survey data have been used for KHNS in the USA, Australia, and China, and for FITS and KNHS in Mexico, Russia, and the Philippines. In the
USA, data from NHANES (the National Health and Nutrition Examination Survey) were used to evaluate meal [4] and snacking patterns [5], energy and protein distribution over the day [6], sedentary behaviors, and functional strength [7]. In Australia, we used data from 3 national surveys to evaluate the energy contribution and foods consumed as snacks over time (1995, 2007, and 2011–2012) [8], and we used the most recent National Nutrition and Physical Activity Survey (NNPAS) to identify meal-specific opportunities to improve dietary intakes for adolescents [9]. The China Health and Nutrition Survey (CHNS) was used to explore health issues related to diet and cardiometabolic risk factors [10] and the double burden of under- and overnutrition and nutrient adequacy of Chinese children [11]. A longitudinal study investigated the impact of snacking on body mass index in children 2–13 years of age [12]. We also identified micronutrient gaps in the diet [13] and investigated urban-rural disparities in energy intake of Chinese school children 4–17 years of age [14].

National survey data in Mexico (Encuesta Nacional de Salud y Nutrición; ENSANUT 2012) include both infant and child participants, allowing research in both FITS and KNHS age groups. In infants and toddlers, we examined early feeding patterns, documenting low breastfeeding rates and early introduction of complementary foods and cow’s milk [15]. We also found that along with traditional dishes, like soups, beans, tortilla dishes, and eggs, many Mexican infants and young children also consumed sweets (like cookies and sweet-
ened breads) and sweetened beverages [16]. These findings, along with other publications using ENSANUT data, were instrumental in supporting the development of Mexican complementary feeding guidelines [17]. Using data from ENSANUT, we also studied dietary patterns in older children, associating increased snacking and eating occasions with higher energy intakes in older (6- to 13-year-old) but not younger (2- to 5-year-old) children [18]. We found that out-of-home food consumption was low overall with only 11% of daily energy coming from out-of-home sources among younger children and 18% for older children [19]. We also evaluated breakfast dietary patterns, characterizing 6 different patterns of consumption, and documented the extent of breakfast skipping in Mexican children (14 and 18% among children 4–8 and 9–13 years old, respectively) [20].

The FITS and KNHS project sponsored the Russian Institute of Nutrition to analyze data from the 2013 Russian National Nutrition Survey to evaluate dietary intakes and nutrient adequacy in infants and children [21, 22]. Work is also underway to analyze data from the Philippines 8th National Nutrition Survey 2013–14 (Food and Nutrition Research Institute, the Philippines).

Where national nutrition surveys do not include age groups of our interest, we have conducted our own studies. The Maternal Infant Nutrition Growth (MING) study in China included 1,409 children 6–36 months of age recruited from maternal and childcare centers in 8 major cities. We found low dietary diversity in the diets of infants and young children, with only 5 foods (i.e., fortified milk, rice, noodles, pork, and eggs) contributing 52–69% of daily energy [23]. Fruit and vegetable consumption was low, especially among infants [24]. The diets of Chinese infants and toddlers <24 months of age were generally low in fat, vitamin B6, and folate, and the diets of infants <12 months of age were also low in iron [25].

A third US FITS was completed in 2016. This study included 3,235 infants and young children up to 48 months of age, and the sample was weighted to be nationally representative [26]. The survey instruments were similar to those used in 2008 for purposes of comparability, but some aspects of the methodology were changed. For example, although telephone 24-h recalls were completed on all participants, we recruited subjects both via telephone and online [26], whereas only telephone recruitment was used in 2008 [2]. We also updated the food grouping scheme to be more aligned with the NHANES What We Eat in America food groups. First results from the study show that nutrient intakes are largely adequate, but low iron intakes in 6- to 11-month-old infants are of concern. High sodium intakes and low intakes of potassium, fiber, and vitamin D are issues for toddlers and preschool children [27]. Other publications to share findings from FITS 2016 are under development.
**Cross-Country Comparisons**

Additional perspective on dietary intakes can be gained by comparing results across countries. For example, there are global recommendations for exclusive breastfeeding for the first 6 months of life, but the foods used for complementary feeding differ by culture and region. When comparing complementary feeding practices, we found higher infant consumption of fruits and vegetables in the USA compared to Mexico or China, largely driven by consumption of baby foods [28]. Rice was widely consumed by infants in China, whereas the major grain source consumed by infants in the USA was infant cereal. Desserts and sweets, including sweetened beverages, were introduced early in Mexico and the USA, but they were virtually absent from the diets of young children in China [28]. Food consumption patterns are established early in life and influence the development of food preferences. We have seen evidence of that with sweets, where we found low consumption of total and added sugars in 4- to 13-year-old children in China representing 8% of total energy intake (TEI), whereas total and added sugars contributed 20 and 26% of TEI in Mexico and the USA, respectively [29], mirroring exposure to sweets in the diets of infants and young children.

Snacking patterns also differ by country [30]. In the USA and Australia, snacking is part of the usual dietary pattern of 4- to 13-year-old children (>95% consume snacks on a given day). Snacks account for one-third and one-quarter of TEI in Australia and the USA, respectively. A different pattern is observed in Mexico (76% consume snacks, providing 15% TEI) and in China (65% consume snacks; providing 10% TEI). One important insight from this research was the prevalent consumption of fruits, milk, and water during snacks, which helps to dispel the myth that all snacking is bad. Of course, there is room for improvement, but the snacking occasion can also be a time to promote more consumption of fruits, dairy, and whole-grain-containing foods.

**Methodological Similarities and Challenges**

In each FITS and KNHS country, dietary intake was assessed using trained interviewers and multiple-pass 24-h recalls on one or more days (Table 1). The FITS and KNHS used data from national nutrition and health surveys when available. This was the case for Australia (KNHS), China (KNHS), Mexico (FITS and KNHS), the Philippines (FITS and KNHS), Russia (FITS and KNHS), and the USA (KNHS). In China and the USA, the national surveys did not include infants or toddlers, so we collected data using similar methods (MING in China; FITS in the USA).
A common analysis approach has been applied across data from these countries. Our standard analysis evaluates population nutrient intakes by looking at means and distributions of intakes, and compares them with established dietary reference intakes, including the estimated average requirements, adequate intake, and tolerable upper intake level. In addition to nutrients, we evaluate meal patterns, including the percent consuming different meals and snacks, the percent skipping different meals and snacks, and timing of consumption. Food groups are applied to all foods and beverages reported, and these are then used to look at eating patterns, including the complementary feeding transition, and to understand the top sources of energy and nutrients in the diet.

Although many countries with comprehensive national nutrition surveys use dietary recalls for individual-level intake estimations, other aspects of the survey methodology differ considerably. One of the most apparent is differences in the dietary data collection itself. Two 24-h recalls on nonconsecutive days were used in Australia, the Philippines, and the USA. In China (CHNS), 3 consecutive 24-h recalls were collected. With multiple days of intake, it was possible to estimate usual nutrient intakes, and we have done this in our research. Without multiple days of intake and the application of a usual nutrient intake algorithm, one could overestimate the proportion of the population at the tails of the intake distribution. In the case of China MING, we, therefore, presented

**Table 1.** FITS and KNHS study countries, sources of data, participant characteristics, and dietary assessment method used

<table>
<thead>
<tr>
<th>Study name</th>
<th>Age</th>
<th>Participants, n</th>
<th>Dietary assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2011–2012 National Nutrition and Physical Activity Survey (NNPAS)</td>
<td>2 years and older</td>
<td>2,213 (4–13 years)</td>
</tr>
<tr>
<td>China FITS</td>
<td>2011–2012 Maternal Infant Nutrition Growth (MING)</td>
<td>Birth to 35 months</td>
<td>1,409 (0–35 months)</td>
</tr>
<tr>
<td>China KNHS</td>
<td>2011 China Health and Nutrition Survey (CHNS)</td>
<td>2 years and older</td>
<td>1,460 (4–13 years)</td>
</tr>
<tr>
<td>Mexico</td>
<td>2012 Mexican National Health and Nutrition Survey (ENSANUT)</td>
<td>All ages</td>
<td>2,057 (0–47 months) 3,985 (4–13 years)</td>
</tr>
<tr>
<td>Philippines</td>
<td>8th National Nutrition Survey 2013–2014</td>
<td>All ages</td>
<td>1,837 (0–35 months) 8,992 (3–12 years)</td>
</tr>
<tr>
<td>Russia</td>
<td>2013 Russian National Nutrition Survey</td>
<td>All ages</td>
<td>4,612 (0–47 months) 22,771 (4–13 years)</td>
</tr>
<tr>
<td>US FITS</td>
<td>2016 Feeding Infants and Toddlers Study (FITS)</td>
<td>Birth to 47 months</td>
<td>3,235 (0–47 months)</td>
</tr>
<tr>
<td>US KNHS</td>
<td>2009–2012 National Health and Nutrition Examination Survey (NHANES)</td>
<td>2 years and older</td>
<td>3,647 (4–13 years)</td>
</tr>
</tbody>
</table>
only population means and medians for nutrient intakes [25]. The national survey in Russia is very different from the other countries we have studied because they collected 2 days of dietary intake, but 1 day is in the spring and the other in autumn [22]. We have treated these as independent days; otherwise, we would not have been able to properly classify many of the younger children by age [21].

As much as possible, the FITS and KNHS have standardized reporting of age categories and food groupings so comparisons could be made. Typical age categories for FITS and KNHS reporting are 0–5.9, 6–11.9, 12–23.9, and 24–47.9 months, and 4–8 and 9–13 years of age. In some countries, we also study adolescents, depending on the research questions. These age classifications allow us to see details of the transition from an all-milk diet in infancy to foods of the family table, and to a more autonomous food choice in older children.

Aligning food groups is more challenging as the specificity needed for some food groups differs depending on the country. For example, cow’s milk is available in the USA as skimmed, 1% fat, 2% fat, and full-fat milk, and it is also available unflavored and flavored. In contrast, reduced fat milk is virtually nonexistent in China, so this level of detail in the food grouping scheme is not needed there. However, since we were interested in comparing eating patterns across countries, it was necessary to align on food grouping schemes. For example, we recoded all of the foods reported in China’s CHNS to the US Department of Agriculture (USDA) food grouping system used for NHANES [12]. For the research on cross-country snacking patterns, higher levels of the USDA food grouping system were aligned to compare food groups consumed during snacks in Australia, China, Mexico, and the USA [30].

We found differences in the lists of nutrients available in food composition tables from different countries. For example, Australia and the USA have very comprehensive food composition tables, whereas the Mexican food composition table was built using a combination of Mexican and other central-American databases (67% of foods), and the food composition tables from the USDA Nutrient Database for Dietary Studies and the USDA National Nutrient Database for Standard Reference, Release 26 (33% of foods) [20]. We imputed missing values to complete data sets for nutrients of interest (e.g., added sugars for Mexico [20] and China [30]). The Philippines are currently in the process of imputing nutrient values, including fiber, sodium, and total sugar, to complete their food composition tables.

Infant feeding practices, eating behaviors, sedentary and physical activities, and sleep are important behavioral and lifestyle attributes that may impact dietary intake and energy expenditure. The extent to which these topics can be explored in FITS and KNHS depends on the data collected in each survey. Child
physical activity, time spent in sedentary activities including screen time, and amount and quality of sleep are being evaluated in US FITS 2016 and will be measured in upcoming studies.

**Summary and Recommendations**

The FITS and KNHS form a global research initiative to study dietary intakes and related eating behaviors in infants, toddlers, and children. We have evaluated national survey data where they exist, and when not available, we have conducted our own studies to fill the gap in knowledge. Countries currently involved in the project include Australia, China, Mexico, the Philippines, Russia, and the USA. The FITS and KNHS are ongoing and will be expanded to include other countries in the future. Although all of these countries collected dietary intake data using one or more 24-h recalls, we found important methodological differences among the surveys. Food composition tables also varied by country, limiting accurate intake estimates to a short list of nutrients in some places. Different countries used different age classifications and different food grouping schemes, making comparisons across countries more difficult. Not all surveys recorded details about the meals or times when foods were consumed.

To address these issues, we have implemented a common analysis approach, supported work to impute nutrient values to complete food composition databases, and harmonized food grouping systems so comparisons could be made across countries. We further recommend that national surveys include all ages, including infants and young children, to be sure we have data from these vulnerable age groups. The quality of 24-h recall data is very important, with better results achieved through the use of the automated multiple-pass methodology, first developed by the USDA and now in use in Australia, Mexico, and our own US FITS. Multiple days of dietary recalls or records are needed to properly apply the statistical algorithms to estimate usual nutrient intakes of a population. This approach is recommended if we want to more accurately estimate the distributions of intakes in our study samples. Dietary intake data are self-reported and not without limitations, but quality can be enhanced with rigorous methodology, making it a valuable resource for dietary guidance and for informing public health policy.

**Disclosure Statement**

Alison L. Eldridge is an employee of Nestec S.A. (Nestlé Research, Vers-chez-les-Blanc) in Lausanne, Switzerland. Nestlé Research has sponsored this research.
References


Abstract
The Kids Nutrition and Health Study (KNHS) in China is part of a global research project focusing on the assessment of children’s dietary intakes and eating behaviors. By analyzing data from the 2011 China Health and Nutrition Survey (CHNS), we found that most Chinese children did not consume enough nutrients, such as fiber, calcium, and vitamin D, whereas the intakes of saturated fat and sodium were excessive in 57 and 85% of children, respectively. Children from urban areas and from higher-income households were more likely to have higher micronutrient intakes and consume more animal source foods, especially dairy products, than those from rural areas and from lower-income households. The prevalence of overweight and obesity in children was higher in urban areas and higher-income families than in rural settings and those from lower-income households. We also reported that almost all children had 3 main meals (breakfast, lunch, and dinner), and 71% of them consumed snacks that contributed 10% of daily energy. Results suggested that a comprehensive approach that includes nutrition education, nutrition intervention programs targeting vulnerable populations, and promotion of physical activity is needed to improve the nutrition and health status in Chinese children.

Introduction
The Kids Nutrition and Health Study (KNHS) is a global research project focusing on the assessment of children’s dietary intakes and eating behaviors, including nutrient intakes, food patterns, and physical activities (PA). China is one of
the countries involved in the study. KNHS China is a collaboration between the China National Institute of Nutrition and Health (NINH; Beijing, China), University of North Carolina (UNC; Chapel Hill, NC, USA), and the Nestlé Research (NR; Lausanne, Switzerland). Data used in this study were from the 2011 China Health and Nutrition Survey (CHNS). Multiple research articles have been published to communicate the results. The objective of this review is to summarize the key findings of the project and to provide insight for evidence-based decision making to improve the quality of children’s diets and nutrition status in China. Some unpublished data are also included to make the overall China case complete.

**Subjects and Dietary Intake: Data Collection**

The CHNS is an ongoing longitudinal survey that has been conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011 by China NINH and UNC [1]. Data analyzed in the KNHS China project were from the 2011 survey. In the 2011 CHNS, a multistage randomized cluster sampling method was used to recruit participants from 9 provinces and 3 mega cities (Beijing, Shanghai, and Chongqing) representing different geographies and economic development stages, with communities from both urban and rural areas. The KNHS China focused on children 4–13 years old. In total, dietary intake data were analyzed from 1,481 children in the age range. In some publications, the age range was extended from 4–13 to 4–17 years (1,905 subjects) to provide information on a broader age spectrum. The final protocol of the CHNS was approved by the Ethical Review Committee of the China Center for Disease Control and Prevention (No. 201524).

Individual dietary data were collected using 24-h recall methods on 3 consecutive days (2 weekdays and 1 weekend day), including all household members older than 2 years. For children younger than 12 years, the mother or a caregiver who handled food preparation and feeding in the household was interviewed to recall the children’s food consumption. The interviews were conducted by trained field interviewers with the assistance of food models and pictures. Types of foods and beverages, amounts consumed, and types of meals and places of consumption of all food and beverage items consumed in the past 24 h were recorded. Household edible oil, sugar, and salt consumption were determined on a daily basis by calculating the changes in home food inventory by weighing [1]. Food recalls were coded and analyzed to calculate nutrient intakes using the Chinese Food Composition Tables published in 2009 [2]. In order to estimate the intakes of some important nutrients that are currently missing from the Chinese
Food Composition Table, such as vitamin D and added sugar, the Chinese food codes were linked to US Department of Agriculture (USDA) food codes by a group of experts. The missing nutrient intakes were then imputed using values from the USDA Food and Nutrient Database for Dietary Studies (FNDDS) 2013–2014 [3, 4]. Detailed analysis methods are described in each section below.

**Nutrient Intakes in Chinese Children**

Dietary intake data were analyzed to assess the nutrient intakes in Chinese children 4–13 years old. The 3-day average intake of each nutrient was compared to Chinese dietary intake recommendations [5]. The estimated average requirement cutoff point method was applied to estimate the proportion of individuals in the group who were at risk of having inadequate micronutrient intakes [6]. In the absence of estimated average requirements, the intake levels were compared to adequate intake. For total and saturated fat, sodium, and added sugar, the percentages of children reported having excessive intakes were also estimated by comparing the average intakes to the upper boundary of the acceptable macronutrient distribution range or tolerable upper intake level. We found that >85% of children did not meet the dietary intake recommendations for dietary fiber, calcium, and vitamin D. Over 50% of children had intakes below the recommendations for thiamin, riboflavin, vitamin C, potassium, and selenium. One third of children 4–13 years old fell below zinc intake recommendations. On the other hand, around 60% of children had excessive total and saturated fat intakes, and almost 85% of children consumed too much sodium (Fig. 1).

Usual daily intake is defined as the long-term average daily intake of a nutrient by an individual. The NINH research team calculated the usual daily intakes of some key micronutrients (calcium, sodium, potassium, iron, zinc, selenium, vitamin A, thiamine, riboflavin, and vitamin C) using the mixed-effect model and quantile estimation procedure developed at the National Cancer Institute [7]. The usual intake results confirmed that a significant proportion of children in all age groups had micronutrient intakes below the recommendations, especially for calcium, selenium, riboflavin, and vitamin C [8]. The team also found that the prevalence of inadequate micronutrient intakes was different between children living in urban and rural areas. Children from urban areas had significantly higher intakes of calcium, vitamin D, and zinc than those from rural areas. Children from rural areas and girls were more likely to have low iron intakes compared to urban children and boys, respectively [9].

Thus, the situation of nutrient intakes is still challenging among Chinese children. Greater dietary diversity has been associated with micronutrient status in
many studies [10, 11]. To improve micronutrient and fiber intakes, especially in rural areas and girls (for iron), promotion of food diversity and education on healthy food choices combined with targeted nutrition intervention programs could be effective approaches to reduce health risks in Chinese children.

**Energy Intake and Its Food Sources**

In China, lifestyle and dietary patterns have changed rapidly as a result of increased consumption of a high fat diet, energy-dense foods, and foods of animal origin. As shown in Figure 1, more than half of children had excessive total and saturated fat intakes. We reported the extent to which average daily energy intake (EI) increased with age (from 1,299 kcal/day in 4- to 6-year-olds to 1,529 kcal in 7- to 10-year-olds and 1,746 kcal in 11- to 13-year-olds). The average amount of EI was higher in boys than in girls [12]. As shown in Figure 2, among children 4–13 years old, carbohydrates, proteins, and total fat contributed 53, 14, and 33% of the total daily EI, respectively, and the energy from total fat was higher than the Chinese dietary intake recommendation (20–30%). Moreover, saturated fat provided around 9% EI, which was also higher than the recom-
mended <8% EI limit [5]. Grains, protein foods, fats, and oils were the top energy-contributing food groups which provided 45, 23, and 11% of daily EI, respectively (Fig. 2).

We further investigated the disparities in EI and its food sources in different gender and social economic groups among Chinese children. Meat, poultry, eggs, fish and seafood, milk, and other dairy products were classified as animal source foods. The proportions of energy from animal source foods was 20%; no difference was observed between boys and girls [12]. The communities were categorized into 3 types using an administrative classification based on common socioeconomic features (such as population density, community infrastructure, accessibility to public transport, hospitals, and supermarkets): highly urban (city centers in mega cities), moderately urban (suburban areas of the mega cities and smaller cities), and rural areas. Family income was calculated according to standardized questionnaires. Individuals were divided into tertiles based on their household income per capita. Although the total EI showed no significant disparity, the proportion of energy that came from animal source foods increased with increasing urbanization levels and increasing household income levels. Among the animal food sources, the largest difference was found in the percent consuming of milk and dairy products; it was much higher in highly urban areas (74.4%) than in rural areas (14.8%) [12]. Therefore, given the high prevalence of inadequate calcium intake, leveraging local dietary intake recommendations to promote milk and dairy product consumption in rural areas, to provide nutrients such as calcium, is needed.

**Fig. 2.** Percent of energy contribution from each food group in Chinese children 4–13 years old.
Double Burden of Malnutrition

The double burden of malnutrition refers to the coexistence of undernutrition and overweight and obesity, and it is an important public health issue in China [13]. Piernas et al. [9] studied the body weight status of Chinese children by analyzing data from children 2–12 years old from the 2011 CHNS where the International Obesity Task classification of underweight, normal weight, overweight, and obesity was applied [9, 14]. Results demonstrated the existence of a double burden of malnutrition in Chinese children. The prevalence of underweight was 13–30%, while the prevalence of overweight and obesity were 7–19 and 5–17%, respectively. Children living in urban settings or from higher-income households were more likely to be overweight or obese, while children living in rural settings and those from lower-income households were more likely to be underweight (Table 1) [9]. This aspect needs to be considered in developing nutrition policies.

Meal Consumption and Food Patterns at Breakfast and Snacking

Meal patterns and food consumption are influenced by dietary culture, socioeconomic status, as well as child age. As shown in Table 2, we found that almost all children reported consuming 3 main meals daily: breakfast, lunch, and dinner. Dinner provided the most energy of total daily EI (34%), followed by lunch (31%), breakfast (25%), and snacking (10%). The snacking eating occasion was defined based on self-reporting of any eating occasion outside of the main meals of the day. The prevalence of snacking was 71% in children, which was increased compared to 14% in 1991 and 54% in 2009 [15].

We focused additional research on 2 eating occasions, breakfast and snacking. Su et al. [16] studied breakfast patterns in 4- to 17-year-olds and found that

<table>
<thead>
<tr>
<th>Area</th>
<th>2–6 years old</th>
<th>7–12 years old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>underweight</td>
<td>overweight</td>
</tr>
<tr>
<td>Urban</td>
<td>14.3</td>
<td>11.2</td>
</tr>
<tr>
<td>Rural</td>
<td>21.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower income</td>
<td>18.8</td>
<td>13.5</td>
</tr>
<tr>
<td>Middle income</td>
<td>21.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Higher income</td>
<td>17.3</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Table 1. Prevalence (%) of underweight, overweight, or obese children by age group and poverty level among Chinese children 2–12 years old [9]
most children (73%) had a home-made breakfast and 83% of them ate at home. Grain foods were the most popular food choice (84%), followed by meat and eggs (32%), fruits and vegetables (24%), and dairy products (including milk) and bean products (24%). Three breakfast patterns were identified by principal component analysis: (1) cereals, vegetables, and fruits (mostly plant origin), (2) dairy products, meat, and eggs (mostly animal origin), and (3) convenience foods (mostly snack foods). The level of community urbanization and household income had an influence on breakfast food choice. Children living in highly urbanized communities and those from high-income families were more likely to have dairy, meat, and eggs at breakfast, whereas children living in rural areas and from low-income families were more likely to have cereal, vegetables, and fruits at breakfast. The results suggested that targeted programs are needed to promote a healthy breakfast. On one hand, consumption of fruits and vegetables should be promoted among children living in urban areas and from high-income families; on the other hand, nutrition intervention programs may be needed to help children living in rural areas and from low-income families to include dairy products enriched with calcium and vitamin D in their breakfast.

Snacking is an important eating occasion in children. In China, 71% of 4- to 13-years-old children had snacking occasions, and the most frequently reported snacking frequency was once per day. Snacking contributed 10% daily EI (Table 2), and it provided disproportionately more dietary fiber, calcium, vitamin C, and vitamin E [17]. Fruits, milk, crackers, yogurt, cakes, and pies were the most frequently reported foods at snacking as well as beverages, which is confirmed by Ouyang et al. [18]. Compared to the 4- to 8-year-old group, the consumption of milk was lower, but consumption of meat and savory snacks was higher among 9- to 13-year-old children [17]. The nutrition quality of snacks is of concern. As part of the total diet, the snacking occasion can contribute to providing a balanced diet. Snacking patterns containing fruits, vegetables, beans, and dairy products should be encouraged. Reducing savory snack consumption and promoting fruit and vegetable consumption are needed across countries, especially among older children.

Table 2. Percent consuming one of the meals or snacking and energy contribution at each eating occasion in Chinese children 4–13 years old

<table>
<thead>
<tr>
<th></th>
<th>Consumption, %</th>
<th>Daily energy intake, %/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>98</td>
<td>25</td>
</tr>
<tr>
<td>Lunch</td>
<td>99</td>
<td>31</td>
</tr>
<tr>
<td>Dinner</td>
<td>100</td>
<td>34</td>
</tr>
<tr>
<td>Snacking</td>
<td>71</td>
<td>10</td>
</tr>
</tbody>
</table>
Physical Activity

Childhood and adolescence are critical periods to establish healthy behaviors. PA habits formed during this period will affect not only the bones, muscles, and mental development, but also the risk of obesity, hypertension, diabetes, and other related chronic diseases. There are very few reports on PA of Chinese children. In this study, PA was classified as PA at school, outside school, domestic work, travel, and sedentary behavior, and was assessed based on metabolic equivalent hours/week [19]. We found that, among the 5 types of activities listed above, the proportion of children and adolescents with sedentary behaviors was highest (97.9%), and PA outside school was lowest (33.6%). The top 2 median levels of activity were PA outside school and sedentary behaviors (39.9 and 36.1 metabolic equivalent hours/week, respectively), which suggested that the time on sedentary behaviors was long. Children living in urban areas or from higher-income families reported more in- and outside-school PA. But in total, only 49% of Chinese children reached the WHO minimum recommendation on PA. PA needs to be promoted outside of school; meanwhile, existing physical education programs need to be strengthened [16].

Limitation

KNHS China is a cross-sectional study aiming to provide a snap shot of the current nutrition situation in Chinese children; no causal relationships can be inferred. Dietary data were based on self-report. As with other dietary survey data, the potential for underestimation of intakes is a concern. For imputing the missing nutrient values in Chinese food composition tables, such as vitamin D and added sugar, the Chinese food codes were linked to USDA food codes. Although great care was given, due to differences in food grouping methods and local food culture, the risk of misclassification exists.

Conclusion

The nutrition status of Chinese children has improved along with the rapid economic development of the last decades. However, in the KNHS China project, we found that compared with dietary intake recommendations, Chinese children did not consume enough micronutrients, especially for calcium and vitamin D. Iron intake was an issue especially in girls and children living in rural areas. The intake of dietary fibers was low in 97% of children, whereas the in-
Consumption of saturated fat and sodium were excessive in 57 and 85% of children, respectively. Geographic location and socioeconomic status have an impact on food quality and nutrient intakes. Children from urban areas and from higher-income households were more likely to have higher micronutrient intakes and consume more animal source foods, especially dairy products, than those from rural areas and from lower income households. We found evidence of the double burden of malnutrition; the prevalence of overweight or obesity in children was higher in urban areas and higher-income families than in rural settings and those from lower-income households, respectively. The disparity found in this study suggests that specific strategies are needed to improve diet quality and address nutrient shortfalls in different community types.

We also reported that almost all children had 3 main meals (breakfast, lunch, and dinner), and over 70% of them reported having snacks that contributed 10% of total daily energy. Children 9–13 years old consumed more salty snacks and less fruits and dairy products than 4- to 8-year-old children did, which deserves attention. Promoting healthy food choices in snacking could contribute to the improvement in nutrition quality of the total diet.

In conclusion, the results from KNHS China suggest that a comprehensive approach that includes nutrition education, nutrition intervention programs targeting vulnerable populations, and promotion of PA inside and outside of school is needed to improve the nutrition and health status in Chinese children.

**Disclosure Statement**

Dantong Wang is an employee of Nestec, S.A. (Nestlé Research, Vers-chez-les-Blanc) in Lausanne, Switzerland. Nestlé Research has sponsored this research.

**References**

Feeding Patterns of Infants and Toddlers: The Mexico Case Study

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Abstract

Understanding the feeding patterns of Mexican infants and toddlers has required large efforts due to the lack of recent reliable data. The double burden of obesity and micronutrient undernutrition is a public health problem in Mexico. This chapter reviews a series of papers reporting the FITS (Feeding Infants and Toddlers Study) Mexico effort. Secondary data analyses from a nationally representative sample of over 5,000 children from the Mexican National Nutrition and Health Study 2012 ENSANUT (Encuesta Nacional de Salud y Nutrición) were used to review the feeding and drinking patterns of Mexican infants and young children. Feeding patterns in Mexican children are established early in life. Low rates of exclusive breastfeeding were found in infants under 6 months of age. Only half of 6- to 47.9-month-old children consumed fruits, and 80% did not consume any vegetables (including potatoes) on the day of the survey. From the age of 12 months, more than 80% consumed sweets or sweetened beverages on any given day. For nutrients, 61% of infants 6–11.9 months old did not meet the estimated average requirement for iron, indicating a nutritional risk. High intakes of food groups with poor micronutrient and high energy levels might explain the nutritional condition for the Mexican population. Mexican experts have used this information to make recommendations and establish complementary feeding guidelines for healthy infants. Public policy and practice must now change accordingly.

Introduction

Understanding the feeding patterns of Mexican infants and toddlers has required large efforts due to the lack of recent reliable data. Mexico is well known as one of the world’s largest countries in terms of overweight and obesity. In
2017, more than 70% of the Mexican adult population 15–74 years of age is either obese or overweight [1]. Childhood overweight and obesity is also very prevalent in Mexico. Overweight and obesity affects 9.7% of preschool children from birth to 4 years of age. It rapidly increases to 34.4% of children from 5 to 11 years. Adolescents also have an overall prevalence of 34.9% for overweight and obesity [2]. Alongside with obesity, anemia is a big health concern in Mexico. According to the 2016 Mexican National Nutrition and Health Study ENSANUT (Encuesta Nacional de Salud y Nutrición), 26.9% of children 1–4 years of age are anemic, and the rate was 38.3% among those 12–24 months of age [3].

The double burden of obesity and micronutrient undernutrition has raised the alarm, identifying the need to discover how and when inadequate consumption of nutrients is taking place in such a diverse country. The types of foods and beverages that children consume have drastically changed in recent years, though there is poor factual knowledge around this matter. Patterns of food and beverage consumption established in such early stages of development may remain unchanged into adulthood. Already, Mexican children and adolescents have an adult-like pattern of food consumption, putting them on a trajectory for overweight, obesity, and inadequate nutrient intakes.

Another issue in Mexico is that many physicians and health care professionals remain as bystanders in the practice of complementary feeding, offering little advice to parents. There is a consensus recommendation for the introduction of complementary feeding that serves as a national reference [4]. Breastfeeding is strongly recommended. The national policy is for exclusive breastfeeding for at least 6 months, and introduction of complementary foods should not start before this age.

**Feeding Infants and Toddlers Study in Mexico**

The FITS (Feeding Infants and Toddlers Study) Mexico was planned to address the lack of knowledge of the actual feeding patterns of Mexican children. Secondary data analyses from a nationally representative sample of over 5,000 children from ENSANUT 2012 were used to provide an in-depth understanding of the feeding and drinking patterns of Mexican children [5–8]. ENSANUT 2012 is a cross-sectional, population-based survey to characterize the health and nutritional status of the Mexican population [9]. The survey used a multistage, stratified, and clustered sampling system drawn to represent all states, 4 geographic regions, and socioeconomic strata in Mexico. The data were collected from 50,528 Mexican households with a response rate of 87%. The survey pro-
tocol and data collection instruments were approved by the Ethics Committee of the Mexican National Institute of Public Health. Written informed consent was obtained from each eligible person 18 years and older and from the parent or caregiver of participants under 18 years. A total of 2,057 children from birth up to 4 years of age were used in the current analyses, including infants 0–5.9 months (n = 182), infants 6–11.9 months (n = 229), toddlers 12–23.9 months (n = 538), and young children 24–47.9 months old (n = 1,108).

One dietary 24-h recall was collected for each child through a face-to-face interview by trained interviewers with the parent or caregiver; a second dietary recall for a randomly selected subsample of children (10%) was collected on a different day. Details were provided on all foods and beverages and the amounts consumed during the previous 24 h. Amounts were estimated using common household measurement aids (including spoons, cups, slices, and handfuls, etc.) and converted to grams and milliliters depending on the type of food consumed. An automated 5-step multiple-pass method was used, and data were collected on both weekdays and weekend days [10].

Breast milk amounts were estimated based on the child’s age and the total amount of other milks (infant formula and cow’s milk) reported on the recall day [11, 12]. Energy intakes, macronutrients, and food sources of nutrients were analyzed. Appropriate and inappropriate foods and beverages, as defined by Mexican and international organizations, were considered as the end point for analyses of feeding patterns.

Feeding patterns in Mexican children are established early in life (Fig. 1). Diets shift quickly from an all-milk diet to a diet high in grains, protein foods (including dried beans), and sweets, but low in fruits and vegetables. By the age of 12 months, young children in Mexico are eating a diverse diet with approximately 25% of their energy coming from sweets, sweetened beverages, and salty snacks. Foods and beverages with poor micronutrient content and high energy might explain the nutritional condition for the Mexican population through all age groups.

Low rates of exclusive breastfeeding were found in infants under the age of 6 months [5]. Breastfeeding initiation was high (96%), but exclusive breastfeeding was low: only 15% among 0- to 3.9-month-old infants and 4% among 4- to 5.9-month-old infants according to the 24-h recall (Fig. 2). Partial breastfeeding was much more common, with 62–78% of young infants receiving breast milk. During the survey, moms were directly asked about months of breastfeeding, and 66% answered that they had breastfed for at least 6 months. This is in clear contrast to exclusive breastfeeding rates for 6 months reported from the 24-h recall in the same survey. Both answers are correct, mainly due to the early use of inadequate substitutes of human milk during the first 6 months of age. Almost
**Fig. 1.** Percent of energy intake from food groups consumed by Mexican children aged 0–47 months.

**Fig. 2.** Breastfeeding rates among Mexican infants and young children.
10% of 4- to 5-month-old babies consumed whole cow’s milk, and up to 29% of 6- to 11-month-old infants did as well. All types of milk consumption decreased drastically from 93% at 6 months of age down to 54% at 24 months. This pattern seems to stay that way all through childhood. Breastfeeding in Mexican infants is inversely related to the socioeconomic status. Only 64% of higher-income moms of 0- to 5.9-month-old infants breastfeed compared to 81% of those in the lower-tertile socioeconomic status.

Complementary foods were commonly introduced between 4 and 5.9 months of age, and only a small percentage of infants younger than 4 months consumed any foods or beverages other than breast milk or infant formula [5]. From 4 to 5.9 months of age, the most commonly consumed foods were fruits (33.8%) and vegetables including potatoes (32.1%) (Table 1). Other complementary foods introduced at this age included grains (12%), mixed dishes (16%), and sweets (15%), including sweetened beverages. Few infants received iron-rich food sources, such as fortified infant cereals or meat. More than one half of 12- to 47.9-month-old children (55.3%) consumed fruits, but approximately 80% did not consume any vegetable as a distinct serving on the day of the recall. After 24 months of age, over 90% of children consumed some type of sweets or sugar-sweetened beverages on any given day [5].

Infant cereals are unpopular among the Mexican population. They are frequently perceived by moms to promote rapid weight gain in small infants. Cereals are given through infant formulas as beverages or as baby food in rare cases of low weight gain. Only 9% of 6- to 8-month-old infants consume iron-fortified

### Table 1. Percent of Mexican infants and young children consuming foods and beverages from different food groups

<table>
<thead>
<tr>
<th>Food groups</th>
<th>4–5.9 months</th>
<th>6–11.9 months</th>
<th>12–23.9 months</th>
<th>24–47.9 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>97.6</td>
<td>92.4</td>
<td>80.5</td>
<td>63.9</td>
</tr>
<tr>
<td>Fruits</td>
<td>33.8</td>
<td>51.5</td>
<td>55.3</td>
<td>45.4</td>
</tr>
<tr>
<td>Vegetables(^2)</td>
<td>32.1</td>
<td>22.0</td>
<td>15.8</td>
<td>19.4</td>
</tr>
<tr>
<td>100% fruit juice</td>
<td>15.3</td>
<td>13.4</td>
<td>18.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Grains</td>
<td>11.6</td>
<td>52.2</td>
<td>70.8</td>
<td>72.4</td>
</tr>
<tr>
<td>Mixed dishes</td>
<td>15.8</td>
<td>61.3</td>
<td>79.8</td>
<td>83.5</td>
</tr>
<tr>
<td>Meats and protein(^3)</td>
<td>1.1</td>
<td>41.0</td>
<td>66.3</td>
<td>70.8</td>
</tr>
<tr>
<td>Sweets and sweetened beverages</td>
<td>15.1</td>
<td>62.3</td>
<td>81.8</td>
<td>90.2</td>
</tr>
<tr>
<td>Salty snacks</td>
<td>5.3</td>
<td>13.1</td>
<td>15.4</td>
<td>21.9</td>
</tr>
<tr>
<td>Water</td>
<td>44.5</td>
<td>60.9</td>
<td>64.3</td>
<td>69.5</td>
</tr>
</tbody>
</table>

\(^{1}\) All types of milk, including breast milk, infant formula cow’s milk, and other milks.  
\(^{2}\) Includes potatoes.  
\(^{3}\) Includes meats, dried beans, eggs, and egg dishes.
cereals according to the ENSANUT 2012 survey. Other carbohydrates are frequently used in baby diets. Pasta soups, sweetened breads (pan de dulce), cookies, and crackers as well as adult cereals are frequently consumed but are not iron fortified or not fortified at levels to meet infant needs. Other iron-rich foods such as meats and poultry have a quite low consumption. Meat consumption in 6- to 12-month-old infants goes from 7 to 20% around the country. After their first birthday, only about 25% of toddlers eat meat on any given day. This low consumption of iron-fortified food may explain that 61% of 6- to 11-month-old infants do not reach the daily estimated adequate requirement of iron. The median consumption of iron at that age is only 3.4 mg per day [3]. As mentioned previously, iron deficiency anemia is highly prevalent amongst 12- to 23-month-old infants.

We also reported that 31 and 35% of 6- to 11.9-month-old infants consumed cow’s milk or sugar sweetened beverages, respectively [6]. According to Mexican and international guidelines [4], the only appropriate beverages for this age group would be breast milk, infant formula, and water. In children 12–23.9 months old, 63% consumed sweetened beverages. These included sweetened teas (23%) and traditional Mexican beverages (30%), such as atoles (hot beverages prepared with corn flour, milk or water, sugar, and flavorings), licuados (smoothie-type drinks made with milk, fruit, and ice), and aguas frescas (sweetened beverages prepared with fruit and water). Because of the fruit and milk content, these beverages also provide some nutrients important in the diets of children, but overconsumption would add additional energy that is not needed in an obesogenic environment [6].

Usual energy intakes of Mexican infants and toddlers (6–47.9 months) exceed estimated energy requirements in 14–32% of the population (Table 2). Iron intakes were low for 61% of infants 6–11.9 months old, who did not meet the estimated average requirement for iron, indicating a nutritional risk. About 5%
of children 12 months and older exceeded the acceptable macronutrient distribution range for fat. More than 30% of toddlers exceeded their tolerable upper intake level for sodium [7].

The extra energy has been linked to consumption of energy-dense foods low in micronutrients, including foods and beverages with added sugar and various maize-based preparations. In fact, sweetened breads and cookies, and sweetened beverages, including traditional beverages, sweetened teas, and fruit-flavored drinks, were among the top sources of energy for 12- to 23.9-month-old infants (Table 3). By the age of 24–47.9 months, the diversity of sweets expanded to include carbonated sodas and candy, along with sweetened breads and cookies, and various sweetened beverages. Overall, the top nutrient contributors in the diet were milk, soups and stews, eggs, egg dishes, and fruits. Tortillas, eggs, and egg dishes were among the top contributors of iron and zinc [8].

### Table 3. Top food sources of energy (daily energy in %) in the diets of Mexican infants and young children

<table>
<thead>
<tr>
<th>Rank</th>
<th>6–11.9 months</th>
<th>12–23.9 months</th>
<th>24–47.9 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Breast milk (26.7%)</td>
<td>Cow’s milk (13.2%)</td>
<td>Sweetened breads and cookies (11.2%)</td>
</tr>
<tr>
<td>2</td>
<td>Infant formula (16.5%)</td>
<td>Sweetened breads and cookies (8.8%)</td>
<td>Cow’s milk (10.7%)</td>
</tr>
<tr>
<td>3</td>
<td>Cow’s milk (10.2%)</td>
<td>Sweetened beverages (8.6%)</td>
<td>Sweetened beverages (8.4%)</td>
</tr>
<tr>
<td>4</td>
<td>Soups and stews (6.5%)</td>
<td>Soups and stews (7.8%)</td>
<td>Tortillas (8.3%)</td>
</tr>
<tr>
<td>5</td>
<td>Sweetened breads and cookies (5.3%)</td>
<td>Infant formulas1 (6.9%)</td>
<td>Soups and stews (5.7%)</td>
</tr>
<tr>
<td>6</td>
<td>Fruit and 100% juice (4.2%)</td>
<td>Fruit and 100% juice (5.6%)</td>
<td>Eggs and egg dishes (5.3%)</td>
</tr>
<tr>
<td>7</td>
<td>Yogurt (3.6%)</td>
<td>Tortillas (5.4%)</td>
<td>Traditional dishes2 (4.5%)</td>
</tr>
<tr>
<td>8</td>
<td>Tortillas (3.0%)</td>
<td>Eggs and egg dishes (4.3%)</td>
<td>Fruit and 100% juice (4.3%)</td>
</tr>
<tr>
<td>9</td>
<td>Eggs and egg dishes (2.6%)</td>
<td>Pasta- or rice-mixed dishes (3.4%)</td>
<td>Dried beans (4.1%)</td>
</tr>
<tr>
<td>10</td>
<td>Sweetened beverages (1.7%)</td>
<td>Breast milk (3.2%)</td>
<td>Sandwiches and tortas (4.1%)</td>
</tr>
<tr>
<td>11</td>
<td>Infant cereal (1.7%)</td>
<td>Yogurt (3.2%)</td>
<td>Pasta- or rice-mixed dishes (3.2%)</td>
</tr>
<tr>
<td>12</td>
<td>Dried beans (1.4%)</td>
<td>Dried beans (2.8%)</td>
<td>Meat-mixed dishes3 (2.1%)</td>
</tr>
<tr>
<td>13</td>
<td>Salty snacks (1.0%)</td>
<td>Meats (2.7%)</td>
<td>Breakfast cereals (2.9%)</td>
</tr>
<tr>
<td>14</td>
<td>Breakfast cereals (2.6%)</td>
<td>Meats (2.9%)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Salty snacks (2.2%)</td>
<td>Yogurt (2.9%)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Sandwiches and tortas (1.7%)</td>
<td>Salty snacks (2.8%)</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Tamales (1.2%)</td>
<td>Candy (1.4%)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Bread/rolls (1.1%)</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>White potatoes (1.0%)</td>
<td></td>
</tr>
</tbody>
</table>

| Σ | 84.4% | 83.6% | 86.9% |

Σ. Total of top sources.

1 Includes growing-up milks (fortified milk-based powders designed for children ≥1 year).

2 Includes tamales, enchiladas, tacos with meat or vegetables, and cheese.

3 Includes beef, pork, chicken, or turkey with vegetables and/or rice, pasta, or potatoes.
Findings from ENSANUT and from the FITS analysis specifically were used by a broad-country panel of experts to develop new feeding recommendations for healthy infants in Mexico [4]. The expert panel set new and more strict recommendations for child feeding. One of the recommendations had to do with the proportions of milk versus foods in the diets of infants and young children. They recommended that the diet of infants from 6 to 8 months should consist of approximately 60% breast milk and 40% solids. From 9 to 11.9 months, infants should be receiving about 53% of their diet as complementary food, and by 12 months, this increases to 62%. Whole cow’s milk should not be introduced until 12 months of age, because cow’s milk is low in iron. Iron sources of fortified infant cereal and meats should also be introduced to meet iron recommendations. Public policy must change accordingly.

**Conclusion**

Continuous study of feeding patterns in a population, especially in children, will be a powerful tool to monitor health and nutrition status of the whole country. Through the FITS research, we have found that 6-month exclusive breastfeeding is exceedingly low in Mexico. Even if 62% of 4- to 5.9-month-old infants receive some breast milk, many of the substitutes are not acceptable. We have seen early introduction of cow’s milk and various sweetened traditional and other beverages being consumed at young age. Another issue for infants is low consumption of iron-rich foods, such as fortified infant cereals and meat. Tortillas are fortified with iron in Mexico, but this does not address the low iron intakes for babies 6–11.9 months of age. Fruits were consumed by only about half of infants and young children, and vegetable consumption is even lower (around 20%). This, along with the pervasive consumption of sweets and sweetened beverages, shows that nutrient-rich foods are being displaced by higher-energy, low-nutrient-dense foods in the diets of Mexican children. Actions to address these issues have been taken in the form of the development of the Consensus on Complementary Feeding of Healthy Infants [4]. This serves as a call to action for pediatricians and other health care workers, but the recommendations still need to be widely implemented in practice.

**Disclosure Statement**

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References

The 2016 Feeding Infants and Toddlers Study (FITS): Dietary Intakes and Practices of Children in the United States from Birth to 48 Months

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Abstract

FITS (the Feeding Infants and Toddlers Study) 2016 is a national, cross-sectional survey to evaluate the diets and feeding practices of US infants and children <48 months ($n = 3,235$). Dietary intakes were assessed using 24-h recalls, including a replicate subsample ($n = 799$), to estimate usual intake distributions and compliance with dietary reference intakes using the National Cancer Institute method. Infant feeding practices and 1-day food group consumption were assessed by age and participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Initiation and duration of breastfeeding were higher in 2016 compared to previous FITS surveys. Nutrient intakes of infants were largely adequate, except for vitamins D and E and iron (18\% did not meet the iron recommendations at 6–11.9 months). WIC-participating infants were more likely to meet iron recommendations, potentially due to higher use of infant formula. More nutrient inadequacies were noted among toddlers and preschoolers, including low intakes of potassium (12+ months), fiber (12+ months), and vitamins D and E (12+ months), combined with high intakes of sodium and added sugars, especially among WIC participants, and saturated fat among those 24–36 months. These imbalances result from low intakes of vegetables and whole grains, and high intakes of processed meats, sweetened bakery foods, and sugar-sweetened beverages.

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Introduction

The United States 2020–2025 Dietary Guidelines for Americans will expand to include recommendations for infants and toddlers (from birth to 24 months, i.e., B-24) for the first time in more than 35 years [1]. Given the very specific nutritional needs of the B-24 age group to support rapid growth and development, as well as the dynamic changes that occur in food consumption patterns, understanding contemporary dietary patterns and feeding practices is essential not only to inform nutrition policy but also to best tailor clinical and practice guidelines for dietary advice for infants and children [2]. Furthermore, establishing sound dietary patterns in childhood is critical for lifelong health and eating habits [3].

FITS (the Feeding Infants and Toddlers Study) is a periodic nationally representative, cross-sectional survey to collect data on the diets and feeding practices of US infants and young children. FITS was conducted in 2002, 2008, and 2016.

The FITS protocol includes extensive data collection on the diets and feeding practices of infants and children (up to 48 months of age), including information on breastfeeding and the use of dietary supplements, and is an ideal data source to inform multiple stakeholders. This chapter summarizes the key findings from FITS 2016 on energy and nutrient intakes, breastfeeding practices, and food and beverage intakes.

Methods

Complete details of the FITS 2016 survey selection and procedures have been published in great detail previously [4]. Briefly, FITS 2016 has a weighted sampling framework to match United States census in order to make the data nationally representative of the American population from birth to 47.9 months of age. Specific care was employed to have representative participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), a federally funded program that provides free food packages, nutrition education, and health care referrals to pregnant and postpartum women, infants, and young children from low-income households [5].

A total of 3,235 children under 4 years of age was included in the 2016 survey. For most analyses, age groups were categorized as follows: younger infants (from birth to 5.9 months), older infants (6–11.9 months), toddlers (12–23.9 months), younger preschoolers (24–36.9 months), and older preschoolers (36–47.9 months); however, breastfeeding and complementary feeding data were also examined by further subdividing the infant age groups. The study protocol and instruments were approved by the Institutional Review Boards of RTI International, the University of Minnesota, and the Docking Institute of Public Affairs, Fort Hays State University.

Questionnaires were administered to determine sociodemographic and lifestyle factors and feeding practices, including breastfeeding and introduction of complementary foods. Dietary intake data, inclusive of dietary supplements, were collected from parents.
or caregivers by trained interviewers using the automated multipass method 24-h dietary recall [6] and the Nutrition Data System for Research (version 2015; University of Minnesota, Minneapolis, MN, USA). A second 24-h dietary recall was collected in a representative subset \((n = 799)\) to estimate total usual intakes and compliance with the dietary reference intake (DRI) guidelines [7] using the National Cancer Institute method [8, 9]. Dietary supplement use was assessed as part of the 24-h dietary recall. Breast milk that was directly fed to a child was not quantified during the dietary recall. Direct breastfeeding volumes are difficult to obtain; volumes were assigned according to existing coding rules established for FITS 2008 [10], informed from the research of Dewey et al. [11, 12] and Kent [13] and supported by a systematic review [14].

All statistical analyses were performed using SAS (version 9; SAS Institute Inc.; Cary, NC, USA) and SAS-callable SUDAAN® (version 11; RTI International; Research Triangle Park, NC, USA) software. Nutrient intakes were compared with DRI data that are available in these age groups, including the estimated average requirement (EAR), adequate intake (AI) in the absence of an established recommended dietary allowance, and the tolerable upper intake level (UL) [7]. The risk of dietary inadequacy is examined by estimating the proportion <EAR of a group, whereas the potential risk for excess is examined by estimating the proportion >UL of a group. In the absence of an EAR, the proportion >AI is an estimate of the adequacy of a group, as no scientific inferences can be drawn from intakes <AI [7, 15]. The DRI includes an acceptable macronutrient distribution range children 12 months and older, and saturated fat is recommended to be <10% of total energy starting at 24 months. Fiber has an established AI for children 12 months and older.

**Results**

**Dietary Supplements**
The use of dietary supplements, almost exclusively vitamin and mineral products, was higher in FITS 2016 than previous surveys, particularly among infants [16, 17]. In 2016, 23% of younger infants and 15% of older infants were reported to use supplements, primarily vitamin D drops. Use of dietary supplements was reported among 21% of toddlers, 35% of younger preschoolers, and 45% of older preschoolers. Once children can chew and swallow, products tended to shift from drops to chewable and gummy multivitamins that contain multiple micronutrients when compared to infant drops [17]. Nutrient intakes from dietary supplements were included in the usual intake estimates presented below.

**Infant Feeding Practices**
Initiation and duration of breastfeeding were higher in 2016 compared to previous FITS surveys, but exclusive breastfeeding rates remained below professional and public health objectives [18]. The proportion of infants fed formula was higher than that of those exclusively fed breast milk in both infant age groups. Exclusive breastfeeding varied by race/ethnicity with significantly lower rates among
non-Hispanic black infants (20 and 10%) when compared with non-Hispanic white (40 and 17%) and Hispanic (36 and 14%) infants from birth to 3.9 months and from 4 to 5.9 months, respectively [18]. By the age of 12 months, most children (79%) were not consuming breast milk or formula [17]. Transition from milk-based diets to inclusion of complementary foods is recommended at 6 months of age [19]; a higher proportion of formula-fed (56%) than breastfed infants (25%) were consuming complementary foods at 4–5.9 months of age [18]. At 6 months, most children were consuming complementary foods, and the type and amount of these foods and beverages influence energy and nutrient intakes.

**Dietary Intakes**

The distribution of energy from macronutrients showed distinct differences among infants with a higher energy contribution from dietary fats when compared with toddlers and preschoolers, who were remarkably similar (Fig. 1). Energy intakes and diversity of foods and beverages consumed increased with age, as expected, to meet metabolic demands. Beginning at 12 months, few infants exceeded the AI for fiber: 3% among those 12–23.9 months old; 9% among those 24–36.9 months old; and 8% among those 36–47.9 months old. After 24 months, many exceeded the saturated fat recommendations of <10% total energy, including 68% of younger and 63% of older preschoolers.

**Nutrients**

Nutrients of potential concern based on deviation from DRI identified from FITS 2016 are summarized in Table 1. Nutrient intakes of the youngest infants (<6 months) were largely adequate, with the mean intakes exceeding the AI for all
micronutrients (i.e., in more than 80% of infants), except for vitamin D (17%) and vitamin E (35%). In older infants, iron levels were of particular concern with 18% of those 6–11.9 months old below the EAR, but a low prevalence of those exceeding the AI recommendations were also noted for vitamin D (24%) and vitamin E (51%). More than three-quarters of children 12–48 months old have at-risk intakes for vitamin D, and one-third to one-half had similarly low vitamin E intakes. Concerns exist about excessive intakes of retinol (i.e., preformed vitamin A) and zinc in all groups with an established UL (i.e., 6 months and older), with estimates ranging from 32 to 49% for retinol and from 41 to 69% for zinc (Table 1).

Sodium intakes should track proportionately with energy intakes to remain within the DRI recommendations. Sodium intakes started to exceed calories at around 12 months (~40% exceeding the UL), and at 24 months more than 70% of preschoolers were exceeding the UL for sodium (Fig. 2). DRI recommendations also suggest that potassium intakes should be near or higher than those of sodium [20], and yet the reverse was apparent among American children starting around 12 months. Beginning at 12 months, few infants exceeded the AI for potassium: 3% among those 12–23.9 months; 6% among those 24–36.9 months; and 4% among those 36–47.9 months.

Food and Beverages
The nutrient imbalances noted in FITS 2016 were likely the result from low or high intakes of certain foods and food groups, or from a lack of diversity in the dietary pattern and/or within certain food groups. First, while most toddlers and

---

**Table 1.** Nutrients of potential concern by age group (data from the FITS 2016; n = 3,235)\(^1\) (adapted from Bailey et al. [17])

<table>
<thead>
<tr>
<th>Low intakes: &lt;EAR/&gt;AI, %</th>
<th>High intakes: &gt;UL/&gt;AMDR, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>iron</td>
<td>vitamin D</td>
</tr>
<tr>
<td>0–5.9 months</td>
<td>100(^2)</td>
</tr>
<tr>
<td>(n = 600)</td>
<td></td>
</tr>
<tr>
<td>6–11.9 months</td>
<td>18(^3)</td>
</tr>
<tr>
<td>(n = 902)</td>
<td></td>
</tr>
<tr>
<td>12–23.9 months</td>
<td>7(^3)</td>
</tr>
<tr>
<td>(n = 1,133)</td>
<td></td>
</tr>
<tr>
<td>24–35.9 months</td>
<td>4(^3)</td>
</tr>
<tr>
<td>(n = 305)</td>
<td></td>
</tr>
<tr>
<td>36–47.9 months</td>
<td>3(^3)</td>
</tr>
<tr>
<td>(n = 295)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Nutrients are of potential concern because a low population exceeds the adequate intakes (AI) or a high population prevalence is below the estimated average requirements (EAR), or because a high population prevalence exceeds the tolerable upper intake level (UL) or acceptable macronutrient distribution range (AMDR) within a certain age group with established values; \(^2\) >AI; \(^3\) <EAR; \(^4\) >UL; \(^5\) >AMDR.
preschoolers consume adequate grains, many (40%) do not consume any whole-grain foods [21]. Second, close to 20% of toddlers and preschoolers did not consume cow’s milk, an excellent source of vitamin D, potassium, and calcium. Fruit, while consistently consumed across age groups starting at 6 months, is primarily in the form of bananas, apples, and 100% fruit juice; about 20 and 30% of children 12 months and older do not consume any fruit or vegetables on a given day, respectively [18, 21]. The vegetables that are consumed are primarily white fried potatoes [21]. Low potassium intakes could be enhanced by consumption of a variety of vegetables and fruits as well as dairy products (Table 2) [22]. Low iron intakes in older infants were associated with low intakes of fortified infant cereal and meats. Iron-rich infant cereal was consumed by only about one-half of 4- to 12-month-old infants, i.e., less than in previous FITS cycles [18]. Consumption of baby food meat has remained very low (<5%) across time [18].

Mixed dishes are the primary contributor to both sodium and potassium in the diets of American children (Table 3). This is because these foods are the most ubiquitously consumed. Thus, careful attention to reducing sodium sources here may be advantageous. Similarly, high sodium and saturated fat intakes likely result from intakes of processed meats and sweetened bakery foods, respectively.

**Fig. 2.** Mean usual energy, sodium, and potassium intakes by age group (data from the FITS 2016 in the USA: n = 3,235).
Added sugar in the diets of American children were primarily coming from sweet bakery foods (i.e., cookies and brownies – also contributing to high saturated fats), sugar-sweetened beverages (excluding 100% fruit juice), and candy and confectionary items. Intakes of added sugars vary by race/ethnicity, particularly for sugary beverages, which were more likely to be consumed among non-Hispanic black children than other race/ethnicity groups [18].

WIC Summary
WIC provides different food packages to infants and children that are tailored to meet age-specific nutrient needs. Eligibility for WIC is primarily based on income, but many that are income eligible do not participate. Nevertheless,
the program reaches about half of infants (51%) and about 30% of children 1–5 years old in the USA [5]. Because program participation is voluntary and only provides a proportion of the total foods and beverages consumed, we can only make associations between participation and dietary exposures.

WIC infants were less likely to be breastfed than higher-income children [23]; however, mean micronutrient intakes were higher for WIC infants possibly due to the fortification and enrichment of infant formula [24]. Our estimates are

Table 3. Food sources of sodium by age group and contribution (%) from food group and specific foods (data from the FITS 2016 in the USA; n = 3,235)\(^1\)

<table>
<thead>
<tr>
<th>Food group</th>
<th>0–5.9 months</th>
<th>6–11.9 months</th>
<th>12–23.9 months</th>
<th>24–35.9 months</th>
<th>36–47.9 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk and milk products, including cheese/yogurt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>89%</td>
<td>39%</td>
<td>19%</td>
<td>15%</td>
<td>14%</td>
</tr>
<tr>
<td>Infant formula (52%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human milk (34%)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Infant formula (23%)</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Human milk (8%)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Cow’s milk (11%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese (5%)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cow’s milk (7%)</td>
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</tr>
<tr>
<td>Cheese (6%)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cow’s milk (6%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese (8%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>1%</td>
<td>7%</td>
<td>6%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Meat and other protein sources, excluding cheese/yogurt</td>
<td>4%</td>
<td>16%</td>
<td>22%</td>
<td>21%</td>
<td>22%</td>
</tr>
<tr>
<td>Meat (12%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotdogs, cold cuts, sausages, and bacon (6%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Meat (17%)</td>
<td></td>
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<tr>
<td>Chicken or turkey (7%)</td>
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<tr>
<td>Hotdogs, cold cuts, sausages, and bacon (7%)</td>
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<tr>
<td>Meat (17%)</td>
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<td>Chicken or turkey (5%)</td>
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<tr>
<td>Hotdogs, cold cuts, sausages, and bacon (8%)</td>
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<td>Meat (18%)</td>
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<td>Chicken or turkey (7%)</td>
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<tr>
<td>Hotdogs, cold cuts, sausages, and bacon (8%)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grains and grain products</td>
<td>1%</td>
<td>13%</td>
<td>20%</td>
<td>17%</td>
<td>22%</td>
</tr>
<tr>
<td>Bread, rolls, biscuits, bagels, and tortilla (5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread, rolls, biscuits, bagels, and tortilla (5%)</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Bread, rolls, biscuits, bagels, and tortilla (5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed dishes</td>
<td>2%</td>
<td>16%</td>
<td>23%</td>
<td>25%</td>
<td>23%</td>
</tr>
<tr>
<td>Spaghetti, ravioli, and lasagna (6%)</td>
<td></td>
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<tr>
<td>Spaghetti, ravioli, and lasagna (6%)</td>
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<tr>
<td>Spaghetti, ravioli, and lasagna (6%)</td>
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</tr>
<tr>
<td>Pizza (5%)</td>
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<tr>
<td>Pizza (5%)</td>
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<td></td>
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<tr>
<td>Pizza (5%)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Salad dressings and oils</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Condiments and sauces</td>
<td>0%</td>
<td>1%</td>
<td>2%</td>
<td>4%</td>
<td>3%</td>
</tr>
</tbody>
</table>

\(^1\) Specific foods within the food groups are denoted in italic.
based on database values of nutrients provided from breast milk and formula, but they do not account for bioavailability. While WIC infants and children appear to have a lower risk of iron inadequacy based exclusively on dietary exposures, we know that iron in breast milk, while lower in amount than in infant formula, is more bioavailable [25]. Thus, more rigorous biochemical assessment of iron status by feeding type is warranted.

WIC provides vitamin-D-fortified milk to children 12 months and older, which may have contributed to a lower risk of inadequate vitamin D intake (% <EAR) than income-eligible nonparticipants. WIC limits milk fat to 2% or less for older children (≥24 months), which may have led to a lower percentage of older children (12–48 months) who participated in WIC exceeding the saturated fat recommendation (<10% of energy intake) compared to both income-eligible and higher-income nonparticipants [24]. High intakes of sodium and added sugars were of concern in all children >12 months, but especially among WIC participants [24].

Conclusion

The dietary intakes of US infants (<12 months) are nutritionally adequate, with exceptions noted for vitamins D and E, and iron (6–11.9 months); but, many DRI recommendations are limited to the AI in this age group. However, starting at 12 months when children transition from breast milk or formula to family foods and foods outside the home, we observed higher-than-recommended intakes of sodium (12–48 months), added sugars (12+ months), and saturated fat (24–36 months) combined with low intakes of potassium (12+ months), fiber (12+ months), and vitamins D and E (12+ months). Retinol and zinc intakes exceed the UL in more than 25% of participants from 6 months of age. Retinol and zinc in the diets of young children generally come from animal food sources, including milk, foods children this age should be eating. Thus, many researchers question whether the UL are set appropriately for children in these age groups.

Feeding practices should be altered to promote increased intakes of vegetables and whole grains, maintaining adequate intakes of fruit and dairy (or other good sources of nutrients and calcium), while reducing intakes of foods with high sodium and added sugars. Establishing optimal dietary patterns in early childhood is critical not only to support growth and development, but also to promote lifelong health. The FITS 2016 data contribute to our understanding of current feeding practices and nutritional exposures and serve as a foundation to help establish evidence-based feeding recommendations for infants and children.
Disclosure Statement

Regan Bailey was a consultant to RTI who coordinated the FITS 2016 analysis; she was paid travel expenses and an honorarium to attend and present this paper at the “Nurturing a Healthy Generation of Children: Research Gaps and Opportunities” Meeting coordinated by the Nestlé Nutrition Institute. Shinyoung Jun has no conflicts of interest to disclose. Alison L. Eldridge is an employee of Nestlé Research, Lausanne, Switzerland (funding source for FITS).

References


Usual Energy and Nutrient Intakes and Food Sources of Filipino Children Aged 6–12 Years from the 2013 National Nutrition Survey

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Abstract
Usual energy and nutrient intakes and food sources were evaluated in school-aged children in the Philippines using data from the 2013 National Nutrition Survey. A total of 6,565 children 6–12 years old from all sampled 8,592 households were interviewed for a 24-h dietary recall (first day). A second-day recall was obtained from a random subsample (50% of children). Usual energy and nutrient intakes were estimated using the PC-SIDE program. Energy intake was compared with estimated energy requirements (EER) considering an active activity level. Macronutrients were evaluated using acceptable macronutrient distribution ranges. Micronutrient inadequacies were computed using the estimated average requirement cutoff point method. Mean energy intake was 24.6% below the EER. A high prevalence of nutrient inadequacy was found: protein 16%, thiamine 55%, riboflavin 67%, vitamin C 81%, vitamin A 63%, vitamin B\textsubscript{6} 30%, vitamin B\textsubscript{12} 9%, folate 70%, calcium 93%, phosphorous 48%, iron 87%, and zinc 38%. Rice was the major food source of energy (52.7%), carbohydrates (67.4%), and protein (35.2%). Rice also contributed a high proportion of daily phosphorous, calcium, thiamine, riboflavin, and iron. This study demonstrated that intakes of many micronutrients of Filipino school children were markedly inadequate. Refined rice was the major food source of energy and nutrients.
Introduction

Nutritional problems marked by the coexistence of over- and undernutrition leads to serious concerns about increased risk of mortality, illness, and infections, delayed development, cognitive deficits, poorer school performance, and fewer years in school. Because of its impact on child survival and development, which results from international/political and economic crises, malnutrition is very much a significant global problem [1].

Diet is regarded as one of the largest risk factors for the global burden of disease [2]. It is, therefore, important to assess the food intake of the population in order to link this with other nutrition-specific interventions to address malnutrition. Children from 6 to 12 years grow very rapidly and can be very active. They need an adequate intake of energy and a diet that provides all the nutrients needed for growth and cognitive performance [3, 4]. The right amount of energy and nutrients reduces the risk for developing stunting, wasting, as well as overweight and obesity. However, the 2013 National Nutrition Survey (NNS) conducted in the Philippines revealed that a significant number of Filipino children are malnourished. For example, among children 5–10 years old, underweight was 29.1%, stunting 29.9%, and wasting 8.6%. Meanwhile, overweight and obesity were also observed in 9.1% of the children [5].

Studies on the prevalence of inadequate nutrient intake are informative for public health, providing useful data for nutrition diagnosis and for the establishment and monitoring of public policies in nutrition, health, agriculture, and social development [6]. Specifically, nutrient and food intake data are used to track changes and trends in dietary patterns in the population and within population subgroups. These data are also used to assess relationships between food or nutrient intakes and disease; plan nutrition intervention programs; identify the most appropriate foods suitable for fortification; compare food availability among different communities, geographic areas, and socioeconomic groups; and develop national food and nutrition policies, as well as agricultural policies [7].

As such, information on the diet of children in the Philippines is required to identify the magnitude and distribution of inadequate intakes in the population and to develop strategies for prevention and control. The objective of this study is to evaluate usual energy and nutrient intakes and food sources of school-aged children using data from the 2013 NNS.
Methods

Subjects
The 2013 NNS is a cross-sectional, population-based survey conducted to characterize the health and nutritional status of the Filipino population [5]. The survey used a stratified 3-stage sampling system drawn to represent all 17 regions and 80 provinces of the country in both urban and rural areas. A total of 8,592 Filipino households were sampled with a response rate of 91%. Data from 6,565 children aged 6–12 years from the surveyed households were used in the current analysis. Family economic status was assessed by wealth quintiles (poorest, poor, middle, rich, and richest). The wealth status was defined by household possession of vehicles, gadgets, and appliances [5]. The Ethics Committee of the Food and Nutrition Research Institute approved the survey protocol and data collection instruments. All surveyed households provided informed consent prior to participation.

Data Collection
Two nonconsecutive-day 24-h dietary recalls (24hR) were collected to estimate individual food intakes [8, 9]. All members of the sampled households were interviewed to collect data for the first 24hR. For the second 24hR, 50% of randomly selected households with first-day 24hR were interviewed. The 24hR was collected on site through a face-to-face interview by trained registered nutritionist dietitians using a structured questionnaire. The interviewer asked about all foods and beverages that the child consumed on the previous day. In most cases, food items recalled were in a cooked state. Other food items were eaten raw and, therefore, recorded in the raw state.

Quantities were expressed in terms of common household measurements such as cups or tablespoons, or by size and number of pieces, and converted into grams or milliliters for analysis using a list of compiled household food weights and measures or through samples or actual weighing. The weights of foods consumed were converted to as purchased and edible portion values. A computer system called Individual Dietary Evaluation System (IDES) was used to estimate the energy and nutrient content of foods consumed. The IDES is the electronic database of an updated Philippine food composition table where appropriate conversion factors were employed per food items.

Energy and nutrient intakes obtained from IDES were screened to identify implausible values. For the evaluation of energy intake, the ratio of daily energy intake to the estimated energy requirements (EER) was calculated for each person per day and then transformed to the logarithmic scale to remove outliers below –3 SDs and above +3 SDs for each age group [10]. After data editing and processing, 19 individuals were excluded from the analysis, giving a total of 6,546 children for the final analysis. For the evaluation of micronutrient intakes, extreme (very high) intakes were defined as those that exceeded 1.5 times the 99th percentile of the observed intake distribution in the corresponding age group. These extreme values were substituted by a random value generated from a uniform distribution in the interval with a lower bound equal to the 95th percentile of observed intake and an upper bound equal to 1.5 times the 99th percentile [10].

Body mass index was calculated as the ratio of weight (in kg) to the square of height (in m²). Weight was measured using mechanical Detecto® platform beam balance scales (Webb City, MO, USA). At least 2 measurements were obtained, with the average recorded to the nearest 0.1 kg. Standing height was obtained for subjects using the Microtoise – an L-shaped device (head bar) to which a spring-loaded coiled tape measure
was attached. At least 2 measurements were obtained, and averages were computed and recorded to the nearest 0.1 cm. For this analysis, only 6,451 children were measured due to nonavailability of some children (114) during the measurement period.

**Statistical Analysis**

Usual intakes and distributions of energy and nutrients were estimated using the PC-SIDE program from the Iowa State University (version 1.0; 2001) [10]. This program estimates the percentiles of usual nutrient intake distributions as well as the proportion below estimated average requirements (EAR) defined by the Philippine Dietary Reference Intakes 2015 [11]. Hence, the prevalence of inadequacy is estimated as the proportion of individuals with usual intakes below the EAR – EAR cutoff point method [12, 13]. In the PC-SIDE program, it is a requirement that the normality test is accepted in order to generate outputs such as mean, percentile, and adequacy level. In our data, the vitamin C intake distributions for all age groups were highly skewed, which caused rejection of normality. We generated and added a small amount of random noise (N ~ 0.35, 0.05) to vitamin C intakes to adjust the intakes and reran the analysis [Carriquiry, 2016; oral communication]. For the prevalence of inadequate intakes of iron, a probability approach was used [14]. First, the risk of inadequacy of each individual was computed and then the prevalence of inadequate iron intake, which is the average risk of inadequacy.

Total energy intakes were compared against EER. EER was calculated using the Institute of Medicine equation considering age, sex, body weight, height, and physical activity level for each individual [15]. In this study, we assumed an active physical activity level for Filipino school-age children because most children, especially those in the barrios, walk to school and/or indulge in some outdoor sports or activities.

Adequate intake (AI) and recommended nutrient intake were used to evaluate sodium, potassium, and vitamin D intakes since these nutrients have no EAR. Although it is not applicable to use AI to estimate nutrient inadequacy, if the mean nutrient intake is at or above the AI value for a respective age group, then a low prevalence of inadequate intake can be assumed [11]. Acceptable macronutrient distribution ranges (AMDR) were used to evaluate carbohydrates, total fat, and protein intakes as percentage of energy. Proportions of inadequacy and excessive intakes were classified as less than AMDR lower range and greater than AMDR upper range, respectively [11].

Calculations for summary statistics were carried out using STATA version 13 (StataCorp, College Station, TX, USA; 2013). Percent contributions of food groups to energy and nutrient intakes were calculated for selected key nutrients.

**Results**

**Energy and Macronutrients**

Means and distributions of energy intake and EER of the children are shown in Table 1. Mean energy intake (1,358 kcal) of all children was 24.6% below the EER (1,780 kcal). Forty-two percent of the children had fat intakes as percentage of total energy below the lower range of AMDR, and hence most of the energy was provided by carbohydrates (Table 2). In addition, 16% of children had protein intakes below the EAR recommended by the Philippine Dietary Reference In-
The mean intakes of total sugar and dietary fiber were 26.8 and 6.9 g/day, respectively.

The prevalence of inadequate total fat intake as percent of energy intake was especially high in rural areas (60%) (Fig. 1). On the other hand, the prevalence of excessive total fat intake was low (5%) but slightly higher in urban areas (8%). Almost all children were within the AMDR for carbohydrate intake (Fig. 1). This was also observed when data were disaggregated by gender and place of residence. In addition, a higher prevalence of excessive carbohydrate intake was seen among children in rural areas (22%). Total fat and carbohydrate intake as percent of total energy was also examined by wealth quintiles (Fig. 1). Children from the poorest quintile had a higher proportion not meeting the AMDR for total fat (80%), while 14% of the children in the richest quintile exceeded the AMDR. Furthermore, 36% of children from the poorest quintile exceeded the AMDR for carbohydrates (Fig. 1).

### Vitamins
Inadequate intakes for many vitamins were found. The vitamin with the highest prevalence of inadequacy was vitamin C (81%). Likewise, nutrient inadequacies for other vitamins were also observed: folate (70%), riboflavin (67%), vitamin A (63%), vitamin B₆ (30%), niacin (13%), and vitamin B₁₂ (9%). Average intakes of vitamins D and E were 2.2 µg/day and 2.6 mg/day, respectively, and these were very low compared with the AI recommended by Philippine Dietary Reference Intakes 2015 (Table 1).

### Minerals
A high prevalence of inadequacy was also observed for calcium (93%), iron (87%), phosphorus (48%), and zinc (38%) (Table 2). Usual intakes of sodium, magnesium, and potassium were 848, 130, and 853 mg/day, respectively. The mean intake of sodium exceeded the requirement, while the intakes of potassium and magnesium were below the requirement (Table 2).
Food Sources

Refined rice was the major source of energy, carbohydrates, and protein, providing 53%, 67, and 35% of total daily intake, respectively (Table 3). Rice also contributed a large proportion of daily intakes of phosphorous (48%), iron (28%), calcium (20%), thiamine (32%), and riboflavin (17%). Another major

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**Table 2. Mean usual nutrient intake and intake distribution for all children 6–12 years old (n = 6,565)**

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>PDRI</th>
<th>Mean/median intake percentiles</th>
<th>Inadequate/excessive reported intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EAR/AMDR</td>
<td>Al/RNI</td>
<td>UL</td>
</tr>
<tr>
<td>Macronutrients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fat, g/day</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Protein, g/day</td>
<td>34.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Carbohydrates, g/day</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total sugars, g/day</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Dietary fiber, g/day</td>
<td>–</td>
<td>15–17</td>
<td>–</td>
</tr>
<tr>
<td>As percentage of total energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fat, %</td>
<td>15–30</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Protein, %</td>
<td>6–15</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Carbohydrates, %</td>
<td>55–79</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Vitamins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiamine, mg/day</td>
<td>0.75</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Riboflavin, mg/day</td>
<td>0.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Niacin, mg/day</td>
<td>9.5</td>
<td>–</td>
<td>20</td>
</tr>
<tr>
<td>Vitamin C, mg/day</td>
<td>34.5</td>
<td>–</td>
<td>1,200</td>
</tr>
<tr>
<td>Vitamin A, μg RE/day</td>
<td>369.5</td>
<td>–</td>
<td>1,700</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;6&lt;/sub&gt;, mg/day</td>
<td>0.9</td>
<td>–</td>
<td>60</td>
</tr>
<tr>
<td>Vitamin B&lt;sub&gt;12&lt;/sub&gt;, μg/day</td>
<td>1.6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Vitamin D, μg/day</td>
<td>–</td>
<td>5</td>
<td>–</td>
</tr>
<tr>
<td>Vitamin E, mg/day</td>
<td>1.6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Folate, μg/day</td>
<td>250</td>
<td>–</td>
<td>600</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium, mg/day</td>
<td>440</td>
<td>–</td>
<td>2,500</td>
</tr>
<tr>
<td>Phosphorus, mg/day</td>
<td>1,055</td>
<td>–</td>
<td>4,000</td>
</tr>
<tr>
<td>Iron, mg/day</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sodium, mg/day</td>
<td>–</td>
<td>500</td>
<td>–</td>
</tr>
<tr>
<td>Zinc, mg/day</td>
<td>4.25</td>
<td>–</td>
<td>23</td>
</tr>
<tr>
<td>Magnesium, mg/day</td>
<td>–</td>
<td>155</td>
<td>–</td>
</tr>
<tr>
<td>Potassium, mg/day</td>
<td>–</td>
<td>2,000</td>
<td>–</td>
</tr>
<tr>
<td>Selenium, μg/day</td>
<td>17.25</td>
<td>–</td>
<td>280</td>
</tr>
</tbody>
</table>

PDRI, Philippine dietary reference intake (2015) recommendations; EAR, estimated average requirement; AMDR, acceptable macronutrient distribution ranges; AI, adequate intake; RNI, recommended nutrient intake; UL, tolerable upper intake level; RE, retinol equivalents.
The major contributor of calcium intake was fish and shellfish (21%). The major sources of fats were pork, sausages (processed meats), and oils. For vitamin C, the major source was from fruit-based beverages (fruit juice drink concentrates and powdered and ready-to-drink fruit juices). Dark green leafy vegetables were the major sources of vitamin A (34%). Bread was a major source of folate, contributing 17%.

**Fig. 1.** Percent contribution of fat and carbohydrates to total energy intake of children by gender and place of residence (a) and wealth status (b).
Table 3. Percentage contributions of the top 10 food groups to selected macro- and micronutrient intakes among Filipino school-age children

<table>
<thead>
<tr>
<th>Food groups</th>
<th>Percent contribution to total daily intake</th>
<th>vitamins</th>
<th>minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>energy</td>
<td>carbohydrates</td>
<td>protein</td>
</tr>
<tr>
<td>Rice</td>
<td>52.7</td>
<td>67.4</td>
<td>35.2</td>
</tr>
<tr>
<td>Bread</td>
<td>4.4</td>
<td>4.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Pork</td>
<td>4.1</td>
<td>–</td>
<td>7.2</td>
</tr>
<tr>
<td>Noodles</td>
<td>3.2</td>
<td>2.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Milk</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Fish and shellfish</td>
<td>3</td>
<td>–</td>
<td>17.5</td>
</tr>
<tr>
<td>Sausages/luncheon meats</td>
<td>3</td>
<td>–</td>
<td>5.2</td>
</tr>
<tr>
<td>Fats and oils</td>
<td>2.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Poultry</td>
<td>1.7</td>
<td>–</td>
<td>6.9</td>
</tr>
<tr>
<td>Cakes</td>
<td>1.5</td>
<td>1.4</td>
<td>–</td>
</tr>
<tr>
<td>Cookies</td>
<td>1.5</td>
<td>1.3</td>
<td>–</td>
</tr>
<tr>
<td>Banana snacks (with sugar and fried)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Beans</td>
<td>–</td>
<td>–</td>
<td>1.6</td>
</tr>
<tr>
<td>Chocolate-flavored beverages</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Crackers</td>
<td>–</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Dark green leafy vegetables</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Deep yellow vegetables</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Eggs and egg dishes</td>
<td>–</td>
<td>–</td>
<td>3.1</td>
</tr>
<tr>
<td>Fruit-based beverages (powdered)</td>
<td>–</td>
<td>1.3</td>
<td>–</td>
</tr>
<tr>
<td>Fruits</td>
<td>–</td>
<td>1.3</td>
<td>–</td>
</tr>
<tr>
<td>Milk</td>
<td>–</td>
<td>–</td>
<td>2.1</td>
</tr>
<tr>
<td>Other sweetened beverages (tea)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Other vegetables</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Potato chips</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Soft drinks</td>
<td>–</td>
<td>1.1</td>
<td>–</td>
</tr>
<tr>
<td>Starchy vegetables</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sugar</td>
<td>–</td>
<td>1.2</td>
<td>–</td>
</tr>
</tbody>
</table>
Discussion

Diet is a determinant factor for malnutrition. Understanding usual nutrient intakes of specific population groups provides useful data for nutrition diagnosis and for planning nutrition intervention programs. This study evaluated nutrient inadequacies among children aged 6–12 years in the Philippines.

The results showed that there is an alarming problem of nutrient inadequacies among Filipino children. Mean usual energy intake of the children did not meet requirements. Inadequate energy intake may compromise their potential for growth and development, quality of life, and education in school. Most energy in the diet came from carbohydrates, and fat intake did not meet requirements. Fats are needed for growth and development of children, and the extraordinary low intake of fats may impair the absorption of fat-soluble vitamins. The prevalence of low fat intakes was especially problematic in rural areas and among the poor to poorest wealth quintiles, demonstrating that poor nutrition is both a social and an economic issue. Poverty limits the quantity and quality of dietary intakes [16]. Macronutrient malnutrition may result in wasting and stunting. Indeed, in the 2013 NNS, underweight among children 5–10 years old was 29.1%, stunting 29.9%, and wasting 8.6%. Meanwhile overweight/obesity (9.1%) was also observed [5]. A study in Kolkata showed that children classified as severely undernourished and children of lower socioeconomic status were found to be “below average” and “well-below average” in motor proficiency categories compared with normal-nourished groups and children of upper socioeconomic status [17]. Stunting represents a loss of potential output for an economy. The calculations of experts suggest that per capita income today is probably 7% higher than it would have been if none of today’s workers had been stunted in childhood. In Africa and South Asia, this “stunting penalty” is likely to be even higher – around 9–10% of GDP per capita [18].

A high prevalence of vitamin and mineral inadequacies was found among the children. A major cause of micronutrient inadequacies is a diet consisting mainly of staple foods, primarily cereals, and lacking animal source foods [19]. In this study, the fact that rice was a major source of thiamine, riboflavin, phosphorous, iron, and calcium showed that indeed the food variety of the children was very low, and nutrient-dense foods were little consumed. Micronutrients are essential to sustain life and for optimal physiological function. The inadequacies of vitamin C, vitamin A, vitamin D, B vitamin, calcium, phosphorous, iron, and zinc intakes may pose significant risks to poor psychosocial development of children consisting of several interdependent domains, including sensory-motor, cognitive, and social-emotional.
functioning. Micronutrient deficiencies are known to affect these developmental processes and functions, resulting in negatively shifting the IQ potential of children [20, 21].

Noteworthy to mention is the alarmingly high prevalence of inadequacy of calcium and vitamin D intakes. Both calcium and vitamin D have important roles in child development and bone growth [22]. A deficiency in either could result in rickets, poor growth, and an increased risk of osteoporosis later in life. Children obtain most of their calcium requirement from milk and cheese, but our study shows that these foods were consumed in minute amounts (data not shown). In a tropical country like the Philippines, supposedly, children can get vitamin D from sunshine; however, we cannot discount the notion that most children spend much of their time indoors.

Fruits and vegetables contributed very low percentages to micronutrient intakes in the children, indicating that these foods were not sufficiently consumed. Low consumption of fruits and vegetables may result in some health issues in future life, such as cardiovascular disease, some types of cancer, and obesity [23, 24]. Providing a variety of foods from each food group to ensure optimal intake of nutrients is important for school-age children. At this stage, children may face new challenges related to food choices and habits, but decisions on what to eat are largely determined by what is provided in the school and at home. The home food environment is important in the development of children’s dietary behavior [25]. Parents have an important influence on the dietary behavior of children because they generally determine which foods are available at home, and they can set rules about what their children are allowed to eat and act as role models with respect to dietary habits [26].

Conclusions

This study used usual intake analysis to demonstrate that the intakes of fat and many micronutrients in Filipino children are markedly inadequate. The shortfalls in nutrient intakes can be largely explained by the fact that refined rice was the major source of many key nutrients while nutrient-dense foods such as milk and vegetables played a minor role in the diet. The results of this study are informative to nutrition policy and education, both for parents and health care professionals, and could be used for the development of various public health strategies to improve diet quality and address nutrient shortfalls in the diets of this population.
Disclosure Statement

The authors declare that no financial or other conflict of interest exists in relation to the contents of the chapter.

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Food and Nutrition in Malaysian Children

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Abstract

Two nationwide studies, namely the South East Asian Nutrition Survey (SEANUTS Malaysia) and MyBreakfast study showed that 13–17% of children aged between 6 and 12 years were either overweight or obese. From dietary assessment, the majority of children achieved the Malaysian recommended nutrient intake (RNI) for energy and protein, but more than 50% did not fulfill the RNI for calcium and vitamin D. The majority of children consumed breakfast regularly; however, 20–30% of children skipped breakfast. The MyBreakfast study showed that 17.7% of the children consumed ready-to-eat cereal (RTEC) at breakfast, while among non-RTEC consumers, bread (44.2%), eggs (31.8%), and nasi lemak (23.9%) were the most common foods consumed. RTEC was the major contributor of whole grain (68.6%), followed by hot cereal (18.6%), biscuits (8.7%), and bread (1.8%). In the SEANUTS Malaysia, among children aged 7–9 years, 13.4 and 9.5% met the Malaysian Dietary Guideline (MDG) for fruits and vegetables while among children aged 10–12 years, only 19.6 and 16.1%, respectively, met the MDG for fruits and vegetables. For the milk group, only 5.5% of 7– to 9-year-old children and 3.7% of those 10–12 years old met the MDG for milk/dairy products per day.

Introduction

Malaysia is a developing country that has been experiencing rapid socioeconomic growth over the last decades, resulting in marked improvement in life expectancy, educational attainment, and income [1]. Rapid socioeconomic
growth has also led to changes in dietary habits and lifestyle, and thus the morbidity and mortality pattern of the population [1]. Food availability from animal products as well as sugar and sweeteners has increased by 82 and 70%, respectively, between the year 1967 and 2007 [2]. Rice is a staple food for Malaysians, but energy contribution from rice has decreased from 1,176 to 731 kcal/day between 1970 and 2009 [3]. Changing trends in the dietary pattern of Malaysians have been associated with the increasing prevalence of obesity and noncommunicable diseases in this country [1–3].

Childhood obesity has become a major concern as the prevalence has increased over the years. In this paper, we will discuss the findings on nutritional status, nutrient intake, and food habits – in particular the breakfast habits of Malaysian primary school children. Results from 2 nationwide cross-sectional studies, namely the South East Asian Nutrition Survey of Malaysian Children (SEANUTS Malaysia) [4] and the MyBreakfast study [5], will be discussed. The SEANUTS Malaysia was conducted in 2010–2011, involving 3,542 children aged 0.5–12 years, with 1,969 of them from the primary school aged between 7 and 12 years [4]. The MyBreakfast study was conducted in 2013, with 8,705 children aged 6–17 years participating in the study, of whom 5,581 were primary school children aged between 6 and 12 years [5]. Both SEANUTS Malaysia and the MyBreakfast study included urban and rural children from all regions of the country, namely, Central, Southern, Northern, East Coast, and East Malaysia regions.

Nutritional Status of Malaysian Children

In both SEANUTS Malaysia [4] and the MyBreakfast study [5], the nutritional status of the children was determined using WHO Growth Reference 2007 [6]. Table 1 shows the distribution of the nutritional status of children in the SEANUTS Malaysia [4] and the MyBreakfast study [5]. Among the children in SEANUTS Malaysia, the prevalence of overweight was higher (14.4%) in urban than rural (12.6%) areas. Similarly, the prevalence of obesity was also higher (20.1%) in urban than rural (13.0%) areas [4]. In the MyBreakfast study, the overall prevalence of overweight and obesity among primary school children was 13.2 and 15.1%, respectively [5]. In the analysis by area, the MyBreakfast study showed that the prevalence rates of overweight and obesity among the children were similar in both urban (13.6% overweight; 15.1% obesity) and rural areas (12.3% overweight; 15.2% obesity). The results from both SEANUTS Malaysia [4] and the MyBreakfast study [5] showed that overweight and obesity among Malaysian children should be of concern as 3 in 10 children were either overweight or obese irrespective of areas where they reside.
Nutrient Intake of the Children in Malaysia

In SEANUTS Malaysia, the mean energy intakes of the children in urban and rural areas were 1,978 and 1,939 kcal/day, respectively [4]. Similarly, in the MyBreakfast study [5], the mean energy intake of children in the rural area (1,779 kcal) was not very different from their counterparts in the urban area (1,814 kcal).

Table 2 shows the prevalence of children not achieving the RNI of selected macro- and micronutrients in the SEANUTS Malaysia [4] and the MyBreakfast study [5]. The majority of the children in both studies achieved the Malaysian RNI for energy and protein. However, at least two-thirds of the children did not achieve the RNI for calcium for both studies. About 9 in 10 children did meet the RNI for vitamin D in the MyBreakfast study. Hence, these 2 nutrients are of major concern in Malaysia. These findings are worrying, as both calcium and vitamin D are important nutrients for bone health. A recent report from the
Table 2. Prevalence of Malaysian primary school children (6–7 to 12 years) not achieving the recommended nutrient intake of selected macronutrients and micronutrients

<table>
<thead>
<tr>
<th>Area</th>
<th>Nutritional status</th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SEANUTS Malaysia [4]</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>n</td>
<td>558</td>
<td>615</td>
<td>1,173</td>
</tr>
<tr>
<td>Energy, %</td>
<td></td>
<td>39.7</td>
<td>31.7</td>
<td>35.7</td>
</tr>
<tr>
<td>Protein, %</td>
<td></td>
<td>0.6</td>
<td>1.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Calcium, %</td>
<td></td>
<td>63.4</td>
<td>66.6</td>
<td>65.0</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>12.8</td>
<td>10.1</td>
<td>11.5</td>
</tr>
<tr>
<td>Vitamin C, %</td>
<td></td>
<td>13.4</td>
<td>8.9</td>
<td>11.2</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>4.3</td>
<td>3.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>52.0</td>
<td>52.6</td>
<td>52.3</td>
</tr>
<tr>
<td>Rural</td>
<td>n</td>
<td>388</td>
<td>408</td>
<td>796</td>
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<tr>
<td>Energy, %</td>
<td></td>
<td>40.8</td>
<td>36.8</td>
<td>38.9</td>
</tr>
<tr>
<td>Protein, %</td>
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<td>1.2</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
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<td>74.8</td>
<td>70.3</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>13.2</td>
<td>18.0</td>
<td>15.5</td>
</tr>
<tr>
<td>Vitamin C, %</td>
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<td>12.1</td>
<td>13.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>10.2</td>
<td>9.6</td>
<td>9.9</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>59.9</td>
<td>66.7</td>
<td>63.2</td>
</tr>
<tr>
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<td>n</td>
<td>946</td>
<td>1,023</td>
<td>1,969</td>
</tr>
<tr>
<td>Energy, %</td>
<td></td>
<td>40.2</td>
<td>33.7</td>
<td>36.9</td>
</tr>
<tr>
<td>Protein, %</td>
<td></td>
<td>0.8</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Calcium, %</td>
<td></td>
<td>64.6</td>
<td>69.8</td>
<td>67.1</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>12.9</td>
<td>13.2</td>
<td>13.1</td>
</tr>
<tr>
<td>Vitamin C, %</td>
<td></td>
<td>12.9</td>
<td>10.8</td>
<td>11.8</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>6.7</td>
<td>5.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>55.2</td>
<td>58.2</td>
<td>56.7</td>
</tr>
<tr>
<td><strong>MyBreakfast Study [5]</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>n</td>
<td>638</td>
<td>797</td>
<td>1,435</td>
</tr>
<tr>
<td>Energy, %</td>
<td></td>
<td>13.6</td>
<td>12.2</td>
<td>12.8</td>
</tr>
<tr>
<td>Protein, %</td>
<td></td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Calcium, %</td>
<td></td>
<td>55.0</td>
<td>62.1</td>
<td>59.0</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>1.4</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Vitamin C, %</td>
<td></td>
<td>34.3</td>
<td>33.9</td>
<td>34.1</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>8.5</td>
<td>8.9</td>
<td>8.7</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>94.4</td>
<td>93.0</td>
<td>93.6</td>
</tr>
<tr>
<td>Rural</td>
<td>n</td>
<td>242</td>
<td>428</td>
<td>670</td>
</tr>
<tr>
<td>Energy, %</td>
<td></td>
<td>12.4</td>
<td>13.6</td>
<td>13.1</td>
</tr>
<tr>
<td>Protein, %</td>
<td></td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Calcium, %</td>
<td></td>
<td>58.3</td>
<td>67.1</td>
<td>63.9</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Vitamin C, %</td>
<td></td>
<td>42.6</td>
<td>46.7</td>
<td>45.2</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>7.0</td>
<td>8.9</td>
<td>8.2</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>94.6</td>
<td>95.3</td>
<td>95.1</td>
</tr>
</tbody>
</table>
SEANUTS Malaysia showed that only a very low percentage of children aged 7–9 years (5.5%) and 10–12 years (3.7%) met the Malaysian Dietary Guideline (MDG) for milk/dairy products per day [7]. As milk consumption is not a habit in Malaysia, a lot more concerted effort is needed to promote milk drinking habits especially among the Malaysian children. Geographically, Malaysia is in the equator, with the sun shining almost every day of the year. Since the children were not able to get dietary vitamin D, it is imperative that the children are encouraged to be outside in the sun, so that vitamin D can be synthesized in the body.

### Food Habits of Malaysian Children

Breakfast consumption has been shown to benefit children’s body weight status, nutrient profiles, and cognitive performance [8]. The MyBreakfast study was the first comprehensive nationwide study on breakfast habits among school children in Malaysia [5]. In this study, breakfast was defined as the first eating occasion after an overnight sleep until 10 a.m. on the weekdays and 11 a.m. at the weekends [5, 9]. Among the children who had completed the Breakfast Habits Questionnaire and anthropometric measurements in the MyBreakfast study, the prevalence of breakfast skippers (ate breakfast 0–2 days/week) and irregular breakfast eaters (ate breakfast 3–4 days/week) was 9.3 and 10.8%, respectively, while 79.9% were found to be regular breakfast eaters (ate breakfast 5–7 days/week) [9]. In the SEANUTS Malaysia, breakfast was defined as the first eating occasion consumed by the children before 10 a.m., and irregular breakfast eaters were defined as children who skipped breakfast on a daily basis [10]. Table 3 shows the distribution of breakfast consumption among primary school children in the SEANUTS Malaysia and the MyBreakfast study.

<table>
<thead>
<tr>
<th>Area</th>
<th>Nutritional status</th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>n</td>
<td>880</td>
<td>1,225</td>
<td>2,105</td>
</tr>
<tr>
<td>Energy, %</td>
<td></td>
<td>13.3</td>
<td>12.7</td>
<td>12.9</td>
</tr>
<tr>
<td>Protein, %</td>
<td></td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Calcium, %</td>
<td></td>
<td>55.9</td>
<td>63.8</td>
<td>60.5</td>
</tr>
<tr>
<td>Iron, %</td>
<td></td>
<td>1.0</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Vitamin C, %</td>
<td></td>
<td>36.6</td>
<td>38.4</td>
<td>37.6</td>
</tr>
<tr>
<td>Vitamin A, %</td>
<td></td>
<td>8.1</td>
<td>8.9</td>
<td>8.6</td>
</tr>
<tr>
<td>Vitamin D, %</td>
<td></td>
<td>94.4</td>
<td>93.8</td>
<td>94.1</td>
</tr>
</tbody>
</table>

Table 2. Continued
Only 65.2% of children in the SEANUTS Malaysia consumed breakfast daily [10]. In the MyBreakfast study, children who consumed breakfast regularly were found to have healthier body weight status and were less likely to become overweight or obese than children who skipped breakfast [9]. Regular breakfast eaters were also found to have higher intake of calcium and vitamins A, C, and D than irregular breakfast eaters [10]. Analysis of the 2-day 24-h dietary recall data of the MyBreakfast study showed that 17.7% of the children consumed ready-to-eat cereal (RTEC) at breakfast, while among non-RTEC consumers bread (44.2%), eggs (31.8%), and nasi lemak (23.9%) were the most common foods consumed at breakfast [11]. RTEC was found to be the major contributor of whole grain (68.6%), followed by hot cereal (18.6%), biscuits (8.7%), and bread (1.8%) [12]. It was also shown that only 1.0% of Malaysian children achieved the MDG for whole grain intake [12].

In the SEANUTS Malaysia, it was found that among children aged 7–9 years \((n = 890)\), only 13.4 and 9.5% met the MDG for fruits and vegetables per day, respectively [7]. The pattern was similar among the older children aged 10–12 years \((n = 883)\) although slightly higher; only 19.6 and 16.1%, respectively, met the MDG for fruits and vegetables per day. For the milk group, a very low percentage of children aged 7–9 years (5.5%) and 10–12 years (3.7%) met the MDG for milk/dairy products per day [7]. Despite this low milk drinking habits, the MyBreakfast study showed that UHT (ultrahot-treated) milk was commonly consumed at breakfast among RTEC consumers [11]. Thus, the consumption of

<table>
<thead>
<tr>
<th>Breakfast consumption</th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEANUTS Malaysia [10]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children (2–12 years old), (n)</td>
<td>1,397</td>
<td>1,400</td>
<td>2,797</td>
</tr>
<tr>
<td>Regular breakfast eaters, % (ate breakfast daily)</td>
<td>68.7</td>
<td>64.8</td>
<td>66.8</td>
</tr>
<tr>
<td>Irregular breakfast eaters, % (no daily breakfast)</td>
<td>31.3</td>
<td>35.2</td>
<td>33.2</td>
</tr>
<tr>
<td><strong>MyBreakfast Study [9]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children (6–12 years old), (n)</td>
<td>2,402</td>
<td>2,920</td>
<td>5,322</td>
</tr>
<tr>
<td>Breakfast skippers, % (ate breakfast 0–2 days/week)</td>
<td>9.1</td>
<td>9.5</td>
<td>9.3</td>
</tr>
<tr>
<td>Irregular breakfast eaters, % (ate breakfast 3–4 days/week)</td>
<td>9.8</td>
<td>11.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Regular breakfast eaters, % (ate breakfast 5–7 days/week)</td>
<td>81.1</td>
<td>78.9</td>
<td>79.9</td>
</tr>
</tbody>
</table>
RTEC at breakfast can promote milk consumption among the children and subsequently may increase the prevalence of children meeting the MDG for milk/dairy products.

**Conclusion**

Childhood obesity has increased at an alarming rate in Malaysia; thus, the problem is still a major concern. On average, children in Malaysia consumed between 1,800 and 1,900 kcal/day, and the majority of the children achieved the RNI for energy and protein. However, nutrients not meeting the RNI for a majority of the children were calcium and vitamin D. Although a majority of the children consumed breakfast regularly, there were still 1 in 5 children who skipped their breakfast. Food groups which were not meeting the MDG were milk, fruits, and vegetables. Milk and dairy products as well as fruits and vegetables were not habitually eaten daily; hence, only 1 in 20 children met the MDG for milk while 1 in 10 achieved the MDG for fruits and vegetables. With the lack of calcium and vitamin D in the diet, the habit of milk and dairy product consumption should be inculcated at breakfast. Similarly, fruit and vegetable intake can be improved at mealtimes particularly during lunch and dinner and as healthy snacks.

**Disclosure Statement**

The authors declare that no financial or other conflict exists in relation to the contents of the chapter.

**References**

Despite considerable advances in food and nutrition globally, several gaps remain in our understanding on how best to feed our children. Many of the presenters showcased new ideas and data on how we may manipulate the food environment or eating rate to alter food intake. In many developing countries, the provision of adequate weaning foods remains a challenge. Sadly, 1 in 4 children under the age of 5 years worldwide are stunted – numerically, making the figure up to 155 million. Moreover, 52 million children under 5 years are wasted and nearly 15 million severely wasted. These numbers stagger the mind and make us realize that there is an urgent need to tackle this global scourge. Inadequate and inappropriate food is at the heart of undernutrition. In order to provide adequate intervention, it is necessary to have reliable data on the levels of over- and undernutrition. The Feeding Infants and Toddlers Study (FITS) and Kids Nutrition and Health Study (KNHS) program facilitates valuable insights into the level and nature of nutrition in children in several developed and developing countries. The workshop was an ideal setting to examine the Nurturing a Healthy Generation of Children: Many of the speakers articulated the Research Gaps and Opportunities. On behalf of the cochairs, we would like to thank all the speakers and participants for their excellent exchange of knowledge and information. The contents of the workshop will remain as a timely reminder for the need to continue working on how best we can nurture a healthy generation of children.

Christiani J. Henry
Abstract

Whilst there is extensive literature on the health benefits of a regular breakfast, there are few guidelines to help policy makers to issue specific targets on optimal nutrient intake at breakfast or the selection of foods to attain these targets. The food and nutritional advice on breakfast offered by most governments is confined to simple advice on food servings. The USA and Mexico typify the few countries that have attempted to issue specific nutrient targets for breakfast. However, these simply reflect general nutrient guidelines for adults, adjusted to suit lower energy needs of toddlers and school children. Little guidance is issued on micronutrient intake, and the advice on food choice does not appear to be linked to patterns of nutrient intake. The application of cluster and principal component analysis, which is used to determine the patterns of daily or breakfast food consumption and also link them to nutrient intake, greatly improved our understanding of optimal breakfast choices. Using 6 national nutrition surveys (Canada, Denmark, France, Spain, the UK, and the USA), the International Breakfast Research Initiative has opted to score each individual with a measure of overall daily nutritional quality (based on the nutrient-rich food index). It is hoped that options for the derivation in breakfast nutrient targets and associated food-based guidelines will arise from an analysis of tertiles of this score. Ultimately, meal-based advice will become the basic building block for digitally based personalized dietary analysis and guidelines.
Introduction

It is widely accepted that breakfast is the most important meal of the day. Breakfast skipping has been associated with poorer overall nutrient intakes with implications for weight and glycemic control, cognition, and cardiovascular disease. Given the importance of breakfast in determining overall diet quality, it is not surprising that specific food and nutrient targets have been proposed for breakfast meals. This contrasts with other meals (snacks, lunch, and evening meal) where such data are extremely limited and almost exclusively directed to advice on snacks. This is not unexpected since, intuitively, it is held that consumers are far more likely to repeat the same breakfast choice over the week than they are to repeat, for example, the same main meal over the week. This concept was analyzed for the Irish National Adult Nutrition Survey for those subjects who were studied over 3 weekdays and 1 weekend day [unpubl. data]. The remaining subjects varied in the number of weekdays and weekend days. The results are given in Table 1. A quarter of the population always had the same breakfast over the entire week. If weekdays alone are considered, then 42% of subjects had the same breakfast on all 3 days. Many other combinations of similarity of weekday and weekend breakfasts can be considered, but the key point is that there is a strong tendency for the same breakfast to be consumed quite regularly over the week. Equally, it is worth noting that for one quarter of the subjects, the weekend breakfast differed from the weekday breakfast. Thus, given the repeatability of breakfast, at least through the working week, the identification of specific guidelines for target nutrient intake and accompanying food intake patterns remain an attractive possibility which would be valuable to policy makers and ultimately consumers.

Maximizing Quality Breakfast Uptake

There are 3 nonnutritive attributes of breakfast which need to be safeguarded in attempting to design any optimal breakfast intake. Breakfasts must be affordable, convenient, and appetizing. On an average school day in the US, about 14 million children take part in the School Breakfast Program; nearly 12 million of them were low-income children who received a free or reduced-price school breakfast [1]. Thus, breakfasts, if they are to be prepared and eaten at home, must be affordable by the most economically vulnerable groups. The same US data also show that a major reason for schoolchildren to miss breakfast at home, especially in rural areas, is the long commute to school. Moreover, participation in a school breakfast program is hampered by commuting delays. Thus, conve-
nience in breakfast preparation is essential. Finally, we know that children turn away from foods when flavor is compromised. One classic example was in Oregon where it was decided to abandon the sale of chocolate-flavored milk in favor of plain milk in 11 elementary schools [2]. The net effect was a 12% fall in sales and a 24% rise in milk wastage. Thus, palatability is a third key element in shaping school breakfast programs.

**Present Governmental Guidelines on Food and Nutrition Standards for Breakfast**

Many governments and state agencies have issued advice on the foods to possibly include in the development of a nutritious breakfast. These data are largely qualitative and are not based on any evidence arising from analyses of prevailing patterns of food choice at breakfast. Moreover, there is a lack of consistency in the definition of recommended categories: “cereal” is a category recommended in Ireland [3], while in New Zealand that is extended to “porridge or muesli” or to a specific branded breakfast cereal [4], and in the UK it is defined as “low fat, low sugar cereals” [5]. Two countries, Mexico and the USA, have issued more detailed guidelines on target nutrient intakes and recommended food selection for breakfast. In the case of Mexico, specific guidelines are issued for nutrient intakes at
breakfast (Tables 2, 3). The values listed for preschool children and schoolchildren correspond on an energy-adjusted basis to the national dietary guidelines for Mexico [6]. The official nutritional guidelines for breakfast for Mexican children are accompanied by detailed standards for specific foods (data not shown). In the case of the USA, the focus is on recommending specific foods and then to set out very precise nutrient profiles which all foods have to follow (Table 4) [7]. For most nutrients, there are qualifying issues related to specific foods. Some are expressed as percent energy, some as units per serving, and some as a maximum percentage of the total weight of food. In both cases, little evidence is presented as to the scientific basis for choosing the particular foods and their portion sizes. In addition, both reports offer limited guidance on micronutrient intake of food composition standards. In the US, school breakfasts are expected to provide a minimum of 25% of the recommended daily allowance (RDA), presumably to mirror an expected energy intake of 25% of daily intake. Taken together, all of these governmental recommendations highlight the need for a more scientifically rigorous approach to recommendation as to optimal food and nutrient intakes at breakfast.

Table 2. Average daily total energy and macronutrients for breakfast as recommended in Mexico [9]

<table>
<thead>
<tr>
<th></th>
<th>Preschool children</th>
<th>Schoolchildren</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total daily energy intake, kcal</td>
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<td>1,579</td>
</tr>
<tr>
<td>Energy intake at breakfast, kcal</td>
<td>325</td>
<td>395</td>
</tr>
<tr>
<td>Carbohydrates, % energy</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Protein, % energy</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total fat, % energy</td>
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<td>25</td>
</tr>
<tr>
<td>Saturated fatty acids, % energy</td>
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<td>10</td>
</tr>
<tr>
<td>Added sugars, % energy</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fiber, g/breakfast</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Sodium, mg/breakfast</td>
<td>&lt;360</td>
<td>&lt;360</td>
</tr>
</tbody>
</table>

Table 3. Nutrient intake data across 6 clusters of Mexican breakfast (minimum and maximum nutrient intakes and fold increase for intakes at breakfast and the total day)

<table>
<thead>
<tr>
<th></th>
<th>Breakfast intake only</th>
<th>Total daily intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cluster with lowest intake</td>
<td>cluster with highest intake</td>
</tr>
<tr>
<td>Fiber, g</td>
<td>2.2</td>
<td>12.0</td>
</tr>
<tr>
<td>Total fat, g</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td>Added sugars, g</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Calcium, mg</td>
<td>197</td>
<td>427</td>
</tr>
<tr>
<td>Folic acid, μg</td>
<td>30</td>
<td>105</td>
</tr>
<tr>
<td>Sodium, mg</td>
<td>348</td>
<td>1,035</td>
</tr>
</tbody>
</table>
Several published studies have sought to exploit the statistical methodology of nearest-neighbor analysis through either principal component or cluster analysis. The application of cluster analysis to describe the pattern of breakfast intake among Mexican children identified 6 meaningful clusters [8]. Due to the variety in dietary patterns identified, ranging from traditional Mexican to Westernized, the nutrient intakes varied considerably across clusters. What might be high in one is low in another and vice versa. This is true when cluster-based nutrient intakes are considered for breakfast only or for the full day, but the level of variation is far higher in the former (Tables 2, 3). The ratio between the cluster with the lowest intake of any nutrient to that of the cluster with the highest intake varies far more for breakfast than for the day as a total. This makes sense since different meals throughout the day have quite different overall nutritional profiles. Other approaches to a combination of principal component and cluster analysis have taken a total overview of nutrient intake. Thus, a French study showed that when this approach was applied to breakfast food, 4 clusters were identified. Data on food intake are presented in the study, but the nutrient profile is given as an overall score for breakfast nutrients [9]. In this study, the mean adequacy ratio (MAR) was used. The

**Table 4. Nutritional standards for foods used in federal school food programs in the USA [7]**

<table>
<thead>
<tr>
<th>Food</th>
<th>Nutrition standard</th>
<th>Qualifying remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain items</td>
<td>Not applicable</td>
<td>Acceptable grain items must include 50% or more whole grains by weight or have whole grains as the first ingredient</td>
</tr>
<tr>
<td>Total fats</td>
<td>&lt;35% energy as served</td>
<td>Exemptions for cheese, nuts and seeds, seafood, eggs</td>
</tr>
<tr>
<td>Saturated fats</td>
<td>&lt;10% of energy as served</td>
<td>Exemptions for cheese, nuts and seeds, eggs</td>
</tr>
<tr>
<td>Trans fats</td>
<td>0 g/serving</td>
<td>(&lt;0.5 g/portion)</td>
</tr>
<tr>
<td>Sugar</td>
<td>&lt;35% by weight from total sugar</td>
<td>Some exemptions for dehydrated fruits and vegetables</td>
</tr>
<tr>
<td>Sodium</td>
<td>&lt;200 mg/item as served</td>
<td>Applies to snack and side dishes</td>
</tr>
<tr>
<td></td>
<td>&lt;480 mg/item as served</td>
<td>Applies to entrée items</td>
</tr>
<tr>
<td>Energy</td>
<td>&lt;200 kcal/item as served</td>
<td>Applies to snack items; includes any accompaniments</td>
</tr>
<tr>
<td></td>
<td>&lt;350 kcal/item as served</td>
<td>Applies to entrée items; includes any accompaniments</td>
</tr>
</tbody>
</table>

**Cluster Analysis and Its Application to Optimal Breakfast Food and Nutrient Choices**

Several published studies have sought to exploit the statistical methodology of nearest-neighbor analysis through either principal component or cluster analysis. The application of cluster analysis to describe the pattern of breakfast intake among Mexican children identified 6 meaningful clusters [8]. Due to the variety in dietary patterns identified, ranging from traditional Mexican to Westernized, the nutrient intakes varied considerably across clusters. What might be high in one is low in another and vice versa. This is true when cluster-based nutrient intakes are considered for breakfast only or for the full day, but the level of variation is far higher in the former (Tables 2, 3). The ratio between the cluster with the lowest intake of any nutrient to that of the cluster with the highest intake varies far more for breakfast than for the day as a total. This makes sense since different meals throughout the day have quite different overall nutritional profiles. Other approaches to a combination of principal component and cluster analysis have taken a total overview of nutrient intake. Thus, a French study showed that when this approach was applied to breakfast food, 4 clusters were identified. Data on food intake are presented in the study, but the nutrient profile is given as an overall score for breakfast nutrients [9]. In this study, the mean adequacy ratio (MAR) was used. The
MAR expresses the intake of each nutrient as a percentage of the RDA, and the mean of all these intakes is the MAR score. Clear differences in the MAR score were evident for breakfast with a range from 18 to 30. Another study, carried out on a sample of German adults, identified 4 breakfast patterns using principal component analysis and linked them to the a priori-defined breakfast quality index [10], which in this instance combined both food and nutrient intakes into scores (vegetables, fruits, whole grains, sugar-sweetened beverages, fruit juice, nuts, legumes, red and processed meat, trans fats, long-chain (n-3) fatty acids (eicosapentaenoic acid and docosahexaenoic acid), and total polyunsaturated fatty acids. The breakfast quality index was also directly related to health outcomes covering glycemic control, cardiovascular disease, and weight control. Thus, while cluster and principal component analysis remains a useful tool in determining optimal breakfast nutrient and food intake, there are major limitations in setting out gradations in optimal nutrient intakes for breakfast.

The International Breakfast Research Initiative

Recognizing the need to explore the possibility of a more structured and harmonized approach to defining nutrient intakes for breakfast, a number of scientists from both sides of the Atlantic have come together under the sponsorship of Cereal Partners Worldwide to explore options to make this possible. Data from 6 national nutrition surveys will be used (Canada, USA, Denmark, France, Spain, and the UK) and will provide estimates of nutrient and food intakes in as harmonized a means as possible. The intention is to explore some options for an a priori-defined scoring. Initially, the use of the nutrient-rich food index will be explored with the subjects examined across tertiles of this score based on the daily nutrient intakes [11]. Breakfast nutrient intakes will then be examined, and from that analysis, some harmonized approach to the development of guidelines for optimal nutrient intakes at breakfast will be proposed. Clearly, wherever possible, existing international nutrient guidelines will be used. However, bearing in mind that the proposed guidelines are for just 1 meal during the day, many shortcomings with existing guidelines will have to be overcome. For the micronutrients, a blanket 20% of the RDA is proposed in the USA. However, current data show that intakes at breakfast for many micronutrients well exceed 20% of the RDA, and quite how these higher prevailing intakes should be protected and promoted remains to be seen.
Exploring Strategies to Set Goals to Optimize Food Intakes at Breakfast

The average daily intake of a food is a function of 3 elements:
- The average mean daily intake of the total population, which will include both consumers of the food and nonconsumers (includes zero values).
- The percentage of the population that consumes the food.
- The intake of the food among consumers only (no zero values included).

Most data on food intake simply report mean daily total population intake and, inevitably, that leads to recommendations to seek an increase or decrease in average daily intake. However, when consumers only are considered, it is often observed that such consumers are at the maximum reasonable level of intake of a target food. Thus, the main problem that we face in shaping advice on food choices is that it is the percentage of the population that consumes the target food that needs to be addressed rather than the level of intake among those who regularly consume a given food. Table 5 provides the data from the Irish National Adult Nutrition Survey and compares food intake for the lowest and highest tertiles of the nutrient-rich food index for the total population and for consumers only. When the former is considered, because of the presence of a significant number of zero intakes, the time taken in days for an average serving to be consumed is very high and, within that, higher at the lower tertile. However,

<table>
<thead>
<tr>
<th>Food</th>
<th>Time to achieve 1 portion of food among the total population, days</th>
<th>Consumers of the food, % of the total population</th>
<th>Time to achieve 1 portion of food among consumers only, days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T3</td>
<td>T1</td>
</tr>
<tr>
<td>White bread</td>
<td>4</td>
<td>14</td>
<td>76</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>6</td>
<td>3</td>
<td>73</td>
</tr>
<tr>
<td>RTE breakfast cereal</td>
<td>3</td>
<td>2</td>
<td>59</td>
</tr>
<tr>
<td>Other cereal</td>
<td>11</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Low-fat milk</td>
<td>3</td>
<td>1</td>
<td>51</td>
</tr>
<tr>
<td>Yogurt</td>
<td>21</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>Eggs</td>
<td>9</td>
<td>12</td>
<td>51</td>
</tr>
<tr>
<td>Fruit juice</td>
<td>9</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Banana</td>
<td>25</td>
<td>8</td>
<td>44</td>
</tr>
</tbody>
</table>

The data are based on the Irish National Adult Nutrition Survey and are presented for the lower (T1) and upper (T3) tertiles of the nutrient-rich food score. RTE, ready to eat.
when nonconsumers are excluded, there is clear evidence that an average portion is consumed about once every 2 days on average for almost all foods. Creating advice to consumers who do not consume a food requires a different strategy than the challenge of asking regular consumers to eat the food more regularly and at higher portions. Most of the progress in changing population habits will be made by the former, that is getting nonconsumers to begin to become consumers. Simple score sheets might arise from the International Breakfast Research Initiative, which will allow educators to help individuals score their breakfast quality based on whether or not they eat a food or how often they consume it.

**Promoting Healthy Breakfasts in the Digital Era**

Unless scientifically strong agencies engage in the use of social media and associated digital technologies to promote healthy eating, the gap will be filled by poorly qualified opportunists. Bearing in mind the growing dominance of the digital revolution in the lives of younger people, there is little choice but to engage with them within this technology. One of the most comprehensive tests of digitally delivered dietary analysis and guidance was the Food4Me study, which covered 1,300 subjects across 7 EU centers over a 6-month period [12]. The results clearly show that the digitally led intervention significantly improved target nutrient intakes. Most of these studies are built around the role of individual foods in delivering a nutritional input. The future will have to abandon a food-by-food approach and focus on meals. Breakfast, which tends to have a constancy of consumption patterns (Table 1), would seem a good place to start. Defining meals using data mining techniques such as decision tree analysis or neural network analysis has proved problematic. This has led to an expert-based approach in deciding the typical dishes chosen for a particular meal, and this has proven the most successful route to date. In an ideal world, a consumer would see images of candidate dishes for that meal on the screen of their digital device. Thus, for breakfast, one image might depict a cereal-based breakfast. Another might depict a coffee-and-croissant or a cooked-meat-and-egg breakfast type. The consumer would click on the dish that they most frequently choose and then, with drop-down menus, refine the image to match exactly their own breakfast. This would be repeated for all eating occasions. Those choices would be entered into the analytical end of the personalized nutrition service, emanating in advice on the daily nutrients, the intakes of which might need to be improved. The suggested eating patterns would be entirely meal based and thus would allow the user to create a weekly
menu towards an optimal diet. Empowering consumers to make choices which best suit them personally is the future, and bland advice such as food pyramids is the past.

Conclusions

Breakfast is without doubt a very important meal and one which is sufficiently constant to merit its own nutrient guidelines and subsequent food-based advice. For any proposal for the development of such to be successful, a number of conditions must be met. The proposals must be based on science, must take account of fortification, must not conflict with WHO targets, and must be amenable to reality checking. Hopefully, the International Breakfast Research Initiative will set this process in motion.

Disclosure Statement

M.J.G. conducts project consultancy with Nestlé and Cereal Partners Worldwide. I.U. has no interests to declare.

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The Importance of Dietary Protein at Breakfast in Childhood

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\textsuperscript{a}Nestlé Research, Vers-chez-les-Blanc, Lausanne, and \textsuperscript{b}Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland

Abstract
In order for the body to maintain a healthy and normal steady state of lean body mass, body proteins constantly undergo breakdown and synthesis. The rate at which lean tissue is synthetized must equal the rate at which it is being broken down in order to maintain body protein levels. During growth, not only is there an increase in the net deposition of protein, but the rates of both protein synthesis and breakdown are also increased leading potentially to an increased demand of dietary protein in conditions of increased turnover. When referring to growth, the growth potential of an individual in height and overall shape tends to be genetically determined so that each individual follows a growth curve canalized in terms of both extent and time course if conditions are favorable, where nutrition status may be classed as such as a favorable condition. To this end, identifying specific moments throughout the day whereby whole body protein balance is in a net negative state may provide key opportunities for specific nutrient provision with the aim of optimizing whole body protein accrual.

Introduction
An important factor influencing the general health and well-being of an individual is the pattern of nutrient intake across the day. Unhealthful meal patterns have been implicated in obesity, cholesterol/lipoprotein levels, glucose metabolism, plasma hormones, caloric density to energy intake, and nutrient utilization \cite{1}. Breakfast is often considered as one of the most important meals of the day as it
is an opportunity to replenish nutrition to the body following a prolonged over-
night fast. Beyond the nutrient replenishment aspect of breakfast, much work has
focused on breakfast consumption and skipping behaviors and their impact on
health outcomes [2], although the causality effect is not clear [3]. However, clear
recommendations relating to the percentage of daily energy that should be con-
sumed at breakfast are lacking. Furthermore, although it is widely accepted that
macronutrients such as carbohydrates are key to replenishing glycogen stores af-
ter sport, very little is known regarding the contribution of protein consumption
at breakfast in establishing a platform for healthy physical growth in children. To
this end, the present work will focus on the physiological consequences of over-
night fasting in children, and the way dietary protein intake at breakfast contrib-
utes to the recovery of whole body protein following an overnight fast.

**Dietary Protein**

Proteins (derived from the Greek word πρώτειος [proteios] meaning “first one”
or “most important one”) are the major functional and structural components of
all the cells in the body and participate in virtually all biological processes occur-
rning in the body. This is achieved by their constituent amino acids that are used
to build and maintain bones, muscles, and skin, and to produce molecules with
important physiological roles, such as enzymes, hormones, neurotransmitters,
and antibodies. To this end, one of the most important aspects and defining char-
acteristics of a given dietary protein from a nutritional standpoint is its amino
acid composition and the capacity of these amino acids to be digested. Beyond
the importance of dietary proteins in the growth and maintenance of body tissue,
they also act as signaling molecules and as a source of energy. Dietary proteins
are composed of 20 amino acids. Of these, 9 are considered to be essential in that
in humans, they cannot be synthesized and are, therefore, required in the diet.

One dietary source providing a nutritionally complete type of dietary protein
in terms of amino acid profile and digestibility is milk. Specifically, an average
glass (≈220–250 mL) of cow’s milk typically contains approximately 7 g of pro-
tein, of which approximately 20% are whey protein fractions while the remain-
ing 80% are composed of casein protein fractions. Although both whey and ca-
sein protein fractions are classed as high-quality dietary proteins, these protein
components of cow’s milk result in very important and disparate physiological
responses. Following the ingestion of whey protein, for instance, the plasma ap-
pearance of dietary amino acids is fast, high, and transient [4]. On the other
hand, casein ingestion results in a slower, lower, and more prolonged response
in terms of plasma amino acid concentrations [4]. In addition, it has previously
been reported in intervention studies carried out in healthy children that whey ingestion stimulates a greater insulin response than casein while casein ingestion results in greater levels of plasma IGF-1 [5]. Therefore, collectively, these differential physiological responses of the main milk protein fractions exhibit important but different metabolic and growth-promoting effects.

**Diurnal Protein Turnover**

When healthy individuals consume regular mixed meals and maintain activities of everyday living, whole body and skeletal muscle protein mass remains essentially unchanged for lengthy periods of time. This is because over time, the rates of protein synthesis approximate the rates of protein breakdown, resulting in the maintenance of whole body protein balance. In the instance where an increase in lean tissue is desired, such as in growing children, it is asserted that the net rate of protein synthesis be greater than the rate of protein breakdown, and this shift must be sustained over time in order to promote overall growth. However, this process is not static and fluctuates across a 24-h period depending on feeding patterns (including macronutrient intake) as well as physical activity duration and type. For example, feeding has been shown to almost double the whole body synthetic response in adults [6], an effect that appears mainly due to the effects of increased amino acid availability (particularly essential amino acids) rather than the feeding-induced increase in insulin concentrations. Evidence to support this contention comes from investigations that have “clamped” insulin levels (by the use of somatostatin and analogs) and still observed robust increases in protein synthesis [7]. Increased amino acid availability not only provides substrates for protein synthesis but also directly modulates intracellular signaling events regulating initiation and elongation phases of mRNA translation [7]. On the other hand, increased insulin availability as observed in the postprandial state following a meal containing carbohydrates has been shown to directly attenuate the rates of protein breakdown [7].

**Dietary Protein in Children**

Dietary protein in children is important for maintaining the growth and remodeling of tissues like bones and muscles [8]. Current recommendations for dietary protein in children do not distinguish between specific times of the day, are similar to those in healthy adults (0.92 vs. 0.83 g/kg per day, respectively), and are assumed to be adequate to ensure a positive nitrogen balance for optimal growth in all children [9]. In contrast to adults, children are in a constant growth
phase with a typical growth rate of approximately 5 cm and growth weight of approximately 3 kg per year up to the age of ∼10 years of age [10].

Identifying key moments whereby dietary protein may be beneficial in children’s physical growth and development has recently been investigated. Specifically, it was recently reported that following exercise, physically active healthy children are in a state of negative whole body protein balance and that protein ingestion immediately following cessation of exercise is able to promote a positive balance in a dose-dependent manner [11]. However, it seems that more is not necessarily better. For instance, recent work suggests that evenly distributing 15 g of dietary protein 4 h apart following cessation of exercise resulted in greater whole body protein balance over a 24-h period than 15 g immediately or 4 h after exercise cessation in children [12].

However, increased intakes of dietary protein in early childhood beyond that of the current recommendations have been associated with increased risk of childhood obesity [13, 14]. Furthermore, the source of dietary protein may also be important as studies have shown stronger associations between high animal-sourced protein intake and higher body weight compared to plant-sourced proteins with the increased weight resulting from greater adiposity [15]. In contrast, further recent work on the longitudinal association of increased dietary protein intake in children reported that higher protein intake in mid-childhood (8 years of age) was associated with increased fat-free mass at 10 years of age. Furthermore, the authors also reported that protein intake from plant sources was beneficial for body composition in these school-age children [16]. The exact reasons behind these observations are not clear. However, it has been proposed to be due to the “early protein hypothesis,” which states that protein intake in early life can stimulate adipogenesis and decrease lipolysis when it is consumed at a level beyond what is utilized for maintenance and growth [17].

Although randomized clinical trials supporting such observations are lacking in older children, this suggests a potential upper limit in dietary protein utilization into lean tissue in younger children, although it is yet to be determined whether this phenomenon persists in later childhood. Therefore, it may be that children require distinct nutritional strategies enabling an adequate daily dietary protein intake which may in part be driven by daily physical activity levels as well as the age of the child [8].

Protein at Breakfast

It has long been acknowledged that the pattern and not just the absolute amount of dietary protein can influence nitrogen retention in both adults and children [18, 19]. According to the latest NHANES (National Health and Nu-
The Importance of Dietary Protein at Breakfast

According to the Nutrition Examination Survey data, the dietary intake patterns for protein and energy of children in the USA are skewed towards the evening meal occasion, with the breakfast occasion reporting the least intake on any given day while the evening occasion reporting up to ~200% of the recommended daily intake for protein [20]. Studies in adults have shown that net protein balance is negative following an overnight fast with protein ingestion in the morning stimulating protein synthesis and inducing a positive net protein balance in lean tissues (including muscles) [21–23]. Moreover, the overnight fasted protein losses are offset by fed-state gains [24, 25], which demonstrates the diurnal variations observed in nitrogen and protein metabolism in weight-stable adults.

However, in the context of healthy children who undergo accelerated growth compared to adults, the breakfast occasion may actually be a key moment for protein ingestion in terms of promoting a physiological environment to sustain these growth requirements. Indeed, we recently reported that following a 10-h sleep, children were in a net negative state of whole body protein balance with whole body breakdown being greater than that of the rate of whole body protein synthesis [26] (Fig. 1). Furthermore, the ingestion of carbohydrates in the absence of protein at breakfast was enough to attenuate the observed overnight losses. However, the addition of protein at breakfast promoted a positive net whole body protein balance by stimulating increases in protein synthesis (Fig. 2). Therefore, the consumption of ~7 g of milk proteins at breakfast in combination with carbohydrates may be an adequate nutritional strategy to promote lean tissue accrual.

**Fig. 1.** Hypothetical diagram highlighting diurnal variations in whole body protein balance as a function of meal timing and quantity representative of Western eating behaviors.
In recent times, a great deal of current research has started focusing on the interaction between the circadian timing system, metabolic physiology, and nutritional science. These circadian oscillations are driven by the existence of underlying intrinsic biological clocks with near 24-h periods. Understanding how such systems interact with the nutrient uptake and utilization at the metabolic level is currently being researched as a means to optimize metabolic functioning in response to nutrition. For example, it has long been reported that the pattern and not just the absolute amount of dietary protein can influence nitrogen retention in both adults and children [18, 19], as well as leucine balance in adults [27]. Recently, emphasis has been placed on the breakfast eating occasion with particular interest on the role of dietary protein intake at breakfast to enhance protein balance, which is negative following an overnight fast [28, 29]. Recent research in adults has demonstrated that an even distribution of dietary protein in adults (90 g of protein evenly throughout the day; 3 × 30 g) resulted in greater muscle fraction synthetic rates than consuming the same amount of protein (90 g) in a skewed fashion (10, 15, and 65 g at breakfast, lunch, and dinner, re-
spectively) [30]. On the one hand, this may indicate the need to consume greater amounts of protein at breakfast. On the other hand, this may highlight the importance of an overall threshold of protein intake that needs to be reached at each meal. Nonetheless, it seems that collectively current research suggests that meal protein intakes and distribution may help to optimize protein metabolism and net protein balance in adults [31].

However, to date, there is little research on the impact of discrete meal protein intake and daily distribution on protein metabolism and whole body net balance in healthy active children. In a recent 24-h controlled clinical trial, a skewed pattern of dietary protein intake seemed to promote greater gains in whole body protein balance compared to a more balanced daily protein intake in children consuming a high-protein diet [26]. It may be that the habitual daily dietary protein intake above the current recommendations for children could potentially mask any impact of the dietary pattern on whole body protein balance. For instance, it has previously been reported that greater intakes of dietary protein (2 g/kg·per day) result in reduced efficiency of postprandial nitrogen retention compared with normal protein intakes (1 g/kg·per day) [32].

In light of the previously reported associations and clinical trials linking increased protein intake with increased adiposity in children, further work should explore the longer-term implications of protein distribution on body composition. This in turn may elicit a viable way to provide the protein needs required for healthy physical growth in children while at the same time limiting the current excessive intake. Furthermore, better targeting the key moments in the life of a healthy physically active child, such as breakfast and the time following exercise/play, could likely provide an increased efficiency of dietary protein utilization while minimizing any detrimental effects of increased dietary protein intake in children.

**Conclusion**

In terms of nutrient availability, current research supports the concept of nutrient intake timing. Specifically, similar to adults, a typically observed overnight fast in children (i.e., a ∼10-h overnight fast) has recently been shown to result in a physiological state of increased catabolism as measured by increased rates of whole body protein breakdown. It is, therefore, important that specific amounts of protein be consumed at breakfast in order to attenuate such losses in whole body protein providing an environment that supports healthy physical growth and development. Specifically, consuming as little as 7 g of milk protein as part of a carbohydrate-containing breakfast seems to be sufficient to promote a positive net protein bal-
ance which persists up to 9 h following breakfast consumption when habitual diet and activity are controlled. Future research utilizing long-term studies are ultimately required to validate whether or not the benefits observed in the short term are translated to long-term benefits in terms of promoting increased lean tissue mass and, therefore, favorable body composition in healthy active children.

Disclosure Statement

At the time of presenting and writing, the author was employed at the Nestlé Research Center.

References

Importance of Breakfast for Children’s Health and Development


Abstract

Breakfast has long been promoted as the most important meal of the day. However, the lack of standard definitions of breakfast, breakfast consumers, and breakfast skippers, and the lack of a description of how “important” the meal is, especially compared with other meals, has hampered the ability to confirm this long-held belief. This review discusses potential definitions of breakfast and breakfast skippers, and how these definitions can affect how researchers, nutrition educators, and policy makers interpret data and make recommendations. Overall, breakfast, especially meals including ready-to-eat cereal, contributes to overall nutrient intake and diet quality. However, the association of breakfast consumption and weight parameters or cognition in children is controversial. Finally, challenges, opportunities, and research gaps with breakfast studies are discussed. The question of whether breakfast is the most important meal of the day remains unanswered.

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Introduction

What do 朝ごはん, Frühstück, desayuno, almusal, aamiainen, bůa ăn sáng, sohar yemoyi, parakuhi, and lijo tsa hoseng have in common? They all mean breakfast – the meal that literally “breaks the fast.” But these terms mean some-
thing very different to the different cultures that use these words for the first meal of the day. In Japan, breakfast may consist of white rice, natto, fried eggs, tofu, miso soup, and tea. In Germany, cheese, meat (especially sausages), boiled eggs, fruit, and vegetables, smoked fish, and hearty, seeded breads with jam and honey are served. In Spain, breakfast is simply café con leche and a small roll or pastry. Even in countries using a common language, for example English, traditional breakfasts are different. In Great Britain, baked beans, black pudding, and grilled tomatoes are typical fare; however, these foods are seldom consumed for breakfast in the USA. As shown below in the nutrient intake and weight sections, within the USA, there is a wide variety of foods consumed at breakfast [1, 2].

For people living in different countries, when someone uses the local term for breakfast, there is a common understanding of what is meant. However, there is no standard definition for breakfast, for a nutritious breakfast, or for breakfast skipping. This is a problem for scientists looking at the effect of breakfast consumption on daily nutrient intake, weight, and other physiologic parameters, or cognition. The lack of any standard definition makes it difficult to interpret the literature.

A wide variety of definitions of breakfast and breakfast skipping has been used in the literature [3], including: “any energy-containing food or beverage (excludes water but not black tea/coffee) consumed between 5 a.m. and 9.30 a.m.,” “any food and/or beverage reported as consumed in the morning or for breakfast or desayuno (Spanish equivalent of breakfast), or brunch,” and “the first meal of the day, eaten before or at the start of daily activities, within 2 h of waking, typically no later than 10 a.m., and of a calorie level between 20 and 35% of total daily energy needs.” Definitions of breakfast skipping included “skip breakfast at least one time per week,” “skip breakfast at least six times per week,” and “not eating a morning meal at home.” These definitions, especially for the breakfast skippers, are at best inconsistent and at worst inappropriate. They also demonstrate how individuals can be placed into the wrong categories for statistical analysis in breakfast studies.

The majority of studies examining the effects of breakfast have been epidemiologic but not clinical trials. Results of any epidemiologic study will be greatly affected by these varying definitions for individual studies, since individuals can easily be placed in incorrect breakfast consumption/skipping groups for analysis. This alone could account for the conflicting results of research related to breakfast consumption [3]. Since it is so difficult to determine the effect of breakfast consumption on physiologic and behavioral parameters, the body of evidence, not an individual study, must be considered.

There is no formal recommendation for consuming breakfast, although the 2015–2020 Dietary Guidelines for Americans (DGA) [4] include breakfast meal
patterns and the 2015–2020 DGA Advisory Committee (DGAC) [5] discusses the nutrient contribution of breakfast. This is a departure from the 2010 DGA, which recommended a “nutrient-dense” breakfast [6] – without actually defining one. Having neither a recommendation for consuming breakfast nor a standard definition has implications for researchers, nutrition educators, and policy makers [3, 7].

The lack of a standard definition also makes it difficult to answer the question: *Is breakfast the most important meal of the day?* How can we know this if we do not know what breakfast is? It is also unclear what is meant by “important” [8]. Important how: To nutrient contribution? To health and weight management? To cognition and school or work performance? These 3 questions are discussed below. But a key, unanswered question is: Has breakfast been adequately compared with other meals/snacks? And the answer to that question is no.

**Nutrient Contribution of the Breakfast Meal**

Data from What We Eat in America (WWEIA) 2013–2014 [9] show that dinner was the most consumed meal of the day, followed by breakfast and lunch; 86% of Americans 2 years of age and older consumed breakfast. Consumption of breakfast varied by age and gender with children 2–5 years of age having the highest levels of consumption, and adolescents (12–19 years) and young adults (20–29 years) the lowest levels. On average, breakfast has a higher overall diet quality because of its higher nutrient density compared to other meals and snacks. For children 2–19 years, breakfast supplied 18% of energy, 40% of the vitamin D recommendation, 25% of calcium, 31% of iron, and only 15% of the sodium recommendation. Breakfast supplies up to 33% of the recommendations for B vitamins. For nutrients to limit, breakfast supplies 17% of the daily intake of saturated fatty acids and 15% of sodium.

There is room for improvement in the nutrient intake at breakfast. The percent contribution of 3 of the 4 nutrients of public health concern (fiber, vitamin D, calcium, and potassium) – fiber (36%), calcium (29%), and potassium (35%) – was highest at the dinner meal. Many of these nutrients are found in foods, such as whole grains, dairy products, and fruit, which are commonly consumed at breakfast, suggesting an opportunity for encouraging consumption of these foods at breakfast. Only vitamin D intake (36%) was highest at breakfast. Breakfast supplied the lowest percentage intake of saturated fatty acids, and only snacks (14%) provided a lower intake of sodium. The average contribution of breakfast to energy, protein, shortfall nutrients, and nutrients to limit [5] to the American diet is shown in Table 1 [9].
Table 1. The contribution of energy, protein, nutrients of concern, and nutrients to limit from breakfast to the American diet in children and adults: What We Eat in America 2013–2014

<table>
<thead>
<tr>
<th>Gender and age, years</th>
<th>Percent reporting</th>
<th>Energy</th>
<th>Protein</th>
<th>Fiber</th>
<th>Choline</th>
<th>Vitamins C</th>
<th>A (RAE)</th>
<th>D</th>
<th>E</th>
<th>Ca</th>
<th>Mg</th>
<th>Fe</th>
<th>K</th>
<th>Na</th>
<th>SFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/F 2–19</td>
<td>84 (1.5)</td>
<td>18 (0.4)</td>
<td>17 (0.5)</td>
<td>18 (0.5)</td>
<td>25 (0.9)</td>
<td>25 (1.5)</td>
<td>33 (0.9)</td>
<td>40 (1.0)</td>
<td>17 (1.3)</td>
<td>25 (0.6)</td>
<td>19 (0.3)</td>
<td>31 (1.0)</td>
<td>20 (0.5)</td>
<td>15 (0.4)</td>
<td>17 (0.5)</td>
</tr>
<tr>
<td>M 2–19</td>
<td>85 (1.5)</td>
<td>18 (0.6)</td>
<td>17 (0.9)</td>
<td>19 (0.8)</td>
<td>25 (1.3)</td>
<td>28 (2.2)</td>
<td>34 (1.4)</td>
<td>39 (1.4)</td>
<td>18 (1.9)</td>
<td>25 (0.9)</td>
<td>20 (0.6)</td>
<td>32 (1.7)</td>
<td>20 (0.7)</td>
<td>16 (0.5)</td>
<td>18 (0.8)</td>
</tr>
<tr>
<td>F 2–19</td>
<td>84 (1.9)</td>
<td>17 (0.5)</td>
<td>17 (0.6)</td>
<td>16 (0.5)</td>
<td>25 (0.9)</td>
<td>21 (1.5)</td>
<td>32 (1.2)</td>
<td>40 (1.2)</td>
<td>15 (0.7)</td>
<td>24 (0.8)</td>
<td>19 (0.5)</td>
<td>30 (1.0)</td>
<td>19 (0.6)</td>
<td>15 (0.6)</td>
<td>17 (0.8)</td>
</tr>
<tr>
<td>M/F 20+</td>
<td>86 (0.7)</td>
<td>17 (0.3)</td>
<td>16 (0.2)</td>
<td>19 (0.4)</td>
<td>24 (0.4)</td>
<td>24 (0.7)</td>
<td>28 (0.6)</td>
<td>35 (1.2)</td>
<td>19 (0.5)</td>
<td>23 (0.4)</td>
<td>20 (0.3)</td>
<td>27 (0.6)</td>
<td>20 (0.3)</td>
<td>15 (0.3)</td>
<td>17 (0.3)</td>
</tr>
<tr>
<td>M 20+</td>
<td>84 (1.0)</td>
<td>17 (0.3)</td>
<td>16 (0.3)</td>
<td>19 (0.5)</td>
<td>23 (0.4)</td>
<td>24 (0.8)</td>
<td>29 (0.8)</td>
<td>34 (2.0)</td>
<td>19 (0.7)</td>
<td>22 (0.6)</td>
<td>19 (0.4)</td>
<td>27 (0.8)</td>
<td>19 (0.3)</td>
<td>15 (0.5)</td>
<td>17 (0.5)</td>
</tr>
<tr>
<td>F 20+</td>
<td>87 (0.8)</td>
<td>17 (0.4)</td>
<td>17 (0.3)</td>
<td>19 (0.5)</td>
<td>24 (0.4)</td>
<td>23 (1.0)</td>
<td>26 (0.7)</td>
<td>36 (1.3)</td>
<td>19 (0.6)</td>
<td>24 (0.4)</td>
<td>21 (0.3)</td>
<td>27 (0.7)</td>
<td>21 (0.3)</td>
<td>14 (0.4)</td>
<td>17 (0.5)</td>
</tr>
</tbody>
</table>

Nutrients of concern include shortfall nutrients identified by the 2015–2020 Dietary Guidelines for Americans (DGA): vitamins C, A, and E, magnesium (Mg), choline, and iron (Fe) (for young children and females 19–50 years of age) and nutrients of public health concern, originally identified by the 2010 DGA: dietary fiber, vitamin D, calcium (Ca), and potassium (K). Nutrients to limit are sodium (Na) and saturated fatty acids (SFA); note that added sugars are not available through these data. All values (except gender, age, and percent reporting) are presented as percent contribution to the diet (standard error). RAE, retinol activity equivalents.

Children who skipped breakfast have been shown to have lower intakes of fiber; vitamins A, E, C, B₆, and B₁₂; folate; iron; calcium; phosphorus; magnesium; and potassium [10]. Adults who skipped breakfast had lower intakes of all micronutrients examined except sodium [11]. Children [12] and adults [11] who skipped breakfast did not compensate for the nutrients missed at other meals.

Most of the articles that have examined the effect of breakfast consumption have considered only 2 categories – “breakfast” versus “no breakfast” – apparently assuming that all breakfast meals are created equally. Cho et al. [13], using data from NHANES III (the third National Health and Nutrition Examination Survey), suggested that different types of breakfast were associated with different health parameters, for example, weight. Those findings led to the examination of “types of breakfast” with different parameters, including nutrient intake [12, 14]. Using more recent data from NHANES, the mean adequacy ratio of 5 shortfall nutrients (i.e., vitamin E, calcium, magnesium, potassium, and fiber) and 13 micronutrients was lowest in breakfast skippers, followed by “other breakfast” consumers, and highest in ready-to-eat cereal (RTEC) consumers [12]. In that study, breakfast was self-defined and “other breakfasts” were not defined; pre-sweetened RTEC (PSRTEC) and RTEC were combined into a single category. Subsequently, it was shown that those consuming PSRTEC also had significantly higher nutrient intakes than those consuming “other breakfasts” [15].

The nutrient contribution of breakfast patterns has been examined in children [1] and adults [2] participating in NHANES, thus helping to define “other breakfasts” and demonstrating the importance of examining what was actually consumed for breakfast. Twelve breakfast patterns, including no breakfast, were identified for children [1] and adults (Table 2) [2]. Placement into most breakfast patterns was associated with higher intakes of nutrients of public health concern; exceptions were: pattern 4 – fiber, vitamin D and calcium; patterns 5, 6, and 9 – fiber; pattern 8 – fiber and vitamin D; pattern 10 – fiber, vitamin D, calcium, and potassium; and pattern 12 – vitamin D and calcium. Assessment of diet quality, using the Healthy Eating Index (HEI) 2005, showed that children in patterns 1, 3, 7, 11, and 12 had higher diet quality and those consuming pattern 10 had a lower diet quality than those consuming no breakfast. Table 3 shows the $β$-coefficients for energy, nutrients to limit, shortfall nutrients, and the HEI scores for the breakfast patterns of children.

Adults [2] also showed significant differences in nutrient intake, but diet quality was perhaps the most interesting result of this study. Of the 12 breakfast patterns, only patterns 1, 3, 4, 6, 8, 10, and 12 were associated with a higher diet quality than no breakfast. Breakfast patterns 5, 7, 9, and 11 were not different from no breakfast.
Together, the data from these studies clearly underscore the problem with understanding the association of nutrient intake and breakfast consumption when considering only the generic term “breakfast.” They also support the repeated finding that RTEC, including PSRTEC, consumption is associated with higher nutrient intake and diet quality.

### Table 2. Breakfast clusters by name, number, and percent of consumers in children and adults: National Health and Nutrition Examination Survey: 2001–2008

<table>
<thead>
<tr>
<th>Cluster No./name</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Grain/LFM/sweets/FJ</td>
<td>3,096 (21.8)</td>
<td>4,714 (24.5)</td>
</tr>
<tr>
<td>2 No breakfast</td>
<td>2,655 (18.7)</td>
<td>3,789 (18.8)</td>
</tr>
<tr>
<td>3 PSRTEC/LFM</td>
<td>2,158 (15.2)</td>
<td>2,238 (12.2)</td>
</tr>
<tr>
<td>4 Grain</td>
<td>1,164 (8.2)</td>
<td>1,725 (10.1)</td>
</tr>
<tr>
<td>5 Eggs/grain/MPF/FJ</td>
<td>951 (6.7)</td>
<td>1,436 (6.7)</td>
</tr>
<tr>
<td>6 PSRTEC/whole milk</td>
<td>923 (6.5)</td>
<td>1,109 (6.0)</td>
</tr>
<tr>
<td>7 RTEC/LFM</td>
<td>866 (6.1)</td>
<td>810 (5.0)</td>
</tr>
<tr>
<td>8 Soft drinks/FJ/grain/potatoes</td>
<td>738 (5.9)</td>
<td>1,044 (4.8)</td>
</tr>
<tr>
<td>9 RTEC/whole milk</td>
<td>582 (4.1)</td>
<td>1,002 (4.5)</td>
</tr>
<tr>
<td>10 MPF/grain/FJ</td>
<td>497 (3.5)</td>
<td>430 (3.0)</td>
</tr>
<tr>
<td>11 Cooked cereal/milk/FJ</td>
<td>355 (2.5)</td>
<td>361 (2.4)</td>
</tr>
<tr>
<td>12 Whole fruit</td>
<td>114 (0.8)</td>
<td>330 (2.0)</td>
</tr>
<tr>
<td>Total</td>
<td>14,200 (100.0)</td>
<td>18,988 (100.0)</td>
</tr>
</tbody>
</table>

C&S, cream and sugar; FJ, 100% fruit juice; LFM, low-fat milk (all milk except whole milk); MPF, meat/poultry/fish; PSRTEC, presweetened ready-to-eat cereal; RTEC, ready-to-eat cereal.

### Breakfast and Weight

A widely held belief among many health professionals is that consumption of breakfast is associated with lower weight; studies also suggest that consumption of breakfast also helps individuals lose weight or maintain a weight loss. So established were these beliefs that the 2010 DGA [6] recommended the public to “eat a nutrient-dense breakfast. Not eating breakfast has been associated with excess body weight, especially among children and adolescents. Consuming breakfast also has been associated with weight loss and weight loss maintenance, as well as improved nutrient intake.”

However, at the time of the 2015–2020 DGA [4], the recommendation had changed: “Healthy eating patterns can accommodate other nutrient-dense foods with small amounts of added sugars, such as whole-grain breakfast cereals or...
Table 3. Comparison of β-coefficients ± SE for energy, nutrients to limit, Healthy Eating Index (HEI), and shortfall nutrients by breakfast cluster compared with no breakfast (pattern 2) for children participating in NHANES 2001–2008

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>grain/LFM/soft drink/FJ</td>
</tr>
<tr>
<td>Energy, kcal</td>
<td>±34.31^d</td>
</tr>
<tr>
<td>Added sugar, tsp</td>
<td>±0.74</td>
</tr>
<tr>
<td>SFA, g</td>
<td>±4.81</td>
</tr>
<tr>
<td>Solid fat, g</td>
<td>±9.03</td>
</tr>
<tr>
<td>Na, mg</td>
<td>±73.20^d</td>
</tr>
<tr>
<td>HEI</td>
<td>±5.00^d</td>
</tr>
<tr>
<td>Dietary fiber, g</td>
<td>±0.32^d</td>
</tr>
<tr>
<td>Vitamin D3, μg</td>
<td>±2.37</td>
</tr>
<tr>
<td>Ca, mg</td>
<td>±28.71^d</td>
</tr>
<tr>
<td>K, mg</td>
<td>±53.75</td>
</tr>
<tr>
<td>Vitamin C, mg</td>
<td>±4.25^d</td>
</tr>
<tr>
<td>Vitamin A, RAE μg</td>
<td>±22.04^d</td>
</tr>
<tr>
<td>Folate, μg DFE</td>
<td>±12.52^d</td>
</tr>
<tr>
<td>Mg, μg</td>
<td>±57.64</td>
</tr>
</tbody>
</table>

Data source: children 2–18 years of age participating in NHANES 2001–2008. DFE, dietary folate equivalent; FJ, fruit juice; LFM, low-fat milk; MPF, meat, poultry, and fish; PSRTEC, presweetened ready-to-eat cereal; RAE, retinol activity equivalents; RTEC, ready-to-eat cereal; SFA, saturated fatty acids; tsp, teaspoon. ^p < 0.05; ^p < 0.01; ^p < 0.001; ^p < 0.0001.

fat-free yogurt, as long as calories from added sugars do not exceed 10 percent per day, total carbohydrate intake remains within the AMDR, and total calorie intake remains within limits.” So, although there are comments about breakfast, there was no specific recommendation for consuming this mean or no recommendation regarding weight loss or maintenance.
Why the change in recommendations? For the most part, the study designs examining breakfast consumption and weight have been prospective cohorts or cross-sectional, where cause and effect cannot be determined. These studies, alone and when included as part of systematic reviews, have produced inconsistent results [3, 16, 17]. Recent clinical trials that have examined the association between breakfast consumption and weight have shown that body weights in the breakfast/no-breakfast groups were not different after 6 or 16 weeks [8, 18].

Many of the studies of breakfast consumption and weight have been hampered by the lack of a standard definition of breakfast, poor study design, small sample sizes, biased reporting of results, incorrect citing of the results of others, and inadequate control groups for the clinical trials [19]. The use of anecdotal evidence, such as that provided by the National Weight Control Registry, supporting the role of breakfast as a behavioral strategy for weight loss [20], does not add significantly to the body of literature.

One of the most important limitations in many of the articles has been the failure to include the type of breakfast consumed. As seen when evaluating the nutrient contribution of breakfast to total nutrients consumed, assessment of different types of breakfast meals may be important when looking at the effect that breakfast has on weight. Studies have shown that those consuming different breakfast meals, notably those containing RTEC, were significantly more likely to have lower body mass indices (BMIs) than those consuming other breakfasts or breakfast skippers [1–3, 12, 13].

Data from NHANES III were analyzed, and 10 breakfast categories were identified: skippers, meat/eggs, RTEC, cooked cereal, breads, quick breads, fruits/vegetables, dairy, fats/sweets, and beverages [13]. Those that were placed into the RTEC, cooked cereal, or quick bread patterns for breakfast had significantly lower BMIs than skippers and those in the meat/egg pattern. Skippers and fruit/vegetable eaters had the lowest daily energy intake. Those in the meat/egg pattern had the highest daily energy intake and one of the highest mean BMIs.

There are several ways to assess the association between breakfast consumption and weight parameters. For children, the likelihood that placement into a specific breakfast pattern [1], compared with no breakfast, was associated with a lower risk of overweight or obesity is shown in Figure 1. The risk of overweight was lower only in patterns 6 and 7. The risk of obesity was lower in patterns 1, 9, and 11. Although not shown graphically, the risk of overweight or obesity was lower for children placed in patterns 1, 6, 7, and 9, when compared with no breakfast. These data clearly show how combining all types of breakfast or limiting studies to RTEC and “other breakfast” can lead to inconsistent results.

In adults [2], only those placed in patterns 1, 4, 6, and 8 had a lower mean BMI and percent elevated waist circumference than those consuming no break-
It is clear that the type of breakfast is important when assessing the effects of “breakfast consumption” on nutrient intake and weight parameters on consumers. It is critical that the type of breakfast be included in the evaluation of the effect of breakfast consumption on any health parameter, since the use of a “generic definition” can itself cause inconsistent results.

Fig. 1. The odds of children 2–18 years of age (n = 14,200) participating in NHANES 2001–2008 being overweight or obese by breakfast consumption pattern: 1, grain/low-fat milk (LFM)/sweets/fruit juice (FJ); 2, no breakfast (comparison group); 3, presweetened ready-to-eat cereals (PSRTEC)/LFM; 4, grain; 5, eggs/grain/meat, poultry, fish (MPF)/FJ; 6, PSRTEC/whole milk; 7, RTEC/LFM; 8, soft drinks/FJ/grain/potatoes; 9, RTEC/whole milk; 10, MPF/grain/FJ; 11, cooked cereal/milk/FJ; 12, whole fruit; LCL, lower confidence limit; UCL, upper confidence limit. p < 0.0042.
Another benefit of breakfast consumption that has long been promulgated is improvement in cognitive performance in school-age children by improving memory, reaction time, vigilance, attention, problem-solving and arithmetic tasks, and logical reasoning. Systematic reviews have examined these relationships \([21–24]\) as well as psychological processes \([25]\). In one recent systematic review \([24]\), 45 studies in 43 articles were reported. The majority \((n = 34)\) only considered the acute effect of a single breakfast meal, and performance was usually assessed within 4 h of breakfast. These studies compared results with breakfast skippers \((n = 24)\) or with a comparison of different types of breakfast \((n = 15)\). Although, breakfast consumption generally showed some short-term (i.e., same morning) positive associations with these outcomes, results were inconsistent across the cognitive domain and types of breakfasts consumed. Results also appeared to be strongest in children who were nutritionally vulnerable. Firm conclusions about the acute effect of specific breakfast types were unable to be drawn \([24]\). Subsequent work by these authors reviewed methodological challenges associated with these types of studies \([26]\).

From a systematic review on the effects of breakfast and breakfast composition on cognition in children and adolescents, firm conclusions could not be

**Table 4.** Weight parameters by breakfast pattern in adults \(\geq 19\) years of age participating in 2001–2008 NHANES (least-square means \(\pm SE\)) (modified from O’Neil et al. \([2]\))

<table>
<thead>
<tr>
<th>Pattern No.</th>
<th>Pattern</th>
<th>BMI</th>
<th>Elevated WC, %</th>
<th>Overweight, %</th>
<th>Obese, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grain/FJ</td>
<td>28.09±0.16*</td>
<td>50±0.01*</td>
<td>34±0.01</td>
<td>31±0.01*</td>
</tr>
<tr>
<td>2</td>
<td>No breakfast</td>
<td>28.89±0.16</td>
<td>55±0.01</td>
<td>34±0.01</td>
<td>36±0.01</td>
</tr>
<tr>
<td>3</td>
<td>Grain</td>
<td>28.58±0.18</td>
<td>52±0.01</td>
<td>34±0.01</td>
<td>35±0.01</td>
</tr>
<tr>
<td>4</td>
<td>PSRTEC/LFM</td>
<td>27.71±0.23*</td>
<td>48±0.02*</td>
<td>33±0.01</td>
<td>29±0.02*</td>
</tr>
<tr>
<td>5</td>
<td>Eggs/grain/MPF</td>
<td>28.85±0.27</td>
<td>55±0.02</td>
<td>35±0.02</td>
<td>36±0.02</td>
</tr>
<tr>
<td>6</td>
<td>RTEC/LFM/fruit/FJ</td>
<td>27.83±0.25*</td>
<td>48±0.02*</td>
<td>35±0.02</td>
<td>28±0.02*</td>
</tr>
<tr>
<td>7</td>
<td>Coffee/C&amp;S/sweets</td>
<td>28.33±0.31</td>
<td>52±0.03</td>
<td>37±0.02</td>
<td>32±0.03</td>
</tr>
<tr>
<td>8</td>
<td>Cooked cereal</td>
<td>27.20±0.25*</td>
<td>46±0.02*</td>
<td>34±0.02</td>
<td>26±0.02*</td>
</tr>
<tr>
<td>9</td>
<td>MPF/grain/eggs</td>
<td>29.80±0.37</td>
<td>61±0.02</td>
<td>31±0.02</td>
<td>41±0.02</td>
</tr>
<tr>
<td>10</td>
<td>LFM/whole fruit</td>
<td>27.94±0.43</td>
<td>50±0.04</td>
<td>34±0.03</td>
<td>30±0.03</td>
</tr>
<tr>
<td>11</td>
<td>Coffee</td>
<td>28.04±0.34</td>
<td>49±0.03</td>
<td>31±0.03</td>
<td>30±0.03</td>
</tr>
<tr>
<td>12</td>
<td>Whole fruit</td>
<td>27.34±0.52</td>
<td>47±0.04</td>
<td>29±0.04</td>
<td>27±0.04</td>
</tr>
</tbody>
</table>

Elevated waist circumference (WC) was defined as \(>102\) cm for men and \(>88\) cm for women. Covariates: age, gender, race/ethnicity, poverty income ratio grouped into 3 categories as \((<1.25, 1.25–3.49,\) and \(>3.49)\), current physical activity level (sedentary, moderate, and vigorous), smoking (yes/no), and alcohol intake (g/day). C&S, cream and sugar; FJ, fruit juice; LFM, low-fat milk; MPF, meat, poultry, and fish; PSRTEC, presweetened ready-to-eat cereal; RTEC, ready-to-eat cereal. * \(p \leq 0.0042\) vs. no breakfast.
drawn since there were too few studies, and findings were inconsistent [24]. “Seven of the eight studies of chronic consumption of breakfast demonstrated equivocal findings for attention in both well- and under-nourished children” [24].

Many of the acute studies [24] had serious design flaws, limiting their generalizability. These included small sample sizes; overrepresentation of certain age groups; artificial situations with a lack of an ad libitum breakfast meal; and laboratory-based studies rather than school-based studies. A number of physiological mechanisms that may have affected the test results were explored; however, there are many other reasons on how children perform on tests. These include innate ability, acute or chronic illness, sleep amount/quality before the tests, interest in school or the test, current mood, and learning disabilities. Other outside influences include exposure to parental discord or neglect, lack of investment in the child, e.g., they do not read to the child; low socioeconomic status; and English may not be the child’s first language, to low-achieving schools.

It is important to design studies that are sufficiently powered with power calculations based on actual effect sizes; that are more field based; that have more realistic ad libitum breakfasts, and that use cognitive function tests with proven sensitivity that cover a variety of cognitive domains [24] to understand the potential relation of breakfast consumption and cognitive performance. A recent rigidly controlled crossover clinical trial with a repeated-measure design was conducted in children 8–10 years of age [27]. Participants were rigidly screened and excluded if they were obese; had a history of learning disabilities, sensory impairments, mood disorders, acute or chronic disease, or attention deficit hyperactivity disorder; or were taking medications. The study was powered at 80%.

Children (n = 128) were admitted to a metabolic research unit 15 h before the morning experimental procedures began. They were subjected to a physical examination, screened for conditions that could affect test results, and fed 1 of 2 isocaloric dinners. A predetermined Latin-square design for assignment of the 6 possible sequences of the 3 different treatments was used: no breakfast and 1 of 2 similar breakfast options. After spending the night in the metabolic research unit, participants had preprandial serum glucose and ketone levels measured to ensure the child could continue with the test. Children were fed a breakfast or given no breakfast at a specific time and underwent a battery of neuropsychological tests, including measures of attention, impulsivity, short-term memory, cognitive processing speed, and verbal learning 2 h later. There were no significant differences seen in children who consumed breakfast or did not for any of the neuropsychological measures administered. Thus, this carefully conducted study showed that breakfast consumption had no short-term effect on neuro-
psychological functioning in healthy school-age children. More of these studies, along with studies of habitual breakfast consumption, are needed to confirm and extend these results [26].

Challenges, Opportunities, and Research Gaps with Breakfast Studies

Making any type of widespread statement about breakfast and any potential benefits is severely hampered by the lack of a standard definition of breakfast. This has been cited repeatedly as a limitation to individual studies examining the effect that breakfast has on nutrient intake and health, but it is also a major problem when trying to interpret systematic review articles or meta-analyses. For nutrition educators or policy makers, it is difficult to know what the best foods to recommend are and what the best times to serve them are. Should “breakfast,” a term that most individuals understand implicitly, as it relates to their culture, be defined using groups of foods, or by a specific energy, macronutrient, or micronutrient prescription? These elements have been suggested as definitions of a quality breakfast [3], a nutrient-dense breakfast [6], or an ideal breakfast [28].

Should the definition of breakfast be forced into a time frame? Many of the proposed definitions fall into an arbitrary time frame that may not fit the needs of all, notably the millions of individuals who work the evening or night shifts or others with erratic work or school schedules [3]. Equally, should the definition be dictated as to place? One of the definitions given earlier in this paper for breakfast skippers considered only breakfast consumed at home. This eliminates as consumers the more than 14 million children who participate in the School Breakfast Program [29] and those children and adults consuming breakfasts away from home.

Finally, when considering if breakfast is the most important meal of the day, the effects need to be compared with those of other meals. While the nutrient contribution of other meals is available through WWEIA [9], an intensive study of lunch and dinner meals as they are linked to weight and cognition has not been conducted.

Conclusion

Foods consumed at the breakfast meal are culturally different, but to most individuals, when they hear the local word for “breakfast,” it is understood what is meant. However, for researchers, nutrition educators, and nutrition policy makers, there is no standard definition of breakfast, breakfast consumers, or breakfast skippers. This hinders interpretation of individual articles and makes it dif-
ficult to compare the literature. It has also led to conflicting results, compound-
ing the difficulty for educators and policy makers to make recommendations for
what to consume at breakfast.

Breakfast has also been heralded as the “most important meal of the day,” not
only because it is for most people the first major eating episode after the longest
period without eating, but because it has been championed as a meal that con-
tributes significantly to nutrient intake, can be used to lose weight or maintain
a weight loss, and can improve cognition and school performance in children.
But is it the most important meal? There are two considerations here: What does
“important” mean? Again, there is no definition. Further, how does the contri-
bution of the breakfast meal to nutrient intake, weight management, or cogni-
tion compare with other meals and snacks? Breakfast has been intensively stud-
ed – lunch, dinner, and snacks, less so.

How breakfast consumption or breakfast skipping is defined influences the
results of studies. In general, nutrient intake and diet quality are better if break-
fast is consumed. Weight and weight management also depend on the type of
breakfast consumed. It has been demonstrated clearly that the type of breakfast
consumed affects nutrient intake, diet quality, and weight; therefore, a simple
definition of “breakfast” does not significantly add to the literature. Less well
defined is the role breakfast plays in the cognition of students. Although accept-
ed as fact, results evaluating acute and chronic consumption of breakfast and
cognition are equivocal. Systematic reviews and a carefully conducted clinical
trial have suggested that there is no association between consumption of break-
fast and cognition in school-age children.

More carefully controlled studies that use a standardized definition of break-
fast consumption and breakfast skipping are needed to determine the effects on
nutrient intake, health parameters, and academic performance. In addition,
equivalent studies of the lunch and dinner meals are needed, before it can be
determined if “breakfast is the most important meal of the day.”

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Abstract
Breakfast has been claimed to improve cognitive function and academic performance, leading to the provision of breakfast initiatives by public health bodies. Children may be particularly sensitive to the nutritional effects of breakfast due to greater energetic needs compared to adults. However, there is a lack of acute intervention studies assessing what type of breakfast is optimal for cognitive performance. In this paper, the impact of breakfast-based glycemic response on cognition in children will be reviewed. The data suggest that a more stable blood glucose profile which avoids greater peaks and troughs in circulating glucose levels is associated with better cognitive function across the morning. Although the evidence to date is promising, it is currently insufficient to allow firm and evidence-based recommendations. What limits our ability to draw conclusions from previous findings is that the studies have differed widely with respect to subject characteristics, cognitive tests used, and timing of cognitive assessment. In addition, few studies have profiled glycemic response in children specifically. There is, therefore, an urgent need for hypothesis-driven, randomized, controlled trials that evaluate the role of different glycemic manipulations on cognition.

Introduction
Breakfast is recommended as part of a healthy diet because it is associated with healthier macro- and micronutrient intakes [1], BMI, and lifestyle [2]. Breakfast has also been claimed to improve cognitive function and academic performance, leading to the provision of breakfast initiatives by public health bodies. Broadly speak-
Ing, nutritional interventions offer opportunities to: (i) optimize cognitive development during infancy and childhood; (ii) ensure the highest levels of cognitive function during adulthood; and (iii) prevent cognitive decline in older age (Fig. 1). Whether breakfast consumption is key to optimizing various health outcomes across different populations is debated. Nevertheless, children may be particularly sensitive to the nutritional effects of breakfast on brain activity and associated cognitive outcomes because of their greater energetic needs compared to adults [3].

The central role of glucose as the major nutrient of the brain, its metabolism, and control have been well documented. All cell processes (including nerve cells) require energy, and aerobic carbohydrate metabolism is both the major source of energy available for brain tissue and of biological energy [4]. The rate of glucose brain metabolism changes across the life span. Initially, there is a rise in the rate of glucose utilization from birth until about 4 years of age, at which time the child’s cerebral cortex uses more than double the amount of glucose compared to adults. Childhood is also a time of intense learning, and children learn many basic reading, writing, and arithmetic concepts during these years. Consequently, the high rate of glucose utilization maintained in children from 4 to 10 years of age coincides with a period of metabolically expensive cognitive processes [5]. Moreover, it has been suggested that overnight fasting induces greater metabolic stress in young children as the higher the brain/liver weight ratio and the greater the metabolic rate per unit of brain weight, the greater the demand on glycogen stores [6].

To maintain this higher metabolic rate, a continuous supply of energy is needed. Hence, breakfast consumption may be vital to providing adequate energy sup-

**Fig. 1.** Nutrition and cognition: potential for optimizing cognitive performance across the life span.
ply for school children, especially if breakfast is missed, as food intake ad libitum is not possible or is limited during school time. Reviews of the effect of breakfast on cognitive performance in children and adolescents suggest that breakfast has beneficial effects, with effects most readily apparent when nutritional status is compromised [7]. Moreover, in developed countries, it has been found that skipping breakfast can result in impaired cognitive performance [7, 8]. However, there is a lack of acute intervention studies assessing what type of breakfast is optimal for cognitive performance. Dietary carbohydrates are of interest as they provide the main source of energy for the brain's metabolic functioning, and there is mechanistic evidence linking postprandial glycemia to cognitive performance in both children and adult populations [9]. Therefore, when considering what type of breakfast may be beneficial, the rate at which breakfast increases and maintains blood glucose, i.e., “the glycemic index” (GI) might be an important factor. After a high-GI meal, plasma glucose concentrations rise rapidly causing a high peak glucose level and a concomitant high insulin response, resulting in a rapid blood glucose disposal which in turn may cause blood glucose levels to decrease to below the fasting concentration in the later postprandial period. Low-GI foods result in more moderate peak blood glucose increments and may also maintain a prolonged net increment in blood glucose above the fasting concentration [10]. Related to this is the concept of glycemic load (GL), which takes the amount of carbohydrates consumed into account and is calculated by multiplying the GI by the amount of carbohydrates available, then dividing by 100 [11]. In the following section, effects on school children's cognitive performance as related to glycemic properties of breakfast interventions will be reviewed [for more general reviews on the effects of breakfast on cognitive performance see 12–15].

**Breakfast-Based Postprandial Glycemic Response and Cognition**

Wesnes et al. [16] tested children aged 9–16 years on 4 separate days under different breakfast conditions, namely 1 glucose drink, 2 different cereals, and no breakfast. Assessment of children's cognitive performance was carried out prior to breakfast and 30, 90, 150, and 210 min after breakfast consumption. The results showed a decline in memory and attention across the morning which was ameliorated when children consumed the cereals. However, both cereals had a high GI (approximately 74), albeit lower than the glucose drink. Mahoney et al. [17] looked at the optimal rate of glucose supply in children aged 6–8 or 9–11 years and found that 60 min after consumption of a low-GI breakfast children in both age groups remembered significantly more than after a high-GI breakfast or no breakfast. The effect was more pronounced in younger children. When
comparing the effects of a low-GI breakfast with a high-GI breakfast across the morning (10, 70, and 130 min after ingestion) in children aged 6–11 years, Ingwersen et al. [18] found that a low-GI cereal prevented declines in attention and memory 130 min after breakfast administration (compared to a high-GI breakfast). Investigating a slightly older age group (12–14 years), Cooper et al. [19] gave children aged 12–14 years either a low-GI breakfast, a high-GI breakfast, or no breakfast, and tested performance 30 and 120 min after breakfast consumption. The findings revealed faster response times (reaction times) 120 min after consumption of the low-GI breakfast on the Stroop task (assessing executive function) and Flanker task (measuring attention) compared with no breakfast, and on the Sternberg paradigm (working memory task) compared to the high-GI breakfast intervention. In addition, children’s accuracy on all tests was better maintained after the low-GI breakfast than the high-GI breakfast and no-breakfast condition. Defeyter and Russo [20] tested participants aged 13–15 years before and 120 min after the intake of a low-GI breakfast or no breakfast, and found that the low-GI breakfast led to improved long-term and working memory performance. Amiri et al. [21] found that consumption of a high-carbohydrate breakfast impaired attention relative to a high-protein breakfast in girls (but not boys) aged 9–11 years, whereas another study found no effect from a high-carbohydrate compared with high-protein breakfast on attention [22]. The fact that in both studies only one breakfast GI condition was used limits our ability to draw firm conclusions about the optimal nature of the postprandial response.

The combined effects of breakfast GI (low versus high GI) and 10-min mid-morning exercise on cognition in children aged 11–13 years were also assessed recently [23]. Cognitive performance was assessed 15 and 105 min after breakfast consumption, and those allocated to the exercise condition did 10 min of exercise (shuttle runs) approximately 45 min after breakfast. The results showed that a low-GI breakfast led to improved response times across the morning on an executive function and working memory task (Stroop and Sternberg paradigm) irrespective of exercise condition. Furthermore, mid-morning exercise had an additional benefit for response times on the executive function task when combined with a low-GI breakfast. No single or combined effect of breakfast GI or a mid-morning exercise was found on measures of accuracy, and no effects were observed on measures of attention (visual search) and mood.

GL – as opposed to GI – has also been shown to affect cognitive performance. Benton et al. [24] investigated the effects of 3 isocaloric breakfasts differing in GL (high, medium, and low GL) on cognitive performance and behavior in children aged 5–7 years. They found 140–210 min after consumption significantly fewer signs of frustration and more time on task for low-GL breakfasts, but no effects on cognitive performance (although correlation analysis suggested that
lower GL improved children’s memory and attention). Using a wider age range (5–11 years), Young and Benton [25] compared 3 breakfasts varying in GL and found that memory and mood were improved 180 min (but not 60 min) after ingestion of the lower GL breakfast. Micha et al. [26] investigated both GI and GL. Within each GI condition (high or low), children aged 11–14 years received either a high- or low-GI breakfast. Low-GI breakfasts predicted better memory performance when cognitive performance was assessed 103–136 min after consumption. In addition, children reported to feel more alert and happy and less nervous after they had the low-GI breakfast. These effects were observed across GI conditions. Interestingly, although a lower postprandial glycemic response was associated with improved long-term memory performance, the high-GI breakfast led to improved performance on a task pertaining to executive function, information processing, and working memory.

Some studies have found no evidence for improved performance following a breakfast that results in lower postprandial glycemic response [27, 28]. In one study, the effects of 3 isocaloric drinks which varied in GL (high, medium, and low) were assessed in children aged 10–12 years [27]. Children were tested before and after drink administration at hourly intervals for 180 min, and glycemic response was assessed using a continuous glucose monitoring (CGM) system. Analysis of the glycemic response revealed significant differences in glycemic response as indexed by incremental area under the curve values between the drinks (high GL > medium GL > low GL); however, no drink effects were observed on cognitive performance. A later study, conducted by the same group, brought about similar results [28]. In this study, children aged 10–12 years were given 3 isoenergetic drinks differing in GI and GL; a glucose drink (GI 100, GL 65), a milk drink (GI 27, GL 5), and a milk/glucose drink (GI 84, GL 35). Following baseline assessment of cognitive performance, children were tested again hourly for 3 h after consumption. As before, glycemic response was assessed using a CGM system. Although postprandial glycemic responses were significantly different between the drinks, there were no effects on cognitive performance. Yet, further analysis revealed sex differences in the susceptibility to cognitive enhancement. Girls, but not boys, had better short-term memory after consumption of drinks with the lower GL compared to the glucose drink.

To summarize, there are fewer studies comparing breakfast type than there are comparing breakfast with no breakfast, and even fewer that specifically assess the influence of postprandial glycemic response on cognitive performance. Within the limited data available, the evidence suggests that a lower postprandial glycemic response may be protective against a decline in cognitive performance over the morning. However, the evidence is far from conclusive. What limits our ability to draw strong conclusions from the findings of previous stud-
ies is that the studies differ widely with respect to subject characteristics, cognitive tests used, and timing of cognitive assessment; and that few studies have profiled glycemic response in children. In the following section, some of the conceptual and methodological factors that might have contributed to the inconsistent set of findings are briefly discussed [see 29 for a more general discussion of methodological issues in studies examining the effects of breakfast].

**Breakfast, Postprandial Glycemic Response, and Cognitive Function: Important Methodological and Conceptual Factors**

Tasks pertaining to attention, executive function skills, and memory have been identified as aspects of cognition most likely to be susceptible to breakfast interventions [15]. In studies that compared breakfast type, a low-GI breakfast was most consistently associated with beneficial effects on attention [16–19, 21], with effects limited to females in one study [21]. Fewer studies reported beneficial effects on memory [16, 18, 24], and again one study only observed effects for girls [28]. Few studies have included executive function tasks in their assessment. One reported beneficial effects on task speed but not accuracy [23]; one showed evidence for improvement after high-GI breakfast [26]; and some showed no effects [16, 18]. Different aspects of cognition pertain to different neural structures and networks, which allows speculation about the areas of the brain that might be particularly susceptible to glycemic manipulation. However, categorization of cognitive tasks to a specific cognitive domain is not consistent throughout the literature. Moreover, a key issue in cognitive assessment of any nutritional intervention is test sensitivity. Cognitive tests that were designed to discriminate between groups and populations for diagnostic purposes are unlikely to be sufficiently sensitive to detect subtle changes in performance due to nutritional interventions [30]. Therefore, in studies where a number of tests were administered, beneficial effects observed in one domain might simply be due to greater test sensitivity rather than domain specificity.

There is a clear need for studies using cognitive tasks that are sensitive to nutritional manipulations but also relevant to the specific learning situation encountered. For school children, learning and educational attainment are strongly related to memory and attention [31]. This is because many typical classroom activities depend on these cognitive resources. Another important aspect of the learning situation encountered by school-age children is the ability to self-regulate. Self-regulation involves modulating systems of emotion, attention, and behavior in response to a given situation or stimulus [32]. Children’s ability to self-regulate is critical for their academic success [33]; consequently, aspects of
effortful control and self-regulation are highly relevant to children’s school performance. Assessment of breakfast interventions on tasks involving aspects of executive function such as cognitive flexibility, working memory, and inhibitory control are, therefore, important. However, as mentioned earlier, few studies have incorporated such tasks, and, consequently, we have an insufficient knowledge base about the effects of breakfast on an aspect of cognitive performance that is vital to children’s educational success.

Temporal differences in cognitive testing (i.e., at what time after breakfast intake cognitive performance was assessed) are another important factor that might have led to some of the inconsistent findings observed in the literature. To date, for studies examining the effects of postprandial glycemic manipulation, these timing ranged from 10 min [18] to 220 min [16, 27]. In addition, some studies assessed cognitive performance repeatedly across the morning [16, 18, 27, 28], whereas others included only one assessment after intervention [17]. Findings to date suggest that effects are usually observed in the late postprandial period (75–222 min) [17, 18]. For future studies, multiple assessments at various time points and especially in the late morning are likely to help reveal the effects and time course of glycemic effects on cognition. Baseline assessment of cognitive performance is another important methodological difference between studies although it is important for controlling inter- and intra-individual differences [30]. Cognitive status at baseline will affect intervention outcomes, and failure to account for them will make a clear interpretation of findings difficult.

Furthermore, there is a clear lack of intervention studies that employ ecologically valid research conditions, such as school-based testing. Although laboratory-based studies allow greater experimental control, the fact that children are tested in a novel environment is likely to result in changes in mood and arousal, which in turn can affect cognition. This is particularly important to consider when children are tested in clinical environments such as a hospital. In such instances, familiarization will be an important component to mitigate the confounding effects of the novel environment. In addition, familiarization to tests and testing procedures is also important when testing children in the field. This relates to the point made earlier about establishing baseline cognitive performance and, more specifically, controlling for baseline cognitive performance to allow assessment of “true” treatment effects. In a similar vein, statistical analysis of the data needs to control for differences within subjects and, in the case of repeated testing, order effects.

Finally, few studies have profiled the glycemic response in children [27, 28]. Technical advances have led to the development of minimally invasive 24-h CGM devices. The minimal invasiveness of CGM devices compared to traditional intravenous or capillary glucose monitoring provides an opportunity to assess glycemic responses in children. Results obtained using CGM devices in
children have shown that they are sensitive to detect differences in postprandial glycemic response in normoglycemic children [27, 28]. In addition, the possibility of differences in postprandial responses to GI manipulation across various populations, as apparent from differences in metabolic demands and general homeostatic and glucose-regulatory mechanisms, requires further study. In terms of age, there is a large variation in studies investigating the effect of breakfast-based GI manipulations, at times ranging from 5 to 16 years [16]. From a metabolic perspective, adolescence might also be a time when greater susceptibility to glycemic variations is observed due to the specific metabolic conditions observed during that time of development [34]. Investigations using clearly defined age groups are needed. These will also help to clarify the nature of the relationship between postprandial blood glucose concentrations and cognition. The precise mechanisms by which increased peripheral and/or central glucose availability affects cognitive processes are still unclear [see 9 for an outline of potential underlying mechanisms]. More biological data are needed to understand how developmental differences in glucoregulation may moderate the effects of GI or GL on cognitive performance in children.

**Conclusion**

Understanding the potential influence of breakfast interventions on children’s cognitive function remains a high priority, given its application to learning and achievement at school. There is evidence to suggest that children may be more

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**Fig. 2.** Evaluation of breakfast interventions in children: conceptual and methodological considerations.
susceptible to breakfast interventions due to higher metabolic and cognitive demands. In terms of nutritional recommendations, based on the evidence above, it appears low-GI or low-GL breakfasts which minimize oscillations in glucose concentrations might be beneficial for optimal cognitive performance across the morning. What limits our ability to draw strong conclusions from the findings of previous studies is the fact that they often differ widely with respect to subject characteristics, cognitive tests used, and timing of assessment. Future research needs to carefully consider conceptual and methodological factors, including potential interindividual differences, adequate selection of tests, and control of extraneous (confounding) variables [9, 29] (Fig. 2).

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Making any type of widespread statement about breakfast and any potential benefits it may bring is hindered by a lack of a standard definition of breakfast. This has been cited repeatedly as a limitation to individual studies examining the effect that breakfast has on nutrient intake and health, but it is also a major problem when interpreting systematic review articles and meta-analyses. For consumers, nutrition educators, or policy makers, it is difficult to define the best foods to consume as well as when to consume them. This is further hampered by the fact that current breakfast patterns are not homogeneous, and the nutrient profiles and effect on health outcomes, such as weight status, vary considerably. Should “breakfast,” a term that most individuals understand implicitly as it relates to their culture, be defined using groups of foods or by a specific energy, macronutrient (specifically protein), or micronutrient prescription? Breakfast has been heralded as the “most important meal of the day” not only because it has been championed as a meal that contributes significantly to nutrient intake/adequacy and diet quality, may be a strategy used to lose weight or maintain weight loss, and can potentially improve cognition in children. It has been demonstrated that the type of breakfast consumed may affect daily nutrient intake, diet quality, and weight; therefore, a simple definition of “breakfast” does not significantly add to the literature. Less well defined is the role breakfast plays in the cognition of children. Although accepted as fact, results evaluating acute and chronic consumption of breakfast and cognition are equivocal. More rigorous studies and round table discussions are needed before we can provide evidence-based dietary recommendations for breakfast intake.

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