Critical Dietary Habits in Early Childhood: Principles and Practice

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\textbf{Abstract}

The adequacy of a diet is usually evaluated based on nutrient intake. As people eat foods but not nutrients, food-based dietary guidelines (FBDG) are needed. To evaluate dietary habits in infants and young children, the following stepwise approach is suggested: (1) develop country-specific FBDG to identify the potential of common nonfortified foods to ensure adequate nutrient intake and (2) examine potential ‘critical’ dietary patterns if main food groups are excluded, such as in vegetarian diets or if a family’s precarious social status leads to food constraints. The German FBDG for infant and child nutrition demonstrate that a well-designed mixture of common foods results in an adequate supply of nutrients, except for vitamin D, iodine and iron. The following solutions are feasible to address deficiencies in these critical nutrients: routine supplementation (vitamin D), fortified complementary food consumption or supplementation for infants as well as inclusion of table salt in the family diet for children (iodine), and individual pediatric care for infants at risk (iron). In the exclusion of food groups of animal origin from vegetarian diets, several nutrients are at risk of becoming deficient if not substituted. Existing studies characterizing vegetarian children are rare. These were mainly published in the 1980s and 1990s and were biased towards a high social status. Thus, firm conclusions on today’s dietary practices and health statuses of European vegetarian children cannot be drawn. A social gradient exists for food patterns and dietary quality in children, but energy intake need not necessarily be affected. Scenarios in Germany suggest that families on unemployment assistance can afford to eat a diet compliant with German FBDG only if they restrict food selection to basic food. Yet, the question of how families cope with financial constraints in everyday life remains.

In conclusion, well-designed FBDG provide various opportunities to identify critical nutrients and critical food habits in early childhood and beyond.

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Introduction

The adequacy of a diet is traditionally evaluated by comparing the usual nutrient intake of a population or population subgroup with reference values for nutrient intake. Recently, the European Food Safety Authority (EFSA) reviewed the existing data on nutrient requirements and dietary intake for infants and young children in European countries [1]. Subsequently, the EFSA used those reference values judged as most appropriate to evaluate the risk of inadequate nutrient intake as reported from nutrition surveys. Complementary evidence from studies reporting status markers of nutrient adequacy was considered, but this was seldom available. As a result, iron, iodine and vitamin D were identified as ‘critical’ nutrients in infants and children in Europe, with mean intakes often below the EFSA reference values and low biomarker status in the case of vitamin D and iron.

In day-to-day living, people eat foods rather than nutrients. Therefore, it is mandatory to assess the food habits of at-risk population groups to identify underlying causes for deficiencies in ‘critical’ nutrients. Subsequently, sound food choices with the potential to prevent or alleviate nutrient inadequacies can be recommended. As almost all foods act as sources of multiple nutrients and because consumers do not eat single foods but rather consume combinations of foods, the dietary food pattern has gained considerable attention in recent decades. Within this concept, potential ‘critical’ dietary habits that may affect multiple nutrients can be identified in cases of intentional exclusion of basic food groups or when there are constraints in general food availability.

To evaluate critical dietary habits in infant and young child nutrition, we suggest the following stepwise approach:

1. Develop country-specific food-based dietary guidelines (FBDG) and identify the potential of the available food supply to ensure adequate nutrient intake at the population level
2. Examine potential ‘critical’ dietary patterns deviating from FBDG in cases in which families exclude main food groups from their children’s diets, such as in families with vegetarian diets, or if a family’s precarious social and financial status leads to food constraints and food insecurity

Step 1: Food-Based Dietary Guidelines

Modular Systems for Infant and Child Nutrition in Germany

Along with the epidemic increase in the prevalence of diet-related chronic diseases in wealthy Western countries, public health nutrition research has opened a new window for dietary recommendations, turning the focus from nutrients to foods. The main objective is to translate classical nutrient-based recommendations into FBDG that should be summarized into short and understandable messages for the public.
These guidelines should consider existing health problems and dietary habits and should address the total diet as opposed to single food groups. Due to population-specific dietary habits, FBDG must be developed for each country [2] and for specific age groups, such as infants or children.

With regard to child nutrition, the EFSA introduced the existing FBDG for infant and child nutrition in Germany as examples of food patterns that ensure an adequate energy and nutrient supply of these age groups. Both of these modular concepts, named ‘Dietary schedule for the first year of life’ and ‘Optimized mixed diet for children and adolescents 1–18 years of age’ are based on common, nonfortified food and a traditional meal pattern [3]. Food selection and food amounts were cautiously optimized to meet the German nutrient-based recommendations that are set to cover the requirements of almost all individuals (mean + 2 standard deviations) with various age groups.

Nutrient Adequacy and ‘Critical’ Nutrients
Evaluation of these FBDG shows that an adequate, and for some nutrients even ample, supply of nutrients for infants and children can be achieved by a well-designed mixture of common foods (fig. 1). However, obvious exceptions to this are vitamin D, iodine and iron, with intakes well below the national reference values. The same nutrients were evaluated as critical to the dietary patterns of European infants and young children by the EFSA as well. Particularly, deficiencies of iodine and iron in early developmental periods may have lasting consequences that lead to impaired cognitive and functional capacities later in life [4, 5]. Thus, fortification and/or supplementation are needed. The German example can demonstrate how the critical nutrient supply inherent in an optimized food pattern can be evaluated and overcome.

Vitamin D
Fortunately, representative biomarker data on vitamin D status in children are available in Germany [6]. They demonstrate an adequate vitamin D status [serum 25(OH)D] as long as infants receive routine vitamin D supplementation. Thereafter, the typical low vitamin D intake in combination with insufficient endogenous vitamin D production via sunlight exposure leads to a sharp decrease in vitamin D levels and high proportions of vitamin D deficiency depending on the cut-offs used. A simple and safe solution recommended by the German Pediatric Society is the continuation of routine vitamin D supplementation from infancy into childhood, at least in high-risk groups if sunlight exposure is insufficient [7].

Iodine
Although the iodine content in cow’s milk has increased due to changes in cow-feeding practices in Germany in recent years, iodine intake from food is not sufficient to meet requirements either in dietary practice or in the German FBDG. Therefore, the use of iodized table salt in the household as well as in the food industry is recom-
mended in Germany. Since iodine status biomarkers are not available for infants and young children, little is known about iodine status in these age groups. In older children, from preschool age onwards, analysis of 24-hour urine samples has shown a decreasing trend in recent years, probably due to decreased use of iodized salt by the food industry [8]. However, infants should not yet receive salted food, since early exposure to the taste of salt may lastingly increase salt preference and blood pressure [9]. Therefore, this age group does not profit from the German population-based iodine fortification strategy [10]. Nevertheless, two alternate solutions are feasible to overcome a deficient

Fig. 1. Nutrient supply according to FBDG for infant and child nutrition in Germany, shown as percentages of German reference values. Solutions to achieve an adequate intake of critical nutrients by supplementation or fortification are marked. a Dietary schedule for the 1st year of life. b Optimized mixed diet for children and adolescents. 1: Iodine supplementation or fortified commercial complementary food. 2: Vitamin D supplementation. 3: Iodine-fortified salt in household and food industry. 4: Vitamin D supplementation.
iodine supply when homemade complementary food is preferred; these include the supplementation of iodine (50 μg/day) or the use of iodine-fortified commercial complementary food (e.g. cereal-milk gruel, which can be easily integrated as one of the 3 recommended complementary meals in the infant FBDG).

**Iron**

Data from a double-blind randomized controlled intervention trial examined high and low meat content in complementary food as part of the German FBFG. Overall, the trial showed fully sufficient iron status biomarkers (e.g. serum ferritin, hemoglobin) in the second 6 months of life, despite a mean iron intake far below the German reference values (6 vs. 8 mg/day), which are well in accordance with the latest EFSA reference values [11]. This finding suggests that the current reference values for iron intake in European infants and young children may overestimate iron requirements in infants, at least if they are fed according to the German FBDG for infant nutrition.

However, in the subgroup of infants who are fully breastfed during the first 4–6 months of life as recommended, up to 20% of infants were found to have iron deficiency (ferritin <12 μg/l) and 6% had iron deficiency anemia (ferritin <12 μg/l, hemoglobin <105 g/l) [12]. A similar iron status prevalence was reported from study samples in other European countries [1].

As iron overload should be avoided and a decrease in iron body stores may be physiological during the second half of infancy, pediatric check-ups for infants and young children at risk of iron deficiency could be a feasible and safe approach to assure adequate iron intake instead of routine iron supplementation. In addition, the applicability of the existing reference values for iron intake in infants in Germany should be critically reviewed.

**Step 2: Critical Dietary Habits**

*Food Exclusion in Vegetarian Diets*  
**Principles**

In principle, vegetarian diets can be categorized by the exclusion of food groups of animal origin (table 1). Nutrition experts can estimate the potential impact on nutrient supply if the excluded food is not sufficiently substituted.

In general, vegetarian diets are supposed to be healthy and superior to the standard omnivorous Western diet, which is energy dense and high in saturated fatty acids, refined carbohydrates, and salt, but low in dietary fiber, antioxidants and other bioactive plant food components. Although the American Dietetic Association and the American Academy of Pediatrics [15, 16] have stated that well-planned vegetarian diets are appropriate for individuals during all stages of the life cycle, including infancy, childhood, and adolescence, the German Nutrition Society and the Research Institute of
Child Nutrition question whether the specific dietary requirements in childhood can be safely met, particularly with vegan diets.

Remarkably, in the course of restricting food groups of animal origin, only those nutrients that are already critical in an optimized omnivorous food pattern are thought to become insufficient, namely, iron, iodine and vitamin D.

**Practice**

The prevalence of children consuming vegetarian diets in Germany is assumed to be on the rise, but valid data are missing. Because manifestations of vegetarian diets are blurred in practice, dietary assessment is difficult, and results may depend on survey methodology. In nationwide surveys in Germany, the prevalence of vegetarian children and adolescents was reported to be between 5 and 6% based on parental or self-evaluation and from dietary records [17].

In a recent systematic review, we evaluated studies on dietary intake and health status in infants, children and adolescents on vegetarian diets [unpubl.]. The inclusion criteria were (1) appropriate characterization of the vegetarian diet and (2) evaluation of nutritional and health status. Case reports (e.g. on vitamin B12 deficiency in vegan diets) as well as studies from nonindustrialized countries were excluded.

### Table 1. Categories of vegetarian diet types and related nutrients [13, 14]

<table>
<thead>
<tr>
<th>Vegetarian diet type</th>
<th>Excluded food</th>
<th>Reduced nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-vegetarian</td>
<td>Mainly meat and meat products (small amounts of fish and/or meat are consumed)</td>
<td>–</td>
</tr>
<tr>
<td>Lacto-ovo-vegetarian</td>
<td>Meat, fish and products made from these</td>
<td>Iron, zinc (highly bioavailable), iodine, n-3 fatty acids</td>
</tr>
<tr>
<td>Lacto-vegetarian</td>
<td>Meat, fish, eggs and products made from these</td>
<td>Iron, zinc (highly bioavailable), iodine, n-3 fatty acids + vitamins A, D</td>
</tr>
<tr>
<td>Ovo-vegetarian</td>
<td>Meat, fish, milk and products made from these</td>
<td>Iron, zinc (highly bioavailable), iodine, n-3 fatty acids + calcium, vitamins B2, B12</td>
</tr>
<tr>
<td>Vegan</td>
<td>All food of animal origin</td>
<td>Iron, zinc (highly bioavailable), iodine, n-3 fatty acids, calcium, vitamins A, D, B2, B12 + protein, energy</td>
</tr>
<tr>
<td>Macrobiotic</td>
<td>Mainly food of animal origin (sometimes small amounts of fish are consumed), specific focus by choosing food of plant origin</td>
<td>Iron, zinc (highly bioavailable), iodine, n-3 fatty acids, calcium, vitamins A, D, B2, B12 + protein, energy</td>
</tr>
</tbody>
</table>
A total of 28 publications [18–45] from 16 studies (13 from Europe, 3 from the USA) were identified, with mostly small samples (<50 participants). These studies were mainly undertaken in the 1980s and 1990s. Most often, the participants came from families of high social status. Nutrient supplementation was common. Nine publications originated from a Dutch study reported in the 1980s that evaluated children and adolescents eating a macrobiotic diet. In around half of the studies, the authors allocated the examined diets to a vegetarian diet category (table 2).

Overall, growth and body weight in these studies was within the lower reference ranges (table 2). Dietary intake and nutrient status were inconsistent between the studies and in comparison to omnivorous control groups. Some potential health benefits, such as beneficial blood lipid levels and high intake of dietary fiber and vitamin C, were observed. Multiple low clinical or biochemical indicators of vitamin status, such as for vitamin B₁₂, vitamin D, and iron, were reported, as well as signs of impaired bone health. Whereas young children on macrobiotic diets suffered from multiple nutrient deficiencies and showed signs of growth retardation, indications for a poor nutritional status were rarely reported within lacto-ovo-vegetarian groups. A poor vitamin B₁₂ status was reported in vegan groups if not supplemented.

The existing database is not sufficient, however, to soundly evaluate present-day dietary practices of vegetarian children. Today, the food industry offers more and more specialized vegetarian products, and vegetarian families might be increasingly aware of the need to consume fortified food or to supplement critical nutrients.

**Food Constraints in Precarious Socio-Economic Situations**

**Principles**

There is a well-known social gradient for nutritional status characteristics in childhood in Europe with regard to excess weight and obesity [46]. A social gradient is also apparent for food consumption habits in children, but on a weaker basis. Strong evidence exists, however, for breastfeeding, where low maternal educational status is a consistent risk factor for low breastfeeding [47]. Regarding the mixed childhood diet, associations with social status seem to be broadly similar to those reported in adults: low social class populations consume less from the ‘healthy’ side of the food palette, in particular fruit and vegetables, and more from the ‘unhealthy’ side, in particular confectionary and soft drinks. In contrast, food habits regarding basic food like milk are more similar between the different social classes [48–50]. The differences in dietary quality between social classes have been suggested to impact nutrient status, but biomarker data are rare [51].

While the consequences of specific food group exclusion on the supply of specific nutrients, such as in nonsubstituted vegetarian diets, are predictable, it is more difficult to estimate the consequences of a generally lower quality diet. This could be the case if food consumption is constrained but an omnivorous diet remains, where all food groups contribute their specific nutrient profiles to supply a whole range of...
Early Childhood Diet

Table 2. Overview of results from a systematic review of studies on children eating vegetarian diets compared to omnivorous groups or reference and normal values (unpublished)

<table>
<thead>
<tr>
<th>Diet type [Ref.]</th>
<th>Nutrient supply</th>
<th>Nutritional status</th>
<th>Health status</th>
</tr>
</thead>
<tbody>
<tr>
<td>General vegetarian (n = 8)</td>
<td>Macronutrients = Ref; Vit B12 ≤ Ref; Vit D &lt; Ref; Fe ≤ Ref; Folic acid, Vit C &gt; Ref</td>
<td>Height = Ref; Weight = Ref</td>
<td>Vit D* &lt; Norm; Vit B12* = Norm; Fe status* ≤ Norm; Fatty acid pattern* = Ref</td>
</tr>
<tr>
<td>Lacto-ovo-vegetarian (n = 3)</td>
<td>Energy ≤ Ref; Infants: Fe ≤ Ref, Zn = Ref</td>
<td>Height ≤ Ref; Weight ≤ Ref; Infants: height and weight = Ref</td>
<td>Fitness = OM; Infants: Fe status* = Norm</td>
</tr>
<tr>
<td>Vegan (n = 3)</td>
<td>Energy ≤ Ref; Fiber &gt; Ref; Vit D &lt; Ref; Ca &lt; Ref; Vit B12 with supplementation &gt; Ref, without &lt; Ref</td>
<td>Height = Ref; Weight = Ref</td>
<td>Vit D* &lt; Norm; BMC, BMD &lt; Norm</td>
</tr>
<tr>
<td>Macrobiotic (n = 2)</td>
<td>Fiber &gt; Ref; Folic acid &gt; Ref; Vit B12 &lt; Ref; Ca &lt; Ref; Infants: energy, fat and protein &lt; OM, Vit B12, Vit C and Ca &lt; Ref</td>
<td>Height ≤ Ref; Weight ≤ Ref; Infants: height and weight &lt; OM</td>
<td>Vit B12* &lt; Norm; BMC, BMD &lt; OM; Psychomotor and cognitive abilities &lt; Norm; Infants: Vit B12*, Ca*, Fe* and Vit D* &lt; Norm; physical and motor development &lt; Norm</td>
</tr>
</tbody>
</table>

BMC = Bone mineral content; BMD = bone mineral density; n = number of studies; Norm = normal value; OM = omnivore; Ref = reference value; Vit = vitamin. * Blood measurements.

nutrients. Yet, the drivers of differences in children’s dietary intake related to socio-economic status have not been well defined to date.

Practice
Reasonable assessment of nutrient supply or nutritional risks due to low social status is difficult in practice. Prospective epidemiological methods, such as dietary records or repeated 24-hour recalls, are laborious for study participants, decrease compliance and increase selection bias.

Food cost scenarios in Germany suggest that families on unemployment assistance could afford a diet compliant with the German FBDG for children and adolescents only if they restrict their food selection to basic foods and do without the convenience and branded products that are popular in today’s family diet [52] (fig. 2). No data are available to show how families cope with such financial constraints in everyday life.
Studies in extreme food deprivation suggest that diet quality as well as child growth and health deteriorate with increasing grades of food insecurity. Energy intake need not necessarily be affected, but the energy provided by healthy food is thought to decrease and that provided less healthy food is thought to increase [48–50]. It remains open whether a less healthy diet is primarily caused by lack of money to spend on food or by unwise budget management [50, 53].

A social gradient in dietary quality may be associated with a family’s cultural or immigration background, but the proportional contributions of these two factors are difficult to untangle. Differences in dietary habits between immigrant and native populations as well as differences between subgroups of immigrants within a country are most often specific to ethnic group and grade of inculturation [54, 55]. Therefore, findings from observational studies with regard to socio-cultural influences on dietary habits cannot be easily transferred from one country to another.

**Conclusion and Perspectives**

The German example shows that even well-designed FBDG for infant and young child nutrition that rely on common nonfortified foods present with 'critical' nutrient deficiencies in vitamin D, iodine and iron. Feasible solutions are, however, available, either by routine supplementation (vitamin D), use of fortified commercial com-

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**Fig. 2.** Food costs (EUR/day) for children and adolescents. Light gray: based on amount provided for nutrition in unemployment assistance. Dark gray: food costs based on the German FBDG, including convenience and brand name foods used in the dietary practice of families. White: food costs based on the German FBDG, excluding convenience and brand foods [52].
plimentary food or supplementation for infants and use of table salt for children (iodine), and pediatric check-ups for infants at risk (iron).

The existing database that is available to evaluate present-day food habits that deviate from FBDG, such as in vegetarian children in Europe, is insufficient. Future research should be devoted to the valid assessment of the prevalence and manifestation of vegetarian diets and their effects on nutrient intake and nutrient status in today’s food environments. Based on such an assessment, a European science-based position on and up-to-date guidance for vegetarian diets in children could be elaborated.

Although a social gradient has been repeatedly demonstrated for compliance with dietary recommendations in children and in adults, valid markers for socio-economic constellations with detrimental effects on child nutrient status are not yet available. Future research could be devoted to the identification of socio-cultural indicators that have relevance for food patterns and resulting nutrient and health statuses in children, in particular in extreme constellations of food insecurity combined with immigration status.

In summary, the development of well-designed, country-specific FBDG could provide various opportunities to identify critical nutrients and critical food habits in early childhood and beyond.

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