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Acquisition of food-related behaviours in children: critical windows for later health

Guest editors:

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- Disseminate relevant knowledge on diet and nutrition to professionals such as health care professionals, teachers, journalists as well as to the general public.

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Introduction: Acquisition of food-related behaviours in children: critical windows for later health. An international pre-FENS congress symposium, Paris July 9th, 2007

The children of Europe, like those of most other parts of the world, are experiencing rapid changes in their lifestyle conditions. Numerous varieties of palatable foods are now available at all times in all places, or nearly so. In parallel, young people of today are increasingly attracted by an unprecedented number of "small screen" activities: television is now competing with the computer and video games to keep children's attention busy for hours in mental activities that are incompatible with physical activity. As an expected result of the increase in energy intake plus the decrease in energy expenditure, the frequency of overweight and obesity is increasing rapidly in European youths. The Danone International Institute, whose activities often deal with child health, has gathered a group of experts from many parts of Europe and the world, in order to help us share experiences and ideas about this critically important public health problem.

The program of this one-day symposium was built so as to address many factors that might affect a child's ability to maintain a healthy body weight and cover nutrient needs during growth. Attention was paid to events that occur before a child is born. Genetic and epigenetic factors were explored, including the important influences affecting foetal development. Recent data about the sensory and nutrient factors influential during first few hours and days of the new-born child were examined. Parental behaviour was examined, with a strong emphasis on the child-mother interaction. Other influences (cognitive, affective, environmental, etc.) were also addressed as they shape the growing child's food choices, likes and dislikes, and ability to adjust energy intake to energy needs.

The invited speakers are internationally respected experts of different aspects of healthy growth. Each of them contributed an original perspective to the numerous nutritional problems associated with growth, particularly but not exclusively body weight control. The organisers' hope was that this unique event would give the audience a chance to appreciate the immense and multi-faceted effort now devoted to solving the many nutrition-related problems in our children. Speakers were asked, after exposing the main recent findings in their own discipline, to propose a few ideas to improve nutrition and growth in children living under the unprecedented circumstances of today: easy access to palatable high energy density foods, plus decreasing occasions for physical activity. The final goal is to interrupt, and then hopefully to reverse the present epidemics of nutrition-related health problems in children, in order to allow our children to grow into healthy adults and enjoy a long, pleasant, active and useful life.

This one-day symposium obviously did not and could not possibly cover all the critical factors affecting child nutrition and health. Considerations about birth weight and dietary imbalance at weaning, among other important topics, were not addressed in our one-day meeting. It is clear that other topics and other speakers could have been included. Hopefully, such contributions will be integrated into the programmes of future Danone Institute symposia. The choice of speakers in the present symposium was guided by simple principles: well recognized experts, different areas of expertise, different areas of Europe and the rest of the developed world. The organisers are perfectly aware that their particular choice of speakers left important areas untouched and that other viewpoints are critical to consider. Nevertheless, we hope that the present set of papers will contribute to the broader debate about child health and development by presenting an original juxtaposition of expert views.

The final chapter of this special issue of the BJN will be devoted to practical advice to improve child nutrition and health based on the speakers' individual contributions. Such advice looks attractive on paper. In order to make it useful, it has to be put into practice, evaluated and improved when necessary. This represents more research, more data, and more scientific assessment. It also requests changes in our present lifestyle, particularly changes in societal influences and education. The field of child health and growth is one very privileged area in which science can make a critical input on long-term consequences. The initiative taken by the International Danone Institute of bringing together scientists of various background and expertise is thus a judicious and important step in this crucial mission of science.

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Cognitive schemas: how can we use them to improve children's acceptance of diverse and unfamiliar foods?

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Foods represent important stimuli for humans, especially for human children. After weaning, it is important that children quickly acquire knowledge about their food environment to avoid ingesting potentially dangerous substances. This paper discusses this process and its implications in terms of schemas. The effects of providing positive taste information to novel foods and of adding familiar flavors to novel foods are interpreted by means of the schema construct. A means of changing schemas through exposure to schema-inconsistent information is presented and evidence for its efficacy is described. Finally, the effect of early variety on subsequent willingness to eat unfamiliar foods is described and once again interpreted by means of the schema construct.

Novel foods: Dietary variety: Children: Social cognition: Schema: Food neophobia

Foods represent important stimuli for humans, especially for human children. After weaning, it is important that children quickly acquire knowledge about their food environment to avoid ingesting potentially dangerous substances. This paper discusses this process and its implications in terms of schemas, a construct that social psychologists use to talk about people's knowledge about the stimuli in their environments[1]. Schemas are cognitive structures that represent organized knowledge about a given type or category of stimulus. Individuals have schemas about all kinds of stimuli. Social psychologists are most interested in social schemas, those referring to people (e.g., university professors, Englishmen, women); however, schemas can also be about other concepts (e.g., furniture), or even about events (e.g., meals). Included in the content of a schema are individuals' basic knowledge and impressions – their ideas about the features that characterize stimuli in that particular category. For example, one's schema about university professors might include the information that they are bookish, methodical, verbose, and badly-dressed. A meal schema might include the notions that a meal involves taking of food while sitting down, the use of dishes and utensils, heating of the food, a particular order of courses[2,3]. There is considerable research indicating that both children and adults use schemas in processing information and that such schemas can affect reactions to previously unencountered members of a category of stimuli. If one meets a new university professor, his or her schema leads to particular *expectations* about what this person is going to be like, and these expectations are likely to affect one's behavior toward this person. In this paper, we explore the implications of the idea that people have schemas about novel foods.

In order to understand the content of children's schemas about novel foods, we offered them a series of such foods[4]. Then we questioned the children about the foods they had rejected, asking "How come you didn't want to taste the _____?" The children's responses revealed negative evaluations of these foods, based on their appearance ("it looks yucky," "it looks like liver," "it looks like barf," "it looks rotten") and negative expectations about their taste ("I don't like it," "I won't like it," "I don't like vegetables"). In other studies, when we have asked children to rate how much they think they would like novel foods, the ratings are always lower than those for familiar foods[5]. We have also conducted studies with adults who also have a similarly negative view of the taste of novel foods. Further, they consider them slightly dangerous and rate themselves as somewhat anxious at the prospect of eating them[6]. Thus, people's schemas about novel foods include the information that they are unpalatable, unappealing, not likeable and even slightly dangerous. It is a fairly simple schema, yet a schema nonetheless.

And it is these negative expectations about novel foods that makes people avoid them. It is as though people have a default expectation: "if it's novel, it won't taste good, and if it's not going to taste good, I don't want to eat it." And that reaction is what is referred to as food neophobia. It has been argued that this neophobia is adaptive and serves a protective function in a potentially hostile food environment[7]. Cashdan[8] has shown that neophobia is at its strongest just at the time when the developing child would be most vulnerable to this dangerous environment, around the age of two, when in traditional cultures the child is weaned and therefore ingesting foods other than mother's milk and also at the time the child becomes relatively mobile and likely to stray from adult supervision. And, further, it occurs before the child has the cognitive resources to understand verbal instructions

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about not eating strange berries and things he or she picks up on the street. So, the child is protected to some degree by its neophobic reaction to unfamiliar foods. For parents and from a nutritional standpoint that can be a problem because there are many novel foods that are not harmful and that the child would benefit from eating. But the child seems to be *biased* against them.

This bias is not surprising. A recent article on cognitive biases in general suggests that such biases might reflect the survival value or relative costs of false positives and false negatives[9]. A false positive occurs when a person does something although it does not produce the anticipated benefit, while a false negative occurs when a person fails to do something that, if done, would have produced a benefit. Each might ultimately have negative consequences, but the magnitudes of the negative consequences are often very unequal. Hazard detection is biased toward "false alarms." For example, it is better to have one's smoke detector go off too often than not often enough. Whenever costs are asymmetrical, people are biased toward making the least costly error. In the case of novel foods, the cost of a false negative (failing to avoid something that shouldn't be eaten) is probably greater than the cost of a false positive (avoiding something that should be eaten). In the first case, the outcome could be catastrophic –the individual could die. In the second, the outcome is much less so – the individual might miss out on a nutritious food. As a result, people/children are biased toward avoiding novel foods. They are overly cautious in order to avoid a costly false negative. In a sense, their schemas about novel foods are instantiations of this bias.

So, assuming that children's negative bias toward novel foods is reflected in their schemas and their schemas maintain this bias, how can we use that information to get children to try novel foods? One strategy would be to persuade them that in a particular case, the schema does not apply (see panels a and b of Fig. 1). In other words, the set of characteristics contained in the schema are not true of this food. This food is an exception: it is an atypical member of its category. *This novel food* is not yucky, doesn't taste bad, is not dangerous – it's good. In fact, that's one of the things that parents do instinctively when they want to get their children to try something new. "Try it – you'll like it. It's good."

There are many studies showing that simply telling people that a novel food tastes good or tastes like something else that tastes good ("it tastes just like chicken"), increases their willingness to try it. For example, Pelchat & Pliner[10] looked at the effect of this kind of "good taste" information on willingness to try novel foods in a school cafeteria in which a meal was pre-paid; students could take whatever they wanted as they went through the line. Pairs of experimental foods were presented simultaneously. In each case, one was novel and the other, familiar (e.g., tortilla chips and blue corn tortilla chips). In experimental conditions, the novel food was accompanied by a sign with "good taste" information; in the control condition, there was no sign. Experimenters, disguised as cafeteria workers, looked to see whether person took the familiar food, the novel food, or both. There was a clear effect of taste information on choice of novel food; in the taste information condition, 55 % of the children took a novel food while in the control condition, only 39 % did so.

Sometimes, especially with younger children, researchers (and parents) present the information that a novel food tastes good by exposing the child to someone (a "model") who eats the food. Instead of *telling* the children the food tastes good, they *show* them it tastes good. There are many

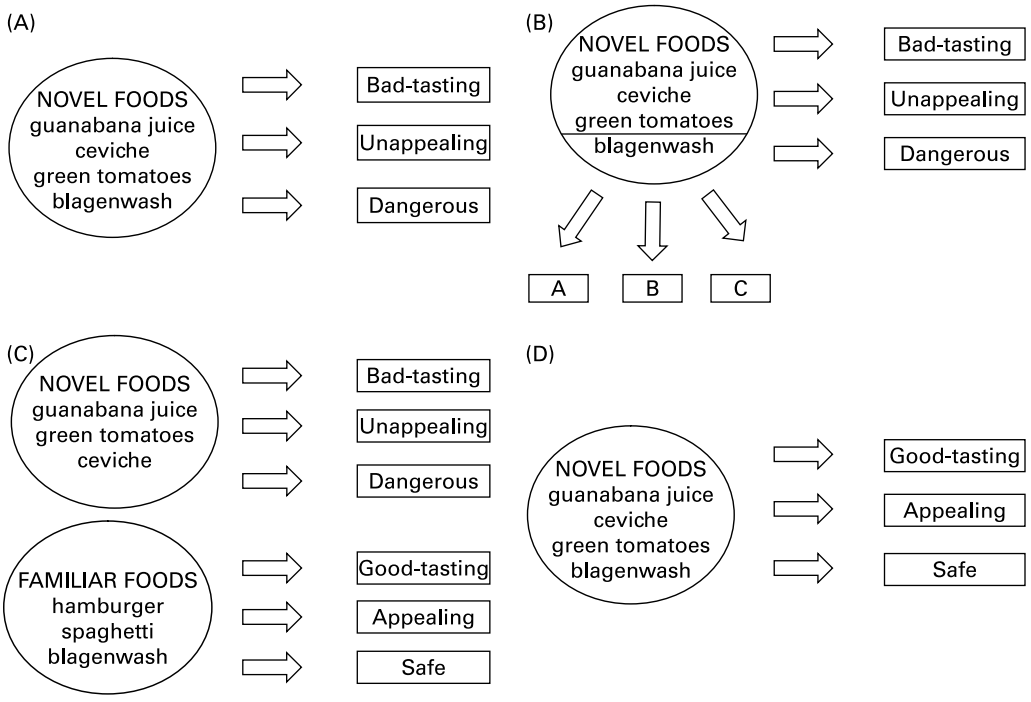

Fig. 1. (A) Representation of a novel food schema, (B) A food for which the novel food schema does not apply, (C) Moving a novel food to the familiar food category, (D) Changing the content of a novel food schema.

studies showing that children are more likely to eat a novel food in the presence of a model who has done so[11–13]. A recent study[14] shows that it must be the *same* food – if someone is eating a different novel food, it does not elicit modeling. Other studies have shown that children are more likely to copy a model when it is their mother rather than a stranger[15] and when the model expresses liking for the food[16]. In the schema context, what these manipulations are doing is telling the individual that the (bad taste) information contained in the novel food schema does not apply to this food – it is an exception.

Another way of circumventing people's novel food schemas is to persuade them that a particular food isn't novel – it doesn't belong in the novel food category (see panel c of Fig. 1). Here Elisabeth Rozin's notion of "flavor principles" is relevant[17]. Flavor principles are the distinctive and pervasive seasoning combinations that characterize and even define many cuisines. For example, what makes southern Italian food seem "Italian" is the fact that it contains olive oil, tomato, and basil or oregano. What makes Chinese food seem "Chinese" is the fact that it is flavored with soy, rice wine, and ginger. Within a culture, flavor principles are ubiquitous, appearing in many dishes and appearing many times a day; thus they are very familiar, and very much liked. E. Rozin & P. Rozin[18] note that individuals have a deep attachment to their culture's characteristic seasonings and find it difficult to imagine food prepared without them. The Rozins have suggested that one of the functions of flavor principles is to facilitate the introduction of a new food staple into a culture; that is, adding the familiar flavor principle to the new food increases willingness to try it by making it appear more familiar (and likely to taste good).

Stallberg-White & Pliner[19,20]demonstrated this phenomenon in two studies designed as laboratory analogues of the introduction of a new food into a culture. They offered participants some novel foods to taste; some were offered in combination with familiar flavour principles in the form of sauces and condiments tailored to the specific experiences of each participant while others were offered with no sauce or condiment. They found that the addition of familiar flavour principles to novel foods increased the willingness of both adults and children to taste them (see Fig. 2). From the schema perspective this kind of strategy involves moving food out of novel food category by adding a familiar flavor principle.

Thus far, we have described two schema-based techniques for getting people to try unfamiliar foods. One involves convincing them that a particular food is an unusual or atypical member of the category of unfamiliar foods; it does not share the usual attributes. The other is to convince them that the food in question does not belong in the category of unfamiliar foods at all.

Fig. 2. Adding a familiar flavor principle to a novel food increases willingness to eat it.

However, if the goal is to increase willingness to taste novel foods *in general*, then neither of these techniques is very efficient because they focus on particular foods – they do not extend beyond the particular food in question. Instead of introducing a long series of exceptions, it would be more efficient to change the content of the novel food schema. The goal would be to change the schema to include the information that novel foods are palatable, likeable, and generally desirable. Research in social psychology has shown that it is possible to change people's schemas by presenting them with *schema-inconsistent* information. In other words, one provides many exemplars which challenge the existing view of the stimuli in a particular category.

In the case of novel foods, provision of such schema-inconsistent information would involve taste exposure to good-tasting novel foods. If an individual thinks that novel foods taste bad, then a good-tasting novel food is *inconsistent* with his or her schema. In two studies by Pliner & Loewen[5], some children received *schema-inconsistent* information in form of exposure to a set of four novel foods that had been carefully pretested to ensure that they were extremely palatable. Other children received information *irrelevant* to novel food schema in form of exposure to a similar set of palatable familiar foods. Such exposure would not provide any information about novel foods. Finally, a third group of children received exposure to a set of unpalatable novel foods; such foods would be *consistent* with a schema containing the information that novel foods taste bad. In the second part of the study, the children were given a behavioral neophobia choice task; they had to choose which foods they would taste later in the session from a series of both novel and familiar foods. These foods were *different* from the ones in the exposure part of the study; no child had seen these foods earlier in the study. Children in the first group, those receiving pre-exposure to good-tasting, schema-inconsistent foods, accepted more of the novel foods in the subsequent behavioral neophobia task than did those in either of the other two groups. Similar results were obtained in a study with adult participants[6]. We interpreted these data to suggest that we managed to change people's schemas to include the idea that novel foods taste good; because their schemas changed, they became more willing to try novel foods.

To this point, the discussion has focused on *changing* children's schemas about novel foods. It is also possible that if one can intervene early enough, one can encourage them to form schemas in the first place that include the information that novel foods are good and fun to eat and basically no different from familiar foods. It might be possible to do that by giving them a great deal of exposure to a variety of foods at an early age. The foods will be novel because, until young children had a large amount of experience with foods, most foods are novel. Given the schema framework, it is important that the foods, particularly those presented earliest, be relatively palatable in order to induce an appropriate schema (containing the information that novel foods taste good).

There is a reasonable amount of correlational evidence that supports this idea. That is, children who are exposed at an early age to a large amount of variety (which, once again,

would of necessity include novel foods) are more accepting of new, different novel foods when they are older. Pelchat & Pliner[21] found that mothers' reports of their 2–6 year old children's current willingness to eat novel foods was related to their reports of early variety in the child's diet. More recently, Russell[22] examined many aspects of parental attitudes and beliefs, feeding practices and their children's food-related attitudes and behaviors. She found that of the four significant predictors of children's food neophobia, three had to do with offering variety: taking the child to restaurants serving unfamiliar foods, offering the child untried foods, exposing the child to variety. Skinner *et al.*[23] showed that exposure/variety between 2–24 months of age was a significant predictor of children's acceptance of fruits at 6–8 years. Rigal and colleagues[24] studied a group of children who formerly had food allergies but who had outgrown them; as part of management of the allergies they were required to eat restricted diet during early childhood. These children were more food neophobic than their nonallergic siblings. Within the allergy group, there were positive correlations between the number of foods forbidden by the physician and also the number of foods excluded by the mother and a measure of neophobia.

In sum, early variety is positively related to later acceptance of novel foods. These data are suggestive but not totally convincing. First, all are based on mothers' reports (mostly retrospective) and, therefore, subject to various biases. Further, all are correlational, subject to the usual ambiguity of direction of causality with that method. A recent study by Gerrish & Menella[25] uses the experimental method, thereby circumventing many of these problems. On Day 1, 4·5 month-old infants who had not yet been exposed to solid foods were tested in the laboratory for acceptance of carrots. On Days 2–10, in addition to their usual diets, they were fed at home by their mothers one serving per day of one of the following: 1) carrots; 2) potatoes; or 3) a variety regimen of peas, potatoes, and squash, one per day in sequence, the sequence repeated three times. On Day 11 they were tested in the laboratory for acceptance of carrots. Babies in Groups 1 and 3 showed a greater increase in acceptance of carrots than did those in Group 2 (see Fig. 3). On Day 12, they were tested in the laboratory for acceptance of chicken. Babies in Group 3 were more accepting of the chicken than those in the other two groups. Thus, the babies with the greatest manipulated exposure to variety were subsequently more willing to accept novel foods, an impressive experimental demonstration of the effects of early exposure to variety.

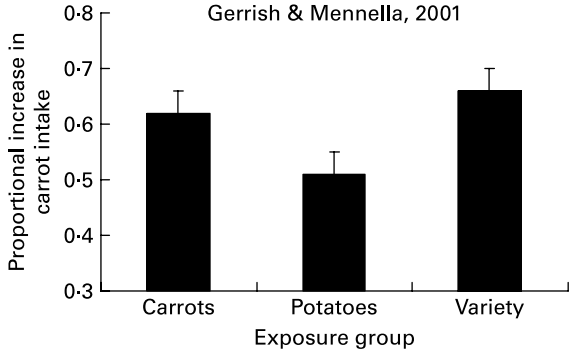

Fig. 3. Exposure to either carrots or a variety of vegetables, not including carrots, increases subsequent consumption of carrots.

We find the schema framework to be a useful heuristic for understanding the literature on children's food neophobia. When one conceptualizes children's reactions to novel foods as schema-influenced responses, it is easy to understand how and why various strategies for increasing willingness to eat specific novel foods are successful. It also suggests a more general approach to the problem of increasing children's acceptance of novel foods. Although the schema framework was applied *post hoc* to the existing literature, it also makes a prediction not previously tested in research. That is, to the extent that early exposure to variety provides a means for inducing a positive rather than a negative schema about novel foods, it should be important that the earliest foods presented be high in palatability. Schemas are based in large measure on the individual's experiences with stimuli in a particular category. Negative experiences produce a schema with negative content, while positive experiences produce a schema with positive content. Furthermore, once formed, schemas are relatively impervious to inconsistent information; that is, it would take a number of instances of schema-inconsistent information to change a schema. Thus, it would be predicted that if a child were presented with unpalatable novel foods early in the formation of his or her schema, that schema should not be positive. Thus, it would be important to ensure that the earliest novel foods to which the child is exposed are relatively palatable. Davis'[26] research on self-selection diets suggests that young children find a wide range of foods to be palatable, including notably fruits and cereals. Indeed, for the three infants whose diets formed the basis of her first report on the self-selection paradigm, fruit constituted from 15 to 50 percent of their total intake by weight over a six-month period. So, practically speaking, infants' introduction to solid foods should begin with those that are most likely to be liked – perhaps fruits, given Davis' results and given that we know from other sources that sweet foods are innately and universally palatable. Note that the suggestion here is not that children's early exposure be to the kinds of high fat sweet foods so beloved of older children and so deplored by nutritionists. The suggestion is that parents capitalize on children's natural liking for the taste of fruit to help promote the formation of positive novel food schemas. Although such a suggestion has never been tested, either experimentally or correlationally, it should be possible to do so. Positive results would provide support for the schema framework described in this paper.

Conflict of interest statement

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Taste preferences, liking and other factors related to fruit and vegetable intakes among schoolchildren: results from observational studies

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The present paper explores the relative importance of liking and taste preferences as correlates of fruit and vegetable (FV) intakes among schoolchildren in Europe. The paper first provides an overview of potential determinants of food choice among children and subsequently summarizes the results of two recent observational studies on determinants of FV intakes among school-aged children. It is proposed that taste preferences and liking are important for children's food choices as part of a broader spectrum of nutrition behaviour determinants. Taste preferences and liking are important for motivation to eat certain foods, but social-cultural and physical environmental factors that determine availability and accessibility of foods, as well as nutrition knowledge and abilities should also be considered.

Study 1 shows that children with a positive liking for FV have a greater likelihood to eat fruits (odds ratio (OR) = 1·97) or vegetables (OR = 1·60) every day, while ability and opportunity related factors such as knowledge, self-efficacy, parental influences and accessibility of FV were also associated with likelihood of daily intakes (ORs between 1·16 and 2·75). These results were consistent across different countries in Europe. Study 2 shows that taste prerences were the stongest mediator of gender differences in FV intakes among children; the fact that girls eat more could for a large extend be explained by there stronger taste preferences.

Fruit and vegetables: Taste preferences: Determinants of food choice

Diet and nutrition clearly play a critical role during childhood and adolescent development. First of all, children and adolescents need to cover not only their nutrient and energy needs for maintenance metabolism and physical activities, but also for growth[1]. Furthermore, eating habits may be less established in childhood and adolescence, and may therefore be better modifiable[2], and food preferences and habits adopted in childhood and adolescence may track to a certain extend into adulthood[3–5].

Nutritional habits are not in line with recommendations among children and adolescents. Many young people eat not enough fruits and vegetables, too much saturated fat, and more energy than they need[6]. In order to promote more healthful eating, we need to know why children and adolescents eat what they eat[7,8].

What, when and how much children eat is influenced by a complex, interrelated set of so-called behavioural 'determinants' and successful dietary behaviour change interventions are dependent on the identification of the most *important* and best *changeable* determinants, because intervention strategies, methods and materials need to be selected or developed that are tailored to the target populations and to the most important and best modifiable determinants of behaviour change.

In this paper we will first give a brief overview of different important categories of determinants of food choice and dietary intake among children and adolescents. Secondly, we will present and discuss the results of two recent observational studies on determinants of fruit and vegetable (FV) intakes that illustrate the relative importance of taste preferences and liking as compared to other potential determinants of FV consumption among school-aged children across Europe[9].

Determinants of food intake: motivation, ability and opportunity

In affluent countries, most people can generally choose what, when and how much they eat. To induce dietary change, one needs to change people's food choices. Studies on personal determinants of food choice have primarily made use of psychological theories to explain food choice and nutrition behaviours[10]. It has, however, been argued that, since children may have less autonomy in making food choices, environmental rather than personal factors may be more important determinants of their nutrition behaviours. More recently, social-ecological models of health behaviour[11] have drawn more attention to such environmental influences on nutrition behaviours. A framework proposed by Rothschild[12] provides a simple, integrative framework to categorise the large and diverse number of potential personal and environmental determinants from various more specific

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behaviour theories. Rothschild identifies three distinct categories of determinants: motivation, ability and opportunity. These categories of determinants are interrelated. For example, in environments with few opportunities for healthful eating, higher motivation and more abilities are needed to maintain a healthful diet.

Motivation

Behavioural decision, motivation or intention have been identified as primary determinants of behaviour[13]. Motivation or intention is influenced by a subjective weighing of expected positive and negative consequences of the behaviour. In general, expectations about short-term outcomes are more important than longer-term outcomes. Taste, satiety and pleasure are short-term consequences of major importance. Taste preferences and liking are regarded as key determinants of food choice[14]. People, and young people maybe more so, eat what they like, and disliked foods are avoided[2]. Certain taste preferences are innate, such as a liking for sweet and salt, and a dislike for bitter and sour. However, taste preferences can be learned and unlearned[15]. 'Hunger' or appetite is also a strong motivator to eat. In Maslov's hierarchy of human needs, the need to cover physiological energy requirements, i.e. overcoming hunger, is among the highest human priorities, and the urge to eat and drink when hungry is an inborn trait.

Since eating is primarily a way to cover the basic physiological nutrient requirements and calorie requirements, satiety, i.e. the feeling that energy requirements have successfully been met, is a strong reinforcer for eating specific foods and we therefore quickly learn to like and appreciate energy-dense foods[2]. Children are therefore 'programmed' to like, or to learn to like, the taste of high-energy, sweet and fatty foods. Nevertheless, many acquire a taste for coffee, tea or beer during childhood and adolescence, which shows that we can even unlearn our innate dislike of bitter.

Some specific types of taste preference learning strategies have been identified. The aforementioned example of learning to like high-energy foods is referred to as 'taste-nutrient learning'. Taste-nutrient learning is an example of operant or instrumental conditioning: a stimulus (eating energy dense, sweet and fatty food) is positively reinforced ('rewarded') by the pleasant feeling of satiety. In the last decades palatable energy-dense foods have become readily available and accessible for most children in western countries. This abundance combined with our innate preference for energy-dense foods may be an important cause for the present-day obesity epidemic. Research shows that high-fat and sugar-rich foods are indeed among the most preferred foods among children and adolescents[16]. Most fruits and especially vegetables have low-energy densities, and many vegetables have a somewhat bitter taste. Preferences for these foods are therefore not so easily learned.

Two other food preference-learning strategies are examples of classical conditioning and are referred to as 'taste–taste learning' and 'taste–environment learning'. If a new, unfamiliar, taste is combined with a taste for which a preference already exists, children will more easily learn to like the new taste. For example, children will more easily learn to like the somewhat bitter taste of tea or the sour taste of yoghurt or grapefruit, if these are first served with sugar. Similarly, a liking for tastes that people are exposed to in pleasant physical or social environments are also learned. Foods first encountered as a child in a friendly, pleasant family environment, may become favourite foods for a lifetime.

A fourth important learning strategy is observational learning or modelling: children learn to like the taste of foods that they see their parents, siblings, friends or other 'important others' eat.

Health related beliefs may also be important. If people are asked about what they find important in their diet and food choice, 'health' usually comes second (or third) after 'taste' (and cost), especially among women[17]. Nevertheless, 40 % of Americans and 57 % of Europeans indicated rarely or never to compromise on taste to improve the healthfulness of their diets[18]. This is probably even more likely among children[19].

Motivation and intentions are important determinants of nutrition behaviours, and taste preferences and liking importantly influence motivation to eat. But not all behaviour is intentional, and we not always act on our intentions[20]. Lack of abilities or lack of environmental opportunities can be important barriers. Environmental cues may also trigger automatic behavioural responses.

Ability

Self-efficacy, or *perceived behavioural control (PBC)*, refers to one's confidence in one's abilities and skills to engage in certain behaviour. PBC is behaviour and context specific. A person can, for example, be confident to be able to eat less fat, but not to increase vegetable intake; and confidence to cut back on fat may be high for regular meals prepared at home, but not for eating out. PBC is strongly related to abilities and skills. Studies in children and adolescents show that food and nutrition-related self-efficacy is associated with healthful food choices and dietary behaviour[21–23]. Skills and abilities are to some extent dependent on practical knowledge. For example, knowing why to eat healthfully, knowing what healthful foods are, and knowing the recommended intake levels may all be conditional for voluntary healthful eating. Although knowledge in itself is unlikely to result in healthful food and nutrition choices – knowledge may be a necessary but insufficient condition for healthy food choice[19] – some recent studies show that knowledge of recommended intake levels of FV was associated with higher intakes in 11-year old school children[23].

Environmental opportunities

Children and adolescents' opportunities to make healthful dietary choices strongly depend on the opportunities their environments have to offer. For example, children's social environment, such as their parents and school staff, importantly influences their range of food choices; their physical environment, such as where they live or go to school, importantly influences what foods are available and accessible to them.

Classifying the food environment

The ANGELO framework[24], which was specifically developed to conceptualise health behaviour environments related

to obesity, distinguishes four 'types' of environments: physical, economic, political and socio-cultural. The physical environment refers to availability of healthy and unhealthy choices, such as points-of-purchase for FV and soft drink vending machines in schools. The economic environment refers to the costs related to healthy and unhealthy behaviours, such as the price of soft drinks, FV or energy-dense snacks in school cafeterias. The political environment refers to the rules and regulations that may influence food choice and eating behaviour. Bans on soft drink vending machines in schools, rules on what treats can and cannot be brought to school, as well as family food rules are micro-level political environmental factors. Other examples are national school food policies or national legislation regarding food-marketing efforts aimed at children. The socio-cultural environment refers to the social and cultural subjective and descriptive norms and other social influences such as social support for adoption of health behaviour and social pressure to engage in unhealthy habits.

Evidence for environmental determinants of nutrition behaviours in youth

Child and adolescent dietary behaviour is likely to be strongly influenced by environmental factors, since children may have less autonomy in food choice. From the age of about three years, children's eating behaviour is influenced by their responsiveness to environmental cues, and a variety of family and social factors start to influence children's eating behaviours[25]. The role of parents and schools is considered to be of particular importance.

Parent and family influences

Parents directly and importantly determine the child's micro-level social, political, physical as well as economical nutrition environments. Eating is a social behaviour, especially for children[2], and observing eating behaviours of others, especially parents, influences their own preferences and behaviour. Such modelling of eating behaviours can even result in establishing preferences for foods or substances that are inherently disliked. A recent review of the literature on environmental correlates of nutrition behaviours in youth indicates that children and adolescents' nutrition behaviours are consistently associated with their parents' behaviours[26]. Parents further influence their offspring's nutrition behaviours by actively encouraging, discouraging or controlling certain behaviours. Restricting children's access to, for example high fat or sugar-rich foods, may encourage rather than discourage preferences for such foods, especially if these same foods are also used to reward children for good behaviour and for celebrations[2]. However, a study conducted in Belgium indicated that clear restrictive family rules about high fat foods during childhood were associated with healthier food choices in adolescence[27], and a recent cross-European study showed that parental demand as well as facilitation to eat FV were associated with higher intake levels in 11 year old children, while 'parental allowance' (i.e. parents allowing children to eat as much as they like), was not[23,28].

From studies on the association between general parenting styles and children's health behaviours, it appears that authoritative parenting, i.e. a parenting style characterised by high parental involvement as well as strictness, is associated with more positive health behaviours including higher FV intakes[29,30], compared to adolescents who reported authoritarian (high strictness, low involvement) or neglectful (low strictness, low involvement) parenting styles.

As a result of these parenting practices and rules, as well as parents' own food preferences and choices, parents influence what foods are available and accessible within the home environment. Availability and accessibility of foods have repeatedly been found to be associated with intake levels in children and adolescents[31].

Finally, family socio-economic position is important. A recent review of the literature confirmed that low parental education, as well as parental income is associated with less healthful diets in children and adolescents[32,33].

School influences

A second important setting for children and adolescent nutrition is the school environment. Children spend much time at school; consume a large proportion of their daily intakes there, and schools offer nutrition education as part of the regular curriculum.

Accessibility and availability of foods in schools are important physical environmental factors. In many countries across Europe, schools provide lunch or other foods for the students, with great differences between countries. For example, in Belgium school lunches are offered in a majority of primary and secondary schools. Parents need to pay for their children to have a school lunch, children are allowed to bring their own lunch to school, and the school lunches are not required to meet official dietary guidelines. Most secondary schools do have vending machines and snack food outlets. In The Netherlands, a neighbouring country, school lunches are not offered. In primary schools, children go home for lunch or children need to bring their lunch to school. In secondary schools, adolescents bring their lunch to school, or they can buy lunch in the school a la carte cafeteria. In Sweden and the UK primary and secondary schools do offer free school lunches but while Swedish schools are required to meet official recommended intake levels, nutrition requirements for school lunches in the UK only state that meals in primary schools should contain at least one item from four major food groups (starchy foods; FV; dairy products; meat, fish or alternative protein source) and in secondary school lunches at least two items from each of these groups should be *offered*. Preliminary evidence from the European Pro Children study indicates that school lunches can make a difference; Swedish kids eat more vegetables at school than children from other countries across Europe, and have a relatively high total daily vegetable intake.

Macro-level environment

An important macro-level factor is how foods are marketed to children and adolescents. Children and adolescents are increasingly seen as an important target group for food marketing[34]. Young people in affluent countries have money to spend themselves, they may also influence food-buying behaviours of their parents, and they are the future adult buyers and consumers. Foods that are most intensively marketed by

means of advertisement and marketing campaign are foods that are high in sugar and fats, and often low in micronutrients. In the US fast food restaurants and soft drink companies spent most on marketing their products. The large portion sizes offered at 'value pricing' (i.e. larger portions cost relatively less), especially in the US, is a marketing strategy that has probably contributed to higher caloric intakes and unnecessary weight gain. Television still is the most important channel for marketing food products, especially for younger children, but food marketing among youth also includes, for example, school-based marketing, Internet advertising, and sponsoring of events. Recent research confirmed that food adverts exposure promotes consumption and that obese children in particular have heightened responsiveness to these food-promotion adverts[35].

Although most countries do regard children as a special vulnerable group for television advertising, there are striking differences between countries in rules and regulations for food marketing to children. Only few countries have a complete ban on television advertising for younger children. But most countries (85 % of 73 countries surveyed by the WHO) do have statutory regulations for food television advertising to children; regulations that define, for example, in what ways foods can be promoted at what broadcasting times. The principle underlying many regulations is that advertising may not be misleading. At the ministerial conference on counteracting obesity organised by WHO Europe, all ministers of countries in the European region signed a charter in which they recognized the importance of marketing[36].

The relative importance of liking and preferences: evidence from observational studies

To explore how important taste-preferences and liking are as population correlates of food intakes among children two recently published studies on correlates of FV intakes, the Pro Children study and the Fruits and Vegetables Make the Mark study are illustrative[28,37].

The Pro Children project

A cross-sectional survey was conducted as part of the Pro Children project in nine European countries (Austria, Belgium, Denmark, Iceland, The Netherlands, Norway, Portugal, Spain and Sweden) during October – December 2003.

Schools constituted the sampling unit, and from each country random samples of at least 20 schools and a minimum of 1300 11-year old eligible children were recruited. A participation rate of 90·4 % was reached in the participating schools; mean age was 11·4 years (range 8·8–13·8, SD = 0·48; 79 % of the children was born in 1992). The final sample sizes varied from 1105 for The Netherlands to 2134 for Portugal, with a total sample size of 13 305. A detailed description of the Pro Children project, including the sampling and data collection procedure is given elsewhere[6,9]. All protocols and questionnaires of the Pro Children projects can be accessed at www.prochildren.org

A self-report questionnaire in all applicable languages was developed to measure FV intake, and possible determinants informed by a social-ecological model[9], a literature review[38], focus group interviews with children[39], individual interviews with parents and school staff, and thorough pretesting as well as a rigorous translation – back translation procedure[39,40]. The questionnaire included questions that were analogous for FV intake on motivational factors such as liking and preferences, and attitudes; ability-related factors such as knowledge of recommended intake levels, self-efficacy and perceived barriers. The questionnaire also included items on opportunity-related factors related to the social-cultural environment: parental and peer modeling, active parental encouragement, parental demands to eat FV, whether parents allow the child to eat as much FV as they like (parental allowances), whether parents actively facilitate FV intake by preparing/cutting FV (parental facilitation) and by giving their children FV to bring to school; and related to the perceived physical environment: availability of FV at home, at school, and at friends' home. An overview of the items, constructs, scaling and psychometrics is reported elsewhere[40,41]. Usual FV intake was measured using a validated food-frequency questionnaire (FFQ)[42].

Multilevel logistic regression analysis was used to investigate the associations of daily fruit (dichotomous) intake and daily vegetable intake (dichotomous) with the different motivational, ability and opportunity factors. The predictors were also dichotomized into 0 (negative or neutral, response category -2 to 0·49) or 1 (positive, response category $> 0{\cdot}49$)[41]. Adjusted odds ratios (OR) and 98 % confidence intervals (CI) were calculated for the total sample, both gender groups and all nine countries separately[28].

Differences in daily intake of FV

In the total sample 43·2 % of the children reported to eat fruit every day, 46·1 % reported to eat vegetables every day. A significant gender difference was found for both outcome measures: 47·7 % of the girls and only 38·9 % of the boys reported to eat fruit daily (OR:1·44, 98 % CI:1·33–1·56), while 51·8 % of the girls and 40·5 % of the boys reported to eat vegetables every day (OR:1·58, 98 % CI:1·45–1·71). Significant differences were also found between the nine participating countries ($p < 0{\cdot}001$). For daily fruit intake, the lowest rates were found in the Nordic countries of Norway, Iceland and Sweden, while the highest proportion of children with daily fruit intake was found in Portugal. For daily vegetable intake, low rates were again found in Norway, Iceland and Spain, and the highest rates were in The Netherlands, Belgium and Portugal.

Correlates of daily FV intakes

For *daily fruit intake*, motivation, ability as well as opportunity factors appeared to be of relevance. Daily fruit intake was more likely to be reported by children with a positive liking for fruit, with a preference for many different fruits and a positive attitude towards fruit intake. Furthermore, daily fruit intake was more likely among children who knew the national recommendation for fruit intake and with positive self-efficacy. In addition, 4 of the 6 social-environmental factors yielded significance. Daily fruit intake was more likely to be reported by children who experienced positive role models, by those with parents who demand them to eat fruit every day, by children with parents who facilitate fruit intake by cutting

up fruit, and by those bringing fruit to school. None of the physical environmental factors was significantly associated with likelihood of daily intake (see Table 1).

Daily vegetable intake was also related to a positive liking of the taste of vegetables, a preference for different vegetables and a positive attitude towards vegetable consumption. Knowing the national guidelines for adequate vegetable intake and a positive self-efficacy to eat vegetables were also significantly associated with daily vegetable intake. All six social-environmental factors were significantly associated with eating vegetables every day. Finally, children who frequently have available vegetables they like at their home were more likely to report daily vegetable consumption.

In country specific analyses a preference for many fruits was significant in 5 out of 9 countries, a liking of the taste of fruit in 3 countries. Regarding ability-related factors, knowledge of the recommendation was significant in all countries, and in 7 countries daily fruit intake was significantly associated with positive self-efficacy. Of the opportunity-related factors, modeling was significant in all countries, bringing fruit to school was significant in 8 of the 9 countries, and parental demand to eat fruit daily was significant in 6 countries.

Liking the taste of vegetables was significantly associated with daily vegetable intake in 6 out of 9 countries, while preference for many vegetables was significant in 8 countries. Among the ability-related factors, self-efficacy and knowledge of recommendations yielded significance in 6 and 5 countries respectively. Parental demand (7 countries) and modeling (5 countries) were the opportunity factors that were positively associated with daily vegetable intake in a majority of countries (see Table 1).

These analyses indicate that liking and preferences are associated with daily intake of FV among school-aged children in Europe. However, other factors related to ability and opportunity were also important with effect sizes of a similar magnitude as preferences and liking. Effect sizes were in general somewhat larger for fruit intake than for vegetable intake.

Gender differences and liking FV: Fruit and Vegetables Make the Marks (FVMM)

A recent comprehensive review of studies on determinants of children's FV intake stated that gender is among the strongest determinants of adolescents' FV intake[38]; in 14 of 17 reviewed European studies girls reported to eat more FV than boys. A study was conducted to explore why boys eat less FV than girls and if differences in preferences for these foods explain consumption differences between boys and girls.

This study was part of the FVMM intervention project including 38 randomly selected elementary schools in two Norwegian counties. The pupils within the 20 control schools were used for the study presented here[37]. Data from survey questionnaires completed in May 2002 and May 2005 were used for the analyses. The questionnaire surveys were completed by the pupils in the classroom in the presence of a trained project worker, within one school-lesson (45 minutes). The FVMM control group is a cohort of 896 pupils (response 84 %), of which 813 and 728 respectively participated in the May 2002 (mean age 12·5) and May 2005 (mean age 15·5) surveys and also reported same gender at both surveys.

FV intake was measured with a validated short FFQ comparable to the Pro Children Study[43]. Potential mediators for the gender differences in intakes were motivation-related (preferences for FV; intention to eat 5-a-day), ability-related (self-efficacy to eat 5-a-day, knowledge about the 5-a-day recommendation) and opportunity-related (accessibility of

Table 1. Odds ratios (ORs[1]) and 98 % confidence intervals (CI) derived from multilevel logistic regression analyses of the Pro Children Study with daily fruit and vegetabale intakes as dependent variables and motivation, ability and opportuinty factors as independent variables

	Daily fruit intake ($n = 13\,168$) OR (98 % CI)	Daily vegetable intake ($n = 11\,905$) OR (98 % CI)
Motivation		
Liking	*1·97* (1·52–2·55)	*1·60* (1·41–1·80)
Preferences	*2·09* (1·79–2·43)	*1·46* (1·30–1·63)
Attitudes	*1·36* (1·14–1·63)	*1·16* (1·03–1·31)
Ability		
Knowledge	*2·25* (2·03–2·49)	*1·41* (1·26–1·58)
General self-efficacy	0·88 (0·64–1·20)	0·82 (0·68–1·00)
Perceived barriers	*1·74* (1·44–2·11)	*1·83* (1·65–2·02)
Opportunity		
Social-environment		
Modelling	*1·95* (1·74–2·19)	*1·43* (1·29–1·60)
Active parental encouragement	0·96 (0·85–1·08)	*1·26* (1·12–1·41)
Demand family rule	*1·60* (1·42–1·81)	*1·50* (1·34–1·68)
Allow family rule	0·85 (0·73–1·00)	*1·22* (1·07–1·40)
Family facilitation	*1·34* (1·20–1·51)	*1·16* (1·03–1·31)
Bring FV to school	*2·75* (2·43–3·12)	*1·99* (1·68–2·36)
Physical-environment		
Availability at home	1·22 (1·00–1·48)	*1·27* (1·12–1·44)
Availability at school	1·00 (0·88–1·13)	1·08 (0·95–1·22)
Availability at friends house	1·07 (0·96–1·19)	1·00 (0·90–1·11)

[1]ORs are adjusted for gender, school and country level.

FV at home and modelling). These variables were assessed with one to five statements with response alternatives ranging from 'I fully disagree' to 'I fully agree', except for the knowledge question which had seven response alternatives (for details see[44]). These scales have been analysed showing good reliability[45].

A variable functions as a mediator when it is associated with the dependent variable (FV intake) and with the indepenent variable, i.e. the potential distal determinant (gender), and when the association between the independent variable (gender) and the dependent variable (FV intake) becomes non-significant or weakens after controlling for the potential mediator[46].

All analyses conducted were different mixed models of repeated measures (i.e. both 2002 and 2005 data were included in the same analyses), all adjusting for school and time (survey), using SPSS 14. The analyses carefully tested each of the steps necessary to establish mediation. The proportions mediated by the mediators were calculated by subtracting the adjusted relationship between gender and FV intake (e.g. τ') from the unadjusted (τ), and dividing the sum by the unadjusted value (i.e. $\tau - \tau'/\tau$)[47].

Girls reported to eat FV more often than boys and reported significantly more positive values for all the potential mediators (see Table 2).

In the single mediation analyses all determinants mediated part of the gender differences, but only adjustment for preferences decreased the gender difference to a level below statistical significance (see Table 3). Preferences alone explained 81 % of the gender difference. In the multiple mediation analyses the six mediators together explained 91 % of the gender difference, with preferences contributing with the largest amount (25 %). In addition, perceived accessibility contributed with 10 % of the explanation (data not shown).

Discussion

FV intakes among schoolchildren are associated with preferences and liking, and the differences in intakes between girls and boys is strongly mediated by preferences. However, preferences are certainly not the only potential determinant of intakes. Ability and opportunity related factors such as knowledge, self-efficacy, parental influences and accessibility of FV are also associated with daily intake. These results were consistent across different countries in Europe. Accessibility of FV further mediates gender differences in intakes and recent research indicates that socio-economic differences in schoolchildren's FV intakes are more strongly related to accesibility differences than preference differences (Bere *et al.*, unpublished data).

The fact that liking and preferences were related to likelihood of daily intake of both FV has been found in earlier studies[22,48–51] and confirms the importance of these motivation-related factors among children. Repeated exposure to many different kinds of FV at early age might be a good strategy to improve liking[25,52] and increased intakes have been found to be associated with increased liking (Tak *et al.*, unpublished data). Especially parents can promote preferences for FV in such a way. The results indeed confirm earlier studies that show that parental social environmental factors are important for dietary behaviors among school-aged children[53]. In line with previous research, perceived modeling was a predictor of daily FV intake[25,50,54–56]. Such social learning strategies are also important for learning to like the taste of FV. Next to this rather 'passive' influence of parental modeling, more active parental encouragement and facilitation was also associated with daily intakes.

Knowledge of the prevailing recommendations was positively related to daily FV intake which indicates that teaching these recommendations in primary schools may help to promote daily intake. School and family influences are very important to influence taste preferences and liking of FV and therefore these are ideal settings for interventions.

Positive self-efficacy was another ability-related factor associated with daily FV intake. The literature is inconsistent about the relationship between self-efficacy and FV intake[22,48,49,55,57], probably due to different possible operationalisations of the self-efficacy construct. Self-efficacy can probably be improved by making FV as available and accessible as possible and thus improve opportunity factors, and the Pro Children Study indicates that bringing FV to school is a good strategy to encourage daily FV intakes.

In the present study only home availability appeared to be a significant physical environmental correlate of daily vegetable consumption but not of daily fruit intake, although the association was close to reaching statistical significance. Earlier studies consistently showed positive associations between availability and FV intakes[50,51,53,55,57,58].

Table 2. Gender differences in fruit and vegetable intake and in determinants of intake at the first measurement in 2002

	Items in scale	Range	Boys	Girls	diff.	*p*-value
FV intake	4	0/40	11·9	14·5	2·6	≤0·001
Accessibility	5	−10/10	3·6	4·9	1·4	≤0·001
Modelling	4	−8/8	2·5	3·1	0·7	≤0·001
Intention	1	−2/2	−0·1	0·2	0·3	0·003
Preferences	4	−8/8	1·3	2·9	1·5	≤0·001
Self-efficacy	3	−14/14	0·1	0·8	0·7	≤0·001
Knowledge	1	0/6	3·5	3·7	0·2	0·008

Table 3. Single mediator analyses: effect of gender on FV intake after adjusting for accessibility, modelling, intention, preferences, self-efficacy OR knowledge

	Models I				
	Potential mediator		Gender		Mediated′ $(\tau - \tau')/\tau$
	β'	$p\beta'$	τ'	$p\tau'$	
Accessibility	0·9	≤0·001	1·3	≤0·001	0·49
Modelling	0·8	≤0·001	2·1	≤0·001	0·20
Intention	1·8	≤0·001	1·8	≤0·001	0·31
Preferences	0·9	≤0·001	0·5	0·19	0·81
Self-efficacy	1·1	≤0·001	1·8	≤0·001	0·30
Knowledge	1·1	≤0·001	2·3	≤0·001	0·10

τ' = difference in FV intake between boys and girls, while adjusting for single potential mediators.

β' = difference in the single potential mediators between boys and girls, while adjusting for FV intake.

Mediated′ = proportion of the gender difference in fruit and vegetable intake mediated by the respectively factors.

Bere *et al.* confirmed that gender is a strong correlate of FV intake and additionally showed that the gender difference in FV intake could be explained by differences in preferences and asseccibility between boys and girls. That perceived accessibility is higher among girls might be due to the fact that parents raise their daughters in a different way than they raise their sons where foods are concerned, which is also illustrated by observations in the Pro Children study: parents of daughters were more involved in the intervention and participate more often in parental activities than parents of boys (Wind *et al.*, unpublished data). That opportunities for girls to eat FV are better than for boys, might also result in higher motivational factors such as taste preferences. However, from this cross sectional study we cannot conclude on causal relationships between determinants.

The two observational studies and the literature indicate that a wide range of determinants are important in children's FV consumption. However, which determinants of FV are exacly the most important ones is still difficult to answer because determinants are interrelated and from a complex pattern.

Conclusion

The present paper showed that the framwork proposed by Rothshild can help to categorize important determinants of FV intake and dietary intake in general. Furthermore, we showed that motivation factors, such as preferences, are among the most important determinants of FV intake among adolescents and that differences in prefences could also explain discrepancies in FV intake levels between boys and girls.

Moreover, opportunities, such as availability and asseccibility of FV, are important as well and more research is needed to assess potential moderating roles of availabity and/of motivational factors.

Conflict of interest statement

None of the authors has any conflicts of interest to report.

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Genetic and environmental determinants of children's food preferences

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Omnivores have the advantage of a variety of food options but face a challenge in identifying foods that are safe to eat. Not surprisingly, therefore, children show a relative aversion to new foods (neophobia) and a relative preference for familiar, bland, sweet foods. While this may in the past have promoted survival, in the modern food environment it could have an adverse effect on dietary quality. This review examines the evidence for genetic and environmental factors underlying individual differences in children's food preferences and neophobia. Twin studies indicate that neophobia is a strongly heritable characteristic, while specific food preferences show some genetic influence and are also influenced by the family environment. The advantage of the malleability of human food preferences is that dislike of a food can be reduced or even reversed by a combination of modelling and taste exposure. The need for effective guidance for parents who may be seeking to improve the range or nutritional value of foods accepted by their children is highlighted.

Heritability: Children: Environment: Food choice: Food preferences: Neophobia

Food likes and dislikes play an important role in food choices, especially in children. Preferences are shaped by a combination of genetic and environmental factors, a better understanding of which is critical to the development of effective dietary interventions.

The importance of food preferences for survival

As omnivores, humans have adaptable dentition and digestive systems that permit them to consume a wide variety of foods. While this bestows considerable advantage, and enables survival in very different environments, there are also risks inherent in distinguishing edible from potentially poisonous items. Children must rapidly learn what is nutritious and safe to eat, and in what combination and context, if they are to avoid the potentially fatal consequences of ingesting toxins or the less immediate but equally important effects of a nutritionally inadequate diet. A combination of innate preferences and the ability to learn new preferences appears to be fundamental to this task.

Characteristics of foods that influence preferences

There are substantial differences between foods in the extent to which children like them, which to some degree, transcend cultural variations. High fat foods such as pizza and French fries, and sweet foods like chocolate or cake, feature reliably in the top 10 favourite food lists of children in the UK, France, Spain, Germany and the USA[1–6]. Vegetables, on the other hand, are almost universally towards the disliked end of the continuum[2–5,7].

This pattern of preferences suggests the existence of innate predispositions towards tastes. A preference for sweet tastes, measured by observation of facial expression, is universally present in neonates[8–10], as is an aversion to sour or bitter tastes[11,12]. These biases probably have adaptive value because sweetness indicates the presence of sugars and valuable calories, whereas bitterness or sourness may signal the presence of harmful toxins or bacteria. Anecdotally, many children also dislike foods with 'bits' or pips, the unexpected presence of which might signal contamination of some kind (de Moura, unpublished results, in press) – a characteristic that is used in marketing foods to children (e.g. '*Yo tubes with no bits*'). Hot taste sensations (e.g. chilli) are often rejected initially[13].

Whilst not present at birth, preference for salty tastes appears at around four months of age. This may be the result of experience with salt in foods, although exclusively breast-fed infants also show a preference for salty over unsalted cereal[14], despite human breast milk being relatively low in salt content. The taste sensation known as 'umami' is imparted by a number of amino acids and ribonucleotides, e.g. monosodium glutamate (MSG). In adults and children, MSG solutions are unpalatable but the addition of MSG to foods increases their palatability[15–17]. Like salt, it appears that umami must be experienced in the context of other flavours to be preferred; i.e. it is a flavour enhancer rather than a pleasant flavour in itself.

Learned features of foods that promote consumption and preference

The other characteristic of food that is reliably associated with children's preferences is energy density[18,19]. Even amongst fruit and vegetables – which are all relatively low in energy – children appear to prefer those delivering most calories per gram such as bananas and potatoes, rather than courgettes and melon[20]. Given that energy density is not a taste *per se*, it is

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likely to be learned through experience of the post-ingestive consequences of eating particular foods. Energy-dense foods are relatively satiating and therefore pleasant feelings of fullness result from consuming them, which could lead to a learned preference for their taste, texture or smell. This has been demonstrated experimentally by adding energy in the form of starch to soups. Following experience with eating the soups that allowed taste and post-ingestive consequences to be associated, adults showed increased liking for the higher-energy soups, particularly when they were hungry[21]. Studies by Leann Birch and colleagues demonstrated that after a number of exposures children prefer flavours associated with higher-energy drinks[22] and higher-fat yogurts[23] compared to flavours associated with lower-energy and low-fat versions. A predisposition to 'flavour-consequence learning' may have served an adaptive function in the impoverished food environment of the distant past, but probably raises the risk of overweight and obesity in the plentiful food environment of the twenty-first century.

The post-ingestive consequences of eating are not always pleasant and children can also learn aversions to a particular food if they experience negative consequences such as nausea and vomiting after consuming it. Once an aversion is established, it is not easily extinguished and avoidance of the food may persist for many years. Learned aversions are formed most readily to unfamiliar foods and this is perhaps why they occur frequently in childhood where diets tend to be more limited than in adulthood and when many foods are still novel[24].

Although not strictly a property of food itself, the extent to which a food is familiar impacts strongly upon its acceptability. In an early study, familiarity accounted for over half of the variance in preschoolers' preferences for a selection of sandwiches, with a further 23 % accounted for by sweetness[25]. For many children – and some adults – unfamiliarity is a reason to shun a novel food. In terms of the adaptive origins of a preference for familiarity, it is plausible that familiar tastes provide an indication of the likely safety of the food being presented. Giving a novel food a familiar flavour (e.g. adding tomato ketchup or curry) can also increase a child's willingness to try it[26]. Familiarity appears to be a matter of taste rather than mere sight, and there are a wealth of studies (discussed in the later section on exposure) demonstrating that repeated exposure to the taste of a food can increase liking for it.

Social facilitation is another striking phenomenon in food preferences. In many animal species, seeing others eating the food, or even smelling the food on their mouth after consumption has taken place out of sight, increases acceptance[27,28]. If conspecifics eat a food without negative consequences, this is presumably an indication that consumption is safe and it allows healthy dietary choices to be facilitated and harmful dietary choices to be avoided. The same phenomenon is seen in children, who are significantly more willing to try something unfamiliar if they have observed someone else eating it[29]. Parents utilise this feature spontaneously when they take a mouthful of the child's food and then mime exaggerated signs of enjoyment.

The other form of learning derives from culture-specific beliefs about appropriate and inappropriate contexts to eat certain foods. One such context is time of day. For example, it is common in Scandinavian countries to eat fish at breakfast and in Germany to eat cheese and cured meat. In India, lentils may be served and in Japan, rice and miso soup. Although a North American child might enjoy such foods at other times of the day, their presentation at breakfast may be met with rejection or even disgust. Children as young as three or four years of age appear to internalise their own culture's ideas about the appropriateness of certain foods at certain mealtimes[30].

Culture also dictates to a large extent the actual foods that a child is exposed to and therefore prefers. Foodstuffs that would be deemed unsuitable for young children in Westernised countries may be routinely offered to infants of other cultures. Even innately dislikeable substances such as chilli pepper, are generally accepted and liked by children growing up in cultures where they are widely used[13]. Clearly, it is adaptive for children to grow to prefer the foods that are locally available.

Variability in food preferences between individuals

As well as variation between *foods* there is variability between *children* in their food preferences. Even among foods that are generally accepted, some individuals express specific dislikes. In a study of 4–5 year-olds' food preferences, we found that the average number of foods that were disliked out of a list of 94 common foods was 10. However, food dislikes were not random: staples (e.g. bread) and sweet foods (e.g. chocolate) were rarely disliked (though some individuals did not like them as much as others) while vegetables and protein foods attracted the largest number of dislikes. Interestingly, across foods, the number of children disliking a food was strongly negatively correlated with the number that had tried it, suggesting either that parents avoid offering widely disliked foods to children or that the aversive qualities of some foods (e.g. smell, appearance) make many children reluctant even to try them[31].

Children also vary in their total number of dislikes. Several dimensions have been identified as related to a higher number of food dislikes, including 'fussiness', 'pickiness' and 'neophobia', and there is an active debate about whether these are distinct dimensions. Food neophobia – or dislike of novel foods – has attracted a good deal of attention. While most children exhibit some degree of caution in response to unfamiliar foods, roughly 20–30 % are significantly neophobic. In a rare longitudinal study, Skinner and colleagues found that food neophobia early in life was related to the number of foods disliked or never tried at age 8 years and negatively related to the number of foods liked[4].

Recent research suggests that the association of neophobia scores with liking is not the same for all types of foods, and that certain types of food are more likely to be rejected by neophobic children than others. In a survey of over five hundred and fifty parents of preschoolers, children who were rated (by their parents) as more neophobic ate fruit, vegetables and protein foods, but not other foods, less frequently than their less neophobic peers[32]. This finding was replicated in a sample of 5–6 year olds, using observed food intakes[33]: higher neophobia was associated with lower consumption of fruit (grapes), vegetables (carrots or tomatoes) and protein foods (chicken and cheese) during school lunches, but there was no association with consumption of starchy, fatty or sugary foods.

What was apparent in this last study was that neophobic children were not only rejecting novel foods but were also more likely to reject certain classes of familiar foods, which is more characteristic of 'pickiness'. Despite the assertion by some that the two are distinct constructs[34], neophobia and pickiness appear to be closely linked, and the tendency to reject novel foods goes hand-in-hand with a tendency to reject less palatable but familiar foods. In developing the Children's Eating Behaviour Questionnaire, Wardle and colleagues found that 'food fussiness' emerged as a factor, with the items loading on this factor including 'picky' items such as 'My child enjoys a wide variety of foods' (reverse scored) as well as traditional 'neophobia' items such as 'My child enjoys tasting new foods' (reverse scored), supporting this idea[31].

Studies of pickiness have found associations with dietary quality, although results have varied. A number of studies have found that picky children have a less varied diet and are especially unlikely to eat vegetables[35–37] although others have found no differences between picky and non-picky infants and toddlers in terms of consumption of foods from the major food groups[38]. However, given the difficulty of assessing young children's diets, these results suggest that pickiness or related traits are likely to influence children's food choices and that this may impact on the quality of their diet.

Genetic influences on food preferences

There are good reasons to suspect some genetic influence on food acceptance, not least because genetic factors are implicated in a number of factors – such as taste sensitivity – that are likely to be related to food choice. In addition, some food dislikes show themselves early in life, before there is any evidence for aversive experiences.

One approach has been to examine family similarity in food preferences. Within-family (usually parent-child) correlations are typically modest[39–42], although sibling-sibling similarities tend to be stronger than parent-child similarities[41], perhaps because they are similar ages. However, without large family pedigrees, it is difficult to distinguish genetic and environmental influences in family studies.

A stronger test of genetic influence on food preferences is provided by twin studies. The twin design takes advantage of the fact that monozygotic (MZ) twins are genetically identical, whereas dizygotic (DZ) twins share on average only 50 % of their segregating genes (the same as siblings). Heritability can therefore be estimated from the extent to which MZ pairs are on average more similar than DZ twins, although when heritability is low, large sample sizes are needed to achieve accurate estimates. Few studies in the food preference area have been carried out with large enough samples to detect moderate heritabilities[43,44], and most have used only very small numbers of foods. A recent exception used a large sample of twins and an extensive list of foods which were grouped empirically into four categories: dessert foods, vegetables, fruits and protein foods on the basis of a factor structure of food preferences previously documented[31]. In this study high heritability was found for protein foods (0·78), with moderate heritability for fruits (0·51), vegetables (0·37) and dessert foods (0·20)[45].

Genetic variation in taste perception might contribute to differences in food preferences, particularly for fruits and vegetables. Thioureas and related compounds are present in many vegetables and other edible plants and have a bitter taste. Variation in sensitivity to the taste of thioureas is known to be genetically based. Around 70 % of white individuals in the USA and Western Europe perceive these compounds to be moderately to intensely bitter; and of these 'tasters', a small proportion are highly sensitive, and classified as 'supertasters'. The remaining 30 % of the population perceive thioureas as only very slightly bitter or completely tasteless[46]. The most frequently studied of these compounds are phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP).

In adults, higher sensitivity to PROP has been associated with lower acceptance of cruciferous and other green vegetables[47–49], salad, fruit[50] and a variety of other bitter foods including coffee, cheddar cheese, tofu and green tea[51,52]. Findings are not unequivocal, however[48–50,53,54]. In children, PROP sensitivity has sometimes been associated with lower acceptance of such bitter-tasting vegetables as raw spinach and broccoli in laboratory taste tests[55–57], but not with everyday intake of vegetables as reported by parents[56,58]. Interestingly, PROP non-tasters have shown increased liking with increasing sucrose concentration while tasters show decreased liking[59], which might suggest differences in their liking for fruit which is naturally sweet. However, the few studies that have investigated the relationship between PROP status and fruit acceptance in children have found no differences between tasters and non-tasters[56,58] and not all researchers have replicated the finding of increased liking for sweet taste in non-tasters[60].

Despite the attractiveness of the idea that variation in taste sensitivities could underlie food dislikes, the weight of the evidence is that PROP taster status has only limited influence on food preferences in everyday life. One alternative genetic explanation could be that neophobia/pickiness are under a degree of genetic control and pickier children are more reluctant to tolerate less palatable foods. Parents – responding to their picky child's limited diet, and worried about their overall energy intake – may 'give in' and serve the child foods it prefers, therefore further reinforcing their avoidance of any but the most palatable foods.

Heritability of pickiness/neophobia

Neophobia has been associated with personality traits such as emotionality[61] and anxiety[62], which have strong genetic links, suggesting that neophobia itself might also be heritable. Moderate parent/child or sibling/sibling correlations have been observed[32,61,63–66], but these could be either genetic or environmental. A recent study used the Child Food Neophobia Scale (CFNS)[66] in a large sample (n = 5390) of 9–11 year-old MZ and DZ twin pairs to examine the relative contribution of genes and environment. The results showed a strong genetic influence on neophobia, with model-fitting estimating heritability at 78 %[67]. These results are further supported by results from a study of Finnish families and British female twin pairs, in which heritability for neophobia was estimated at 69 % and 67 % respectively[68]. This is consistent with the idea that the trait of reluctance to accept novel or less palatable foods could play a role in dislikes for specific foods.

Environmental influence on variation in preferences

Twin studies have the advantage of not only being able to estimate genetic influence, but also to estimate the influence of a shared family environment. In simple terms, this calculation is based on assessing the extent to which the twins' similarity for a trait is greater than would be expected from the heritability of that trait. In the twin study described above, the evidence was that there was no shared environment effect for neophobia; twins were as similar in neophobia scores as predicted from their genetic resemblance but no more[67].

However, different results have been found for preferences for specific categories of food. Similarity in liking for fruits, vegetables and dessert foods within twin pairs was found to be a joint function of shared genes and shared environment[45]. This is consistent with the idea that although parental feeding styles may not be able to influence general tendencies towards disliking novel and unpalatable foods, they do have more influence when it comes to helping the child to accept specific individual foods.

Modifying food preferences

Although humans are predisposed to prefer certain tastes and regard novel foods with suspicion, they are also predisposed to learn through experience, and therefore environmental factors are very influential in food preferences. These factors may range from the availability of foods in local shops to the extent of TV advertising that a child is exposed to, but in the lives of young children, the most important factors are those related to parents and the home.

Exposure

Given the influence of familiarity on children's food, providing children with frequent opportunities to taste a wide variety of novel foods is likely pay dividends in terms of healthier eating habits. A growing body of research has demonstrated that from the very earliest age (and even before birth), experience with a tastes increases its acceptance. Julie Mennella and her colleagues have completed a number of studies demonstrating that exposure to flavours in amniotic fluid and in breast milk increases acceptance of the same flavours at weaning[69]. Early introduction of foods during weaning is associated with greater acceptance in later childhood[32,70,71] and experimental studies have repeatedly shown that regular and repeated opportunities to sample tiny tastes of unfamiliar foods increases both liking and consumption of those exposed foods[62,72–77]. Although there are circumstances in which exposure works less well (e.g. when foods are unusual or widely disliked, or when exposure is too frequent), recent research has shown that it is a simple and effective technique that parents can employ to increase children's vegetable preferences[78]. For a review of this literature see Cooke, 2007[79].

Modelling

Parents' consumption of fruit and vegetables was the strongest predictor of their child's intake in a recent survey of over 550 families with preschool children[33]. A number of factors are likely to contribute to this, including the foods that are available in the home, but it is likely to be due in part to children's tendency to imitate the behaviour of significant others. Modelling's effect on consumption has been repeatedly documented in the experimental literature on children's food choices[80–83]. Observing others eating may change preferences directly, or alternatively it may increase the likelihood of consumption, which then promotes liking through taste exposure.

Reward

The promise of a reward is a common strategy used by caregivers to encourage consumption in an unwilling child. In certain circumstances, it appears that treating a food in this way – as the instrumental component of a contingency – can actually reduce liking[73,84,85]. On the other hand, using food *as a reward* increases children's liking[86]. For example Newman and Taylor found that liking for a snack was reduced after consumption was rewarded by being offered a better-liked snack in 4–7 year olds[85]. Likewise, Birch et al found that preference for a drink that was rewarded declined whilst preference for other juices that were consumed without reward increased[87]. A further study by this group found that rewards produced negative shifts in preference for drinks whether they were verbal or tangible[84]. Our own research has demonstrated that children who received a 'sticker' as a reward for eating pieces of red pepper increased their liking and consumption of pepper over 10 rewarded days of tasting, but there was a trend for the effect to be less strong than in the group who tasted the pepper each day without being rewarded. Reward may therefore weaken the positive effect of exposure alone[77].

Explanations for paradoxical effects of reward generally draw on the child's interpretation of the context in which the foods are presented. Social psychologists argue that being given an extrinsic and tangible reward for performing a behaviour undermines an individual's intrinsic motivation, resulting in a reduction in the performance of the behaviour in future[88]. Others point out that humans do very little without some form of extrinsic reward and that what matters is the type and timing of the reward[89]. Certainly, there are children who cannot be persuaded to try a food without some incentive, and if the promise of a gold star or sticker provides the required incentive to start the exposure process, it may be a necessary step on the road to improving a child's eating patterns.

Conclusions

Children's food preferences are important determinants of their food intake and as such are of interest to researchers and practitioners alike. The predisposition to prefer sweet and salty tastes and to learn to prefer energy-dense foods may once have been adaptive, but are more likely to promote over-consumption and obesity in the plentiful 21st century food environment. The innate tendency to reject sour and bitter foods may have protected from toxins in the past but now contributes to the widespread dislike of vegetables among children and many adults; to the detriment of their dietary quality. On top of the predispositions towards acceptance and rejection shown by the whole species, there are also differences between people, both in specific food preferences and general tendencies towards neophobia/pickiness. We hypothesise that neophobia/

pickiness are related traits that include the tendency to be put off eating a food either by lower palatability or greater novelty; hence the association between neophobia and specific food preferences. There is now evidence that neophobia is a strongly heritable characteristic while specific food preferences are modestly heritable and are also influenced by the family environment. Thus food preferences are the product of an interplay between genetic and environmental factors resulting in substantial individual differences in the extent to which children are suspicious and fussy about food in general and in their likes and dislikes for specific foods. The advantage of the malleability of human food preferences is that dislike for a food can be reduced or even reversed by a combination of modelling and taste exposure. Unfortunately, few parents receive any guidance in how to promote food acceptance and a challenge for future research is to develop effective interventions that can be widely disseminated, to improve the eating patterns of young children.

Conflict of interest statement

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Influence of parental attitudes in the development of children eating behaviour

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The present paper is a review of available data on effects of parental feeding attitudes and styles on child nutritional behaviour. Food preferences develop from genetically determined predispositions to like sweet and salty flavours and to dislike bitter and sour tastes. There is evidence for existence of some innate, automatic mechanism that regulate appetite. However, from birth genetic predispositions are modified by experience. There are mechanisms of taste development: mere exposure, medicine effect, flavour learning, flavour nutrient learning. Parents play a pivotal role in the development of their child's food preferences and energy intake, with research indicating that certain child feeding practices, such as exerting excessive control over what and how much children eat, may contribute to childhood overweight. Mothers are of particular interest on children's eating behaviour, as they have been shown to spend significantly more time than fathers in direct interactions with their children across several familial situations.

A recent paper describes two primary aspects of control: *restriction*, which involves restricting children's access to junk foods and restricting the total amount of food, and *pressure*, which involves pressuring children to eat healthy foods (usually fruits and vegetables) and pressuring to eat more in general.

The results showed significant correlations between parent and child for reported nutritional behaviour like food intake, eating motivations, and body dis- and satisfaction. Parents create environments for children that may foster the development of healthy eating behaviours and weight, or that may promote overweight and aspects of disordered eating. In conclusion positive parental role model may be a better method for improving a child's diet than attempts at dietary control.

Understanding children's eating attitudes and behaviour is important in terms of children's health. Evidence also indicates that dietary habits acquired in childhood persist through to adulthood[1]. In addition, research also indicates a role for childhood nutrition on adult health[2].

Parents provide food environments for their children's early experiences with food and eating. Several studies have shown that a child's eating behaviour is strongly influenced by the family environment. The family eating environments include parents' own eating behaviours and child-feeding practices. Results of research on behavioural mediators of familial patterns indicate that parents' own eating behaviours and their parenting practices influence the development of children's eating behaviours.

Parents create environments for children that may foster the development of healthy eating behaviours and weight, or that may promote overweight and aspects of disordered eating. Characteristics of these environments include socio-demographic factors, parental activity, parental eating styles[3] and parents' child-feeding styles. Parents shape the development of children's eating behaviours, not only by the foods they make accessible to children, but also by their own eating styles[4], behaviour at mealtimes and child feeding practices[7]. Parent's child-feeding practices are associated with children's eating behaviours, including specific eating styles, food selection and preferences[5], and the regulation of energy intake[6].

Innate

Food preferences

Children's food preferences strongly influence intake and it is therefore vital to understand how these preferences arise. Psychological research is beginning to reveal the complex interplay of innate, learned and environmental factors which shapes children's eating patterns. Food preferences develop from genetically determined predispositions to like sweet and salty flavours and to dislike bitter and sour tastes. There is evidence for the existence of some innate, automatic mechanism that regulate appetite. In 1–3 years infants energy intake regulation is effective if there is a wide offer of plain foods.

With plain foods, children choose their diet and have a regular growth, without instructions from adults. Beside the theory of self-regulation there is evidence that eating behaviour can be learnt and it is possible to modify energy intake by a repeated offer. Taste acquisition for specific foods is a consequence of learning.

Young children are also predisposed to be neophobic about food. Particularly towards the second year of life, coinciding with an important period of transition to an adult diet, there is a tendency to avoid novel foods (neophobia). Neophobia (literally 'fear of the new') manifests itself as a rejection of unfamiliar foods in favour of familiar ones. In a survey of almost 600 2–6-year-old children, neophobia was significantly negatively associated with fruit, vegetable and meat intake[8] THOUGH

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NOT WITH consumption of dairy foods, starchy staples or cakes and biscuits[9].

Food aversions can be learnt in one trial if consumption is followed by discomfort. However, from birth genetic predispositions are modified by experience. There are mechanisms of taste development and positively associated with:

Mere exposure: the more exposure we have to a stimulus, the more we will tend to like it; foods which have been eaten more often tend to be liked more; this is the way that specific preferences grow in different cultures. Several studies suggest that an exposure based approach has promise for improving the quality of children's diets. Particular strengths of the technique are its simplicity and relatively low demands of both parents and children.

Medicine effect: we like better a food that we eat when we are healthy instead of a food proposed when we are ill.

Flavour learning: between 2 foods of different taste, administered one added with sugar and one without, there is preference for the first food also when proposed without sugar.

Flavour nutrient learning: the more a food is energy-rich the more is appreciated, this is a primordial model. Man can recognize the most caloric foods indispensable to life[10].

Family environment

In the experience context, during the early years, parents play a particularly important role. There are many variables within the family setting that can affect children's eating behaviour and, ultimately, their weight outcome. Included among these are parents' eating behaviours, foods made available to children, and child feeding strategies utilized. Parents play a pivotal role in the development of their child's food preferences and energy intake, with research indicating that certain child feeding practices, such as exerting excessive control over what and how much children eat, may contribute to childhood overweight[22] (Table 1).

The children behaviours (dietary intakes-eating style, weight, physical activity) are influenced from parent characteristics. The family environment influence:

1. the *children intake* by eating styles, diet composition, food preferences, child-feeding practices, availability of energy-dense foods in the home, restaurant eating *v.* meals prepared at home, family meals *v.* eating away from the table

Table 1. Family factors that influence bidirectionally parents and child

Parent characteristics	Child characteristics
Parents' weight status	Dietary intakes
Perceived responsability for child feeding	Eating style
Parent's dietary intake	Weight
Food preferences	Physical activity
Feeding practice	
Portion size	
Food available at home	
Food accessibility	
Eating locations ambient temperatures and lighting	
Time of consumption, ambient sounds	
Temperature and smell of foods	
Family meals *v.* eating away from table	
Family income	
Physical activity	

From Davison & Bearch 2001 Obesity Reviews.

2. the *children energy expenditure* by physical activity patterns, physical activity preference, metabolic rate, enjoyment of physical activity, encouraging children to be active, providing opportunities to be active

The parents can influence the development of children eating behaviour through a set of regulatory acts aimed at helping children adapt to their environments:

- Sustenance: providing food, protection from environment threats
- Stimulation
- Support
- Structure: organizing eating environments
- Surveillance: monitoring and control over eating

Parental control

A recent paper[5] describes two primary aspects of control: *restriction*, which involves restricting children's access to junk foods and restricting the total amount of food, and *pressure*, which involves pressuring children to eat healthy foods (usually fruits and vegetables) and pressuring to eat more in general. Parents may use a combination of these methods to obtain a desired result; for example, pressuring a child to eat healthy foods by using bribes or rewards consisting of sugary snacks that are otherwise restricted[19].

Parent restriction has short term and long term effect on children's intake. It enhances preference, increases attention and intake at first, then this curb increases intake, increases eating in the absence of hunger, doesn't produce ability to self-regulate diet but causes negative self evaluation, greater weight gain from 5 to 11 years[5].

Pressuring children to eat, likewise appears to be counterproductive, reducing children's ability to regulate their energy intake[6]. A further study[11] has linked 'pressure to eat' to reduced consumption of fruit and vegetables in 5- year-old girls. A common assumption runs through these studies: that controlling children's intake of food is a causal factor in their poor eating patterns. It is entirely plausible, however, that the direction of causality runs counter to this; that, in fact, parents use of control is a response to unhealthy eating habits. Others researches have explored the impact of controlling food intake by rewarding the consumption of 'healthy food' as in 'if you eat your vegetables I will be pleased with you'. For example, Birch *et al.* [12] gave children food in association with positive adult attention compared with more neutral situations.

This was shown to increase food preference; but as concluded by Birch: "although these practices can induce children to eat more vegetables in the short run, evidence from our research suggests that in the long run parental control attempts may have negative effects on the quality of children's diets by reducing their preferences for those foods."[13]

Initial evidence indicates that imposition of stringent parental controls can enhance preferences for high-fat and energy-dense foods, limit children's acceptance of a variety of foods and disrupt children's regulation of energy intake by altering children's responsiveness to internal cues of hunger and satiety. This can occur when well-intended but concerned parents assume that children need help in

determining what, when, and how much to eat and when parents impose child-feeding practices that provide children with few opportunities for self-control[14].

Maternal influences

Mothers are of particular interest on children's eating behaviour, as they have been shown to spend significantly more time than fathers in direct interactions with their children across several familial situations, including mealtimes[15].

Mothers who exert a greater degree of control over their child's food intake had children who demonstrated less ability to regulate energy intake. External parental control of the child's dietary intake may indirectly foster the development of excess adiposity in the child.

Birch and colleagues[16,17] point out that mothers, who were preoccupied with their own weight and eating, reported higher levels of restricting daughters' intake, encouraging daughters to lose weight over time. In this study, mothers' encouragement of daughters' weight loss was linked to daughters' restrained eating behaviour. This relationship was partially mediated by daughters' perception of maternal pressure to lose weight. These findings suggest that mothers' preoccupation with weight and eating, via attempts to influence daughters' weight and eating, may place daughters at risk for developing problematic eating behaviours.

The predictors of maternal child-feeding style are maternal and child characteristics. Birch and colleagues[5] affirm that mothers reported using more restrictive feeding practices when they perceived daughters as overweight and reported using more pressure in child feeding when they perceived daughters as underweight.

Mothers' child-feeding practices were related to mothers' own investment in weight and eating related issues, daughters' observable weight status, mothers' perceptions of daughters' weight status, and mothers' concern for their daughter developing a weight problem in the future. This model held for maternal restriction, in that mothers reported greater use of restriction in child feeding when they had greater weight and eating concerns of their own, when daughters were overweight, when they perceived that their daughters were at risk for developing a weight problem, and when they had concerns about daughters' weight[18].

Recommendations for practice on nutritional behaviour

The parental attitudes and behaviour are central to the development of children's eating habits, so it's important to give to the parents some strategies about their child's nutritional behaviour as:

1. Guidance for parents should include information on how children develop patterns of food intake in the family context.
2. Practical advice for parents includes how to foster children's preferences for healthy foods and how to promote acceptance of new foods by children.
3. Parents need to understand the costs of coercive feeding practices and be given alternatives to restricting food and pressuring children to eat
4. Setting a good example: parental role modelling is important in establishing children's food choice. Depending on their own foods choice, parents can be either positive or negative role models. For example in some study fruit and vegetable consumption is higher in children[20] and adolescents[21] who eat at the same time as their parents and in pre-schoolers who eat the same food at mealtimes which further supports this view. It's very important that parents, guardians and caregivers must provide appropriate role modelling through their own behaviour, that is, influence children to "do as I do" rather than "do as I say".
5. Respond to satiety clues and do not overfeed; infants and young children can usually self-regulate total energy caloric intake; do not force children to finish meals if not hungry
6. Parents should remember that they are responsible for choosing foods and when and where food should be eaten.
7. Two natural parental impulses, pressuring children to eat and restricting access to specific foods, are not recommended because they often lead to overeating, dislikes and paradoxical interest in forbidden items
8. Strategies to improving nutrition in young children are for parents, not children:
    - to choose meal times;
    - provide a wide variety of nutrient-dense foods, such as fruits and vegetables, instead of high-energy- density/nutrient-poor "junk" foods;
    - age-appropriate portion size;
    - limiting snacking and use of juice or sweetened beverages;
    - allowing children with normal body mass index to self-regulate total caloric intake;
    - having regular family meals to promote social interaction and role model food-related behaviour
    - limit video and television watching to less than 2 hours daily.

Conclusions

The development of children's food preferences involves a complex interplay of innate, familial and environmental factors, not all of which are likely to promote a healthy and varied diet. Parents employ a variety of strategies to improve their children's eating habits some of which have been found to be counter-productive. Over-control, the offering of rewards, and the provision of nutrition information to children appear to have negative effects on food acceptance patterns. Parents own food preferences, on the other hand, are enormously influential and eating together as a family provides a valuable opportunity for parents to model good eating habits. Together with the evidence that repeated taste exposure can increase acceptance of healthy foods, these findings should inform the guidance given to parents during early childhood. Effective prevention programs must focus on providing anticipatory guidance on parenting to foster patterns of preference and food selection in children more consistent with healthy diets and promote children's ability to self-regulate intake. Guidance for parents should include information on how children develop patterns of food intake in the family context. Practical advice for parents

includes how to foster children's preferences for healthy foods and how to promote acceptance of new foods by children. Parents need to understand the costs of coercive feeding practices and be given alternatives to restricting food and pressuring children to eat. Providing parents with easy-to-use information regarding appropriate portion sizes for children is also essential as are suggestions on the timing and frequency of meals.

Conflict of interest statement

None of the authors has any conflicts of interest to report.

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Impact of education on food behaviour, body composition and physical fitness in children

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The increasing prevalence of obesity during growth and development is significantly related to the education of children, and also to that of parents who influence food intake and physical activity from the beginning of life. The effect of maternal level of education has been shown in regular anthropometric surveys in 10-year intervals since 1951. This concerns the mother's own nutrition and physical activity regimen as well as the child's nutrition since birth, including the duration of breast-feeding. Children of parents with overweight and obesity were shown more often to be obese, as was the case for children from families with the lowest level of education, or from smaller communities where the level of education is usually lower than in larger cities. The composition of the mother's diet during pregnancy had, for example, an effect on the blood lipids of newborns. During preschool age, less body fat, a higher level of HDL, and higher levels of cardiorespiratory fitness, skill and physical performance were found in active children. In school-age children, when obesity increases, a number of prevention programmes using diet, exercise and behavioural intervention have been developed for schools, communities, churches, and/or have been organized by special institutions and medical centres, which were most efficient in family groups. The greatest reduction of weight, BMI and fatness, and improvement of functional capacity, and hormonal and metabolic parameters were achieved in summer camps or spas, with consistent and monitored nutrition, exercise and behavioural treatment. Fluctuation of positive outcomes occurred due to the interruption of the educational process during the school year, and repeated long-lasting interventions have been always necessary for permanent desirable results.

Education: Nutrition: Obesity prevention

Inadequate life habits introduced during the last few decades, which can result in health complications including obesity, concern at present also children and adolescents. The International Obesity Task Force[1] and the WHO[2] evaluated the global epidemic of obesity also as an essential educational problem. The significant impact of the environment – especially nutrition[2,3] – has been considered during recent years as the most important one, especially influencing subjects with genetic predispositions concerning metabolic characteristics, etc.

During growth, the development of the organism can be best influenced due to its plasticity; the impact of negative environmental stimuli[2–4] concerning lifestyle can be at least partly eliminated in those whose education helps to resist or compensate undesirable influences and who adhere to the principles of rational diet and overall lifestyle. Adequate cognitive growth and social maturation resulting from proper education can contribute to adequate dietary, motor and social habits, which might result – under further positive environmental conditions – in good health, and also in an optimal somatic, functional, psychological and social development, which is the best criterion with regard to the efficiency of educational interventions.

Historical aspects

The increase in prevalence of overweight and obesity has been shown in most industrially developed countries, but also in other countries where life conditions have changed rapidly during recent years[1,2]; this concerns also very young subjects. Comparisons along time, and/or among populations with different degrees of industrial, economic and social development, demonstrate that. For example, the measurement of Czech children started in 1895 by Professor J. Matiegka (5; published in 1927) enabled the comparison of child development since the end of the nineteenth century until recent time. At the end of the nineteenth century, children were not only smaller, but overweight and obesity was obviously much rarer[5].

International comparisons

In spite of a lower prevalence of overweight and obesity in the Czech Republic as compared with the USA and Europe[1,2], the increasing trend has indicated an urgent need to intervene by all possible means, including proper and innovative education. After initial measurements of Czech children in 1895, regular measurements have continued in 10-year intervals since the half of the last century until present, always in tens of thousands of subjects (each follow-up of about 20–60 000 children; 6–11).

The last measurements in 2001 included 18 584 younger children from 6 to 10·99 years of age, and 40 525 schoolchildren and adolescents[7,11]. Average values and percentiles of eleven anthropological parameters were established, and the

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effect of various factors (ascertained by questionnaires, thirty-five items) such as family situation, education of parents, birth weight, duration of breast-feeding, participation in exercise, etc were evaluated, and their impact was compared in different periods of these studies since 1951.

Comparison of the changes of BMI centiles since 1951 up to 2001 in Czech children was conducted[6–8,11]. Values of BMI at the 10th percentile did not change, values of 50th percentiles changed a little only at certain ages, mostly in boys. BMI at the 90th percentile have shifted during the 50-year period more markedly; in boys along the whole age span, but in girls only up to 14 years of age. This means that the percentage of children with marked degrees of obesity has increased relatively most from 1951 to 2001[11]. Older adolescent girls have taken greater care about their body size and silhouette, obviously also due to changed diet. The effect of the Western criteria of beauty has had a significant effect also in this respect, which was finally quite a desirable one.

Secular and developmental changes

Secular changes of growth and development were shown; in addition, the measurements in Czech children could also demonstrate the shift of adiposity rebound (AR) to an earlier age[9–12], which is an especially important finding about recent child growth and development. It is possible to assume that this has occurred also in other child populations. This shift is considered as a marker of an easier and earlier development of enhanced fatness, and increased BMI during following development (Tables 1 a, b; 12). This results obviously from the changes in lifestyle since the earliest periods of life – nutrition and reduced physical activity of the family, which is significantly influenced by the level of education of parents.

Compared with 1951, the time of AR has gradually shifted to earlier ages. Among boys at the 50th percentile for BMI-for-age, AR occured at the age of 4·9 compared with 6·2 years in 1951. AR among girls at the 50th percentile occured 1·2 years earlier. AR at the 10th and 50th percentiles occured later among girls compared with boys in 1951 as well as in 2001. In contrast, girls at the 90th percentile experienced AR earlier than boys at the same percentile (Tables 1a, b; 12). Similar long-term studies since the end of the nineteenth century have not been conducted in children of other countries.

The prevalence of subjects characterized by higher and/or lower BMI centiles changes markedly according to age – adolescents older than about 15 years at the occasion of the last measurement in 2001 generally had a lower prevalence of overweight and obesity[8,11,12]. Development and growth under conditions of communities with different numbers of inhabitants also had an impact on the prevalence of BMI in different centiles: higher BMI was more frequent in children from smaller communities[7,10,11]. This finding could also be related to the effect of education in families, which has been always found to be on a higher level in greater cities. The effect of genetic and hereditary factors was also shown by a higher ratio of children with higher values of BMI who had parents characterized by higher BMI[7,11].

Table 1a. Age (years) of adiposity rebound in 1951 and 2001 in boys[12]

	Percentile		
Year of the survey	10th	50th	90th
1951	6·4	6·2	6·0
2001	5·3	4·9	4·2
Difference	1·1	1·3	1·8

Table 1b. Age (years) of adiposity rebound in 1991 and 2001 in girls[12]

	Percentile		
Year of the survey	10th	50th	90th
1951	6·5	6·4	5·8
2001	5·6	5·2	4·1
Difference	0·9	1·2	1·7

Effect of mother's nutrition and birth weight

Another study in Italian mothers and children showed a significant effect of the composition of the mother's nutrition during pregnancy on the metabolic characteristics of newborns. The amount of proteins and carbohydrates in the mother's diet during various trimesters of pregnancy had a significant relationship with the level of, for example, serum lipids (total cholesterol, HDL-cholesterol) in their offspring (Table 2). However, when we analysed the effect of mother's nutrition with regard to gender, it was shown that this effect was significant only in boys[13,14]. As considered more recently, obesity can have its origins during pregnancy – already in the womb. Pregnant women are now advised to cut out certain foodstuffs – for example, junk food, for their children's sake[1].

Increased birth weight of children of healthy mothers indicates, *inter alia*, higher dietary intake during pregnancy. Children born heavier were characterized by greater proportion of individuals with higher BMI also at the age of 6–10·99 years

Table 2. The relationships between the composition of the mother's diet in different trimesters of pregnancy, and level of serum lipids in newborns[14]

		Newborns			
		Both genders		Boys	
Mother's diet	Trimester	r	p	r	p
Protein (g/d)	1st			HDL −0·544	0·04
Carbohydrate (g/d)	1st	TCh −0·466	0·03	TCh	
	2nd	−0·597	0·004	−0·654	0·01
	2nd	HDL −0·536	0·01	HDL −0·635	0·01
	3rd	TCh −0·436	0·04		
		HDL −0·439	0·04	HDL −0·579	0·01

TCh, total cholesterol.

(*n* 18 584; 7,11). Similar results were gained in another study when following preschool children (*n* 9092; 13). Those who were born heavier also had at the age of 6–7 years higher body weight and BMI, and were characterized also by higher values of other bodily dimensions, for example, circumferential measures (greater chest and hip circumference), and higher level of motor performance in selected motor tasks. Children born heavier were more skillful, for example, had better results in the test of ball throwing by the left hand[13].

Duration of breast-feeding has been shown to be a significant factor relating to body size during later growth. Studies of Czech children showed a higher percentage of children characterized by higher BMI which were not breastfed, as compared with children who were breastfed up to more than 6 months of age[11]. As found in the group of children born in 1995–2000 (*n* 9602), duration of breast-feeding was longest in mothers with the highest level of education (university; 13). Education and instruction of mothers with regard to their diet during pregnancy and duration of breast-feeding have gained great attention in recent decades in not only in the Czech Republic[13,15], but also in all other countries, and mostly a positive effect of breast-feeding was demonstrated in a number of studies with regard to obesity prevention, and also to other health risks, psychological and emotional development, etc[1].

Effect of family education

Educational level in the family, i.e. education level of the father and of the mother, has also shown a positive impact – the percentage of children with the highest BMI at the age of 6 to 10·99 years of age was highest in families where both parents had a lowest degree of education[11]. Similar results were also found in another study of preschool children mentioned above (*n* 9587), in which parents were divided into four categories according to educational level (1, basic level; 2, skilled manual worker; 3, high school with higher school certificate; 4, university education). This study also showed better results, i.e. the lowest prevalence of obesity (BMI above 90th centile), in children from families with a father with the highest level of education (level 4) and a mother with a middle degree of education (level 3)[13]. Apparently, higher parental education influences significantly the regimen of life in the family including nutrition and also the physical activity regimen, preventing overweight and obesity of children.

Education of the mother also has an effect on the selection and number of refused foods for their children of preschool age[16]. More educated and knowledgeable mothers selected with greater care foodstuffs for their children, which were not suitable for optimal development. The role of mothers was always mostly important, for example, familial patterns of overweight were found to be mediated by mother's dietary disinhibition[17]. Family lifestyle, parental BMI and parental eating attitudes were shown, for example, by a longitudinal study to be a predictor of children's BMI[18]. This concerns also television viewing, physical activity and snacking, which influence negatively the BMI of children[1,2,19,20].

Too-large weight increments in children during the initial weeks and months of their life – considered formerly as positive – are at present evaluated as a marker of easier development of obesity during later development. Previous energy recommendations (WHO[1,2]) are at present considered too high, as an adequate somatic development can be assured with about 10–15 % lower energy intake. Babies are thus often overfed due to outdated growth charts and RDAs. Therefore, present RDAs for children have been reduced. This issue was discussed also in special meetings and congresses concerning this problem (for example, at the occasion of the recent International Congresses of Nutrition (IUNS) in Montreal in 1999, in Durban (2005), or, for example, in the congress on 'Fetal origins of adult diseases' (Mumbai 2001) where a special session on obesity was also included. The WHO has also focused attention on this particular problem[2].

Effect of energy output and physical activity

The mentioned problems have been discussed under conditions when basic RDAs are met, as usual in developed countries. But all recommendations must also be considered in relation to overall energy needs, i.e. also related to the energy output, influenced mainly by physical activity level[13]. Studies in preschool children have given basic data on somatic and motor development from 3 to 6 years[13,19]. Comparison of preschool children (mean age 4·7 years) differing in the level of spontaneous physical activity showed that more active children achieved slightly lower values of BMI and of fat percentage, along with slightly higher energy intakes and higher levels of cardiorespiratory fitness (as evaluated by the results of a modified step test for preschool children; 13,19). HDL level was significantly higher, which indicates that their metabolic development was more positive. Percentage of body fat correlated positively with total cholesterol and TAG level[19] which showed that increased fat deposition has an undesirable effect already in children of 4·7 years of age.

Therefore, when evaluating energy intake, food choice and habits, it is necessary to relate them also to energy output, as a higher dietary intake has a different impact in children with higher and/or lower levels of physical activity and motor performance.

Similarly, as with regard to nutrition, also activity and exercise habits can be established due to various family conditions and level of education at an early age, which are dependent not only on genetic factors (as shown by motor studies in mono- and dizygotic twins – see 13), but also, in this respect, on family habits and educational practices. As shown by psychologists in humans, not only nutrition habits, but also motor habits and physical activity level can be ingrained by education as early as 2–3 years of age[13,19], and can result also in delayed consequences concerning health and overall metabolic and physical fitness in later years of life. This was, however, proved mainly in laboratory models with experimental animals[13] where the long-term follow-up is possible. However, any child can learn and be educated to eat properly, or the reverse. Moreover, a child can learn to move, or learn not to move, and to prefer to be sedentary.

Not only somatic, but also motor development and level of physical performance were shown to be influenced by regular exercise[13,19], as shown in children participating in specially organized physical education for young preschool children together with their mothers (and/or fathers, or any other caretaker[13,19]. This form of physical education was introduced in the Czech Republic during the 1960s on a mass scale, and has been continuing until the present time. Early intervention

during preschool age is desirable, as the level of physical activity is spontaneously high[13,19,21]. After entering the primary school the motor activity of children decreases both spontaneously (as shown by a longitudinal study; 13) and due to the change in lifestyle.

Combined educational approach during school age

During school age and pre-adolescence, overweight and obesity increase more often. A combined approach including monitored diet, exercise and behaviour is again most often used, and differentiated – in an optimal case – according to age, degree of sexual maturation, gender, duration and degree of overweight and/or obesity[22–24]. The mentioned factors are used both for the prevention and treatment of obesity. The best situation in this respect had special out-patient courses, which were organized both for parents and children.

As shown by further studies, in well-organized groups with long-lasting nutrition education and control of somatic changes, very good results were achieved. Short- and long-term effects were beneficial when such a combined approach using dietary–behavioural–physical activity intervention were followed up[23]. A favourable effect of a structured out-patient programme using the same items in a group of obese children – OBELDICKS – was found[24,25].

Clinical counselling and education had better results in family-based group treatment of obesity as compared with individual treatment. Children who participated in group treatment lost more weight for height (6·8 %) than children receiving routine counselling (1·8 %). After 6 months after this intervention, positive results were partly lost, but for changes in weight, height and BMI, the differences were always significantly better when group counselling was used[26]. In-patient treatment along with nutrition education was also introduced in special clinics, but this concerned especially severely obese children who had additional health problems[27].

More recently introduced multidisciplinary programmes of a combined educational dietary–behavioural–physical activity intervention resulted not only in the reduction of BMI and lowering of excess fatness, but also reduction of serum lipids, improved fitness and in improvement of nutritional and physical activity habits. Education and instruction were well organized, and the follow-up was continued during 1 and 2 years[24,25]. Various similar out-patient educational programmes and interventions were also conducted, for example, in Finland, Germany, Spain, Czech Republic, Netherlands, Poland and also in the USA, Chile and Israel, all with good results.

As a basis of such programmes, communities[28] and churches were also used. All interventions, including diet and exercise, were arranged both in the framework of school hours, and also as an after-school programme[29,30]. Reduction of television viewing as a marker of reduced physical activity is also the part of some programmes.

Special programmes also included education aimed at increasing the consumption of vegetables and fruit. Promotion of milk and milk product consumption was focused in other programmes and educational interventions as a mean for obesity prevention and improved skeletal development (for example, USA, Poland, Sweden, Italy, Greece, etc). Positive results of such educational programmes and interventions conducted in Sweden, Belgium, Spain, Australia, UK, France, Finland and others were reported (for example, 31–36), and were also presented in a number of lectures and posters, especially in sessions on public health and prevention of the last European Congress on Obesity (ECO) in Budapest in April 2007.

A special problem has always been the drop-out from such intervention programmes, when children and adolescents interrupted their participation and for various reasons did not continue. Often the programmes were not attractive, and the educational part not efficient enough. This occurred mainly when there existed interfering influences from the environment, family, etc during the normal school year and at home. Such conditions could make the application of intervention programme difficult and complicated. Lack of fast positive results also discouraged some children. But those subjects who continued in this sort of programmes and interventions had positive results which mostly outlasted the period of the mentioned studies[34–37]. Drop-out has always had serious consequences, as those who did not continue most deteriorated further their somatic, functional, metabolic status, etc and increased more excess fatness, along with further health problems not only at present, but also in future life.

Educational and treatment effect of summer camps

Of especial importance, summer camps have been organized, both under natural conditions or in a spa, mostly for children and adolescents who were more obese[38–40]. Such camps have been organized since the 1950s, for example, in the Czech Republic (former Czechoslovakia), later also in the UK[41,42], and other countries.

Their purpose can be best achieved, but their organization is costly. The educational practices from all points of view can be optimally arranged, and their impact best controlled, especially from the point of view of fat reduction. This also included the preparation of optimal meals (with monitored energy intake and exclusion of inadequate foodstuffs) and an overall dietary regimen during the day time, along with an adequate and suitable exercise and physical activity regimen.

Behavioural interventions were also included in programmes of such summer or spa interventions, and psychological treatment was essential; all children were comparable in their problems, which enabled more efficient education and treatment. Thus, children felt relaxed and without inhibitions, especially when considering, for example, organized exercises and sports of all suitable character (swimming, games, running, trekking, dancing, etc). The reduction regimen was thus accepted spontaneously and with greater willingness, and was significantly supported by positive results, which were regularly checked[38–42].

There was always a significant reduction of body weight, BMI, and total and subcutaneous fat (Fig. 1). The distribution of subcutaneous fat also changed, i.e. it decreased more markedly on the trunk than on the extremities, and the indices of fat distribution also became closer to the values of normal-weight children of the same age[38]. Heart rate increased less during the same standard workload on a veloergometer, and the same was found for oxygen uptake[39,40], i.e. the energy cost of the same workload on a treadmill decreased significantly after excess fat loss. This was found even when the effect of weight bearing during a workload was excluded on a bicycle ergometer[40].

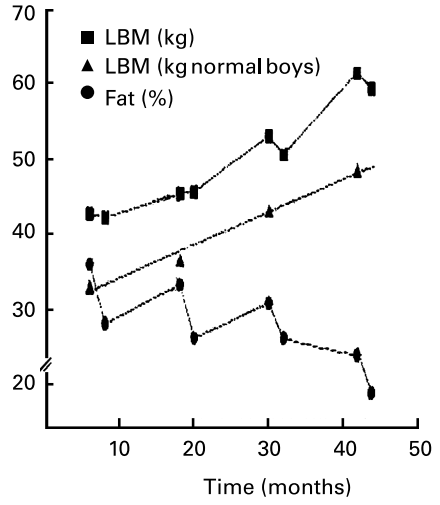

Fig. 1. Changes of body composition – lean, fat-free body mass (kg) in obese boys (—●—) as compared with the development of lean body mass (kg) in normal-weight boys (followed each year at the same age[46]), and of body fat (%) (—▲—). Four-year longitudinal study when boys were repeatedly measured each year by densitometry, always before and after four summer camps with reduction treatment (monitored dietary intake, controlled exercise, behavioural intervention and education), from 11 to 14 years (eight measurement 39).

Along with weight, fat, leptin, serum lipid levels and blood pressure decreased significantly[40,43,44]. Also blood levels of selected hormones changed significantly along with weight and fat reduction, i.e. insulin, cortisol, thyroxine, etc[45].

Regular control of body weight, BMI, fatness, performance in various sport disciplines and their positive results encouraged children to adhere to the programme and continue until the end of such summer camps. Moreover, children felt happier, relaxed and without inhibitions, and remembered such treatment with pleasure during the whole school year. The psychological effect of the stay in summer camps in groups of children with similar problems and with the same educational intervention was especially positive, and resulted in the best effects during a relatively short time period, as compared with all other treatments. Similar results were also found during spa treatment of the obese[12,43].

Fluctuation of weight, fat and physical fitness after interruption of treatment

However, during the school year the results of such interventions usually partly disappeared, and further increase of weight and BMI and fatness were observed[38–40]. But when it was possible to continue with the mentioned education and intervention during the year (for example, when following children regularly in out-patient departments in paediatric clinics, or in other special centres), and also to repeat such a treatment in summer camps during following years, the final results meant a significant improvement of somatic, functional, biochemical and other parameters even after more years (Fig. 1; 40). This concerned also health status – not only the present, but also future status – as shown particularly by cases of especially motivated subjects.

In regularly exercising boys in sport schools or clubs (more than 6 h per week of regular training in light athletics and basketball during 8 years) there was a significant effect on body fat development as compared with boys who only had physical education at school (which was the same for both groups) and only irregular exercise (less than 2 h per week[46]).

Perspectives and conclusions

As commented before, the best management of obesity is not to let it develop at all, using proper education and intervention. This was proved especially in those who were committed and educated from the very beginning of life[13,19].

However, measures for preventing obesity were known already in the ancient cultures of the Egyptian, Chinese, Indian, Roman and Arabic Empires, etc. The founder of pedagogy – 'teacher of nations' according to UNESCO – John Amos Comenius elaborated the whole education system in greater detail already in the 17th century[47]. His recommendations for education concerning both nutrition and physical activity of children are appropriate even today, and should be implemented with greater effort even under present conditions.

Early beginning of nutritional education and intervention, and adhering to such programmes are recommended as one of the most efficient means for positive health not only during growth, but during the whole life. This is started by the nutritional status of the mother, adequate nutrition during pregnancy, breast-feeding period and proper nutritional and educational management of the child from birth, and of course later on. Repeating all these old wisdoms is still justified: the deterioration of the overall situation, i.e. the global epidemic of obesity which concerns at present also children and adolescents, means an urgent health problem for the whole lifespan. But changing life conditions requires new innovative programmes of intervention, starting with an adequate education which until now has not been shown as effective enough.

Activities of intergovernmental organizations

The WHO has paid attention to this problem, and not only to obesity which has already started, but also to educational interventions not only in families, but also schools which should prevent it. This should contribute to health development, and includes, as for example, 'Nutrition-Friendly School initiative NFS1', both diet and increased physical activity and exercise (WHO – 'move for health' . . .health and development through physical activity and sport'; 48). A document on 'Nutritional education in primary schools: a planning guide for curriculum development: Promoting lifelong healthy eating habits' was produced by the FAO in 2005 (Rome)[49a,b]. Other documents of the WHO and FAO are available during recent years, and can also contribute to the prevention of health risks resulting from obesity.

Conflict of interest statement.

The author has no conflicts of interest to report

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Teaching children with diabetes about adequate dietary choices

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Recent recommendations by the American Diabetes Association suggest that children with type 1 diabetes should follow the recommendations for age, sex and body size of the general population. In the case of being overweight or obese, weight-control strategies should be applied. Adherence to recommendations should be pursued by continuous nutritional education that should start at the onset of diabetes and maintained by means of nutritional counselling to the family. The second main target of nutritional intervention is to encourage a reproducible daily meal plan that can be maintained by acquiring good habits when making nutritional choices. Finally, children and parents should be taught how to count carbohydrates, which would help them manage exceptions in their daily meal plan. Specifically, nutritional recommendations for children with diabetes focus on limiting the intake of foods of animal origin (red meat, cheese, cold cuts), moderating fat intake and promoting the intake of foods that naturally contain fibre (mainly vegetables, legumes, fruit). There are two at-risk periods in the lives of children when nutritional education procedures as well as diabetes care in general are less likely to be effective: early years of life and adolescence. In the case of very young children, new behavioural-based intervention strategies to help parents improve mealtimes could be useful in teaching diabetic children to learn to follow a structured eating schedule, which is desirable for long-lasting efficacy in diabetes care. In adolescents, eating disorders and insulin misuse for weight control purposes are concrete and difficult problems to deal with. A good balance between eating for pleasure and maintaining one's health is a challenge for anyone. Appropriate nutritional education helps children with diabetes to find this balance and enjoy a better quality of life.

Children: Diabetes: Nutrition

Two epidemics have been currently identified that affect industrialized countries: obesity and diabetes[1,2]. The forecast for the future is a further progressive increase in the prevalence of these metabolic disorders, also in children. Interestingly, as a consequence of widespread obesity, impaired glucose tolerance and type 2 diabetes, which in the past were almost exclusively limited to adulthood, are becoming more common in children and adolescents[2]. It is likely that the discouraging results of prevention and treatment programmes for childhood obesity available today are the reason behind the rapid rise in the incidence of glucose metabolism disorders in children[3]. Nowadays, although the prevalence of type 2 diabetes is increasing in young individuals, type 1 diabetes is still the most common form of diabetes in children and adolescents[2].

The management of type 1 diabetes is multifactorial but nutrition plays a key role in both blood glucose control and prevention of micro- and macrovascular complications of the disease[4]. In this article, we report nutritional recommendations with a special focus on ages at high risk for low compliance: young childhood and adolescence.

Type 1 diabetes

Most cases of type 1 diabetes (type 1A) are due to pancreatic β-cell destruction by an autoimmune attack that leads to absolute insulin deficiency and impaired glucose homeostasis[5]. In a minority of cases (type 1B diabetes) usually occurring in individuals of Asian or African descent, no causes have been identified that underlie the disorder[6]. There are two main factors in the pathological process that characterize the immune form of diabetes: susceptibility and environmental triggers[7].

Susceptibility

About 50 % of genetic susceptibility to type 1 diabetes is conferred by the HLA locus. *DR3/4*, *DQA1*0301-DQB1*0302*, and *DQA1*0501-DQB1*0201* have been identified as high-risk HLA haplotypes, whereas *DQA1*0121-DQB1*0602* HLA haplotypes have been associated with diabetes resistance[8]. DR molecules (DRB1*1401) have also been associated with protection from diabetes[8]. *Insulin-VNTR (IDDM2)* and *CTLA-4 (IDDM12)* genes cumulatively contribute to explain a further 15 % of the genetic susceptibility to the disease[9]. Other genes that may be involved in the immune pathogenesis of type 1 diabetes are currently under investigation.

Environmental triggers

Several environmental triggers involved in altering immune function, thereby initiating β-cell destruction, have been suggested: viruses (congenital rubella, enteroviruses, coxsackie,

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etc), environmental toxins (for example, nitrosamines) or early exposure to some foods such as cows' milk proteins, cereals or gluten[10–16].

Insulitis and humoral response

In susceptible individuals, the T-cell-mediated immune system is abnormally activated which leads to two main consequences: (a) an inflammatory response within the islets (insulitis) and (b) a humoral (β-cell) response with production of autoantibodies directed toward insulin (IAA), glutamic acid decarboxylase (GADA/GAA) and the protein tyrosine phosphatase IA2 (IA-2AA)[17]. These autoantibodies are markers of insulitis, but their active role in the pathogenesis of the disease has not yet been demonstrated. One or more of these antoantibodies may be detected years before the clinical onset of diabetes; the presence and persistence of multiple autoantibodies increase the likelihood of progression to clinical disease[17,18]. Interestingly, individuals who develop type 1 diabetes are also susceptible to several other autoimmune disorders (Hashimoto's thyroiditis, coeliac disease, Graves' disease, myasthenia gravis, Addison's disease and vitiligo)[19].

Incidence

The incidence of type 1 diabetes differs among geographical areas: China has the lowest incidence (about 0·5 cases/100 000 per year) and Finland and Sardinia (Italy) the highest (about 50 cases/100 000 per year), but it is continuously increasing (2–5 %/year) worldwide[20,21]. Moreover, migrating populations bring within a short time a change in incidence that becomes that of the country to which they migrated[22]. This evidence indirectly supports the importance of environmental factors in the development of the disease.

Cumulatively, 5–10 % of the total cases of diabetes in the entire population are due to type 1 diabetes.

The age at onset is progressively decreasing: most cases (40–50 %) are diagnosed before the age of 4 years. Another 20–30 % of cases are diagnosed before the age of 18 years. The remaining cases occur in adulthood[2].

One of the potential factors involved in the progressive increase in the incidence of type 1 diabetes in young children may be the overload of the β-cell, mediated by a variety of mechanisms, that may sensitize it to become immune to damage and apoptosis, thus accelerating ongoing autoimmune processes leading to its destruction[23]. Rapid growth rate, physical stress (infection, inflammation) or psychological stress increase insulin requirement, whereas excess fat cell accumulation promotes insulin resistance. Overfeeding in the intra-uterine life or in early extra-uterine life leads to accelerated growth and overweight[24,25]. Even a moderate excess of child growth, not necessarily associated with obesity, has been associated with the risk of type 1 diabetes as well as with obesity later in life[26].

Targets of treatment

The reduced capacity to synthesize and secrete a sufficient quantity of insulin due to the progressive reduction in the number of β-cells leads to hyperglycaemia, glucosuria, ketoacidosis, polyuria, polydipsia, weight loss, etc[4]. All of these symptoms can be reversed by giving exogenous insulin to the patient. Insulin administration is the cornerstone of treatment for type 1 diabetes. However, insulin requirements depend largely on and change according to time, meals, skeletal muscle activity, stress, infections, etc; therefore, insulin injections should be modified frequently during the day according to blood glucose levels, meal size and composition, as well as the kind, intensity and duration of exercise. Consequently, there are three main targets of the treatment for type 1 diabetes: (a) to obtain good blood glucose control by means of insulin administration, frequent blood glucose monitoring, adequate nutrition and physical activity; (b) to avoid severe hypoglycemia episodes; and (c) to prevent micro- (retinopathy, nephropathy, neuropathy) and macro- (cardio-, cerebro-, peripheral-) vascular complications[4].

Nutritional recommendations

Nutrition plays a key role in appropriate blood glucose control as well as in preventing and treating some of the risk factors for diabetes complications, such as obesity, hypertension and hyperlipidaemia. As recently reported in a position statement by the American Diabetes Association, the appropriate goals of medical nutrition therapy are[27]:

1. to achieve and maintain:
   - blood glucose levels in the normal range;
   - optimal lipoprotein profile;
   - normal blood pressure;
2. to provide self-management training to guarantee safe exercise sessions;
3. to prevent or slow the development of complications.

These targets should be achieved while at the same time addressing individual nutritional needs, growth and development, as well as maintaining the pleasure of eating. Nutrition counselling should be individualized and sensitive to personal and family needs, willingness to change and ability to make changes. Meal plans should take into account individual preferences but also cultural influences, exercise and physical activity patterns, as well as family eating patterns and schedules.

The main target of nutritional treatment is to educate the patient and the family to follow the RDA and to maintain a reproducible daily meal plan. A free meal plan should be permitted exceptionally. Although insulin injections adequate to carbohydrate intake allow the promotion of glucose disposal and blood glucose control, it is also true that it is very difficult to follow recommended energy and nutrient intake with irregular meal patterns and meal composition, which could easily lead to insulin misuse, weight and fat gain or exposure to hypoglycaemia.

We recommend consulting a qualified dietitian with experience in paediatric nutrition and diabetes, especially if the dietitian is a member of the interdisciplinary team taking care of diabetic children. The main role of the dietitian is to offer nutrition education, in full respect of the RDA, aimed at teaching the child and his family to achieve good reproducibility in their nutritional choices. Once this target has been reached, education on carbohydrate counting should be provided, aimed at managing exceptions in the daily meal plan.

Nutrition education should begin at the onset of diabetes and maintained through periodical nutrition counselling sessions with individual families or with patients or groups of patients.

Current nutritional recommendations for children with diabetes suggest to:

(a) limit the intake of foods of animal origin (red meat, cheese, cold cuts);
(b) limit the intake of fats (also by teaching to check food labels);
(c) promote the intake of foods that naturally contain fibre (mainly vegetables, legumes, fruit);
(d) avoid sugar-free foods or 'special foods' for diabetics.

Energy

Children and adolescents with type 1 diabetes have the same energy and nutrient requirements as all healthy children and adolescents of the same age, sex and body size. However, in diabetic patients, constant efforts to maintain appropriate body composition also through adequate energy and nutrient intake are crucial to obtaining both insulin sensitivity and blood glucose control. Body-weight control, avoiding overweight and obesity, is important also for reducing micro- and macrovascular complications[28]. Moreover, limiting visceral fat accumulation further reduces the risk of co-morbidities[29]. As for the general population, a healthy lifestyle, regular physical activity and adequate eating habits are necessary to regulate energy balance and to achieve and maintain an appropriate BMI and body fat distribution, also in subjects with type 1 diabetes.

Carbohydrates

Healthy diet recommendations for the population suggest that at least 45 % of the energy intake in a single day should come from carbohydrates[30]. ISPAD Consensus Guidelines increases the lower limit of carbohydrate intake to 50 % of total energy[31] (Fig. 1).

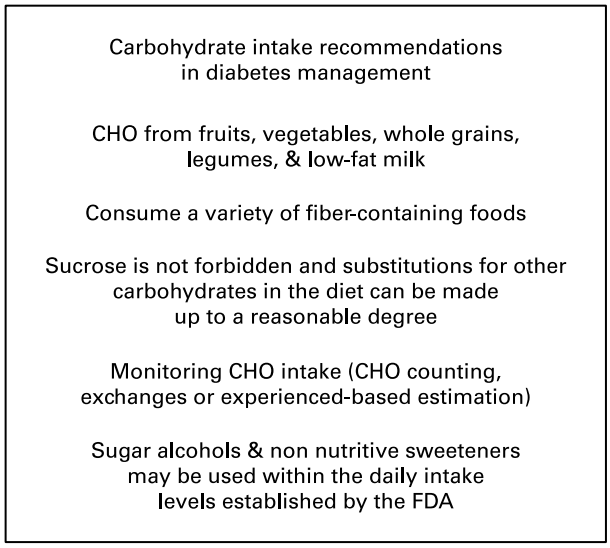

Fig. 1. Carbohydrate (CHO) intake recommendation in type 1 diabetes[27,31]. FDA, Food and Drug Administration.

Carbohydrates and insulin treatment

Carbohydrate ingestion promotes physiological insulin secretion. Increasing carbohydrate intake increases the insulin secretion rate. However, it is not only the quantity but also the type or source of carbohydrates found in foods, the composition of the meal (i.e. macronutrient and fibre content), digestibility and style of preparation (cooking method and time, etc) that influence postprandial glucose levels[27,32]. Therefore, there are two possible strategies to adapt carbohydrate intake and insulin administration in a subject wanting in insulin: (a) to inject a dose of insulin calculated on the basis of the carbohydrate intake with each meal; (b) to inject fixed daily insulin doses, maintaining the energy and composition of daily meals and snacks rather constant. Most children and adolescents with type 1 diabetes use rapid-acting insulin through injections or through an insulin pump so that they have to modify insulin doses and adapt the amount of insulin injected according to the amount of carbohydrates ingested with the meal or snack. A minority of patients use fixed daily insulin doses and they have to maintain their carbohydrate intake constant on a daily basis, regarding time of eating and amount of carbohydrates ingested per eating episode.

Children receiving basal-bolus insulin therapy can use the insulin : carbohydrate ratios to regulate mealtime insulin doses[4]. Therefore, it is essential that the child/adolescent and his/her parents learn to estimate the nutrient content of a meal. Several methods are available to estimate the nutrient content of a meal: counting carbohydrates, the exchange system and experience-based estimation[33]. Counting carbohydrates must be considered an important way to manage exceptions in food planning. However, the great flexibility offered by one technique, such as counting carbohydrates, is not enough to choose it exclusively and ignore changes in daily meal plan and meal composition. In fact, the line between flexibility and anarchy is very thin, especially in adolescence. The final target of nutrition therapy is to adopt educative interventions that will help diabetics have a healthy, balanced and adequate diet that reflects dietary regularity.

Carbohydrates and exercise

Skeletal muscle activity promotes glucose oxidative and non-oxidative disposal. The kind, intensity and duration of exercise, as well as training and environmental conditions under which exercise is performed, affect glucose metabolism[34]. Increasing the intensity of exercise increases the proportion of glucose oxidized in muscle compared with fat[35]. Moreover, in the post-exercise phase, glycogen synthesis in muscle promotes non-oxidative glucose disposal[36]. The transfer of glucose from the circulation to muscles may cause hypoglycemia both during and after exercise when glucose output in the liver is unpaired by glycogen depletion. Therefore, a reduced insulin dose injected before planned exercise and the ingestion of carbohydrates before, during and/or after exercise may be necessary to maintain acceptable blood glucose levels. Frequent blood glucose monitoring and insulin adjustments are often necessary to allow the child to participate in school, team and individual sports.

Adults performing moderately intense exercise increase their glucose utilization by 2–3 mg/kg body weight per min above baseline requirements[37]. Assuming that this calculation could also be valid in older children and adolescents, in 1 h of exercise at moderate intensity, a 10-year-old boy with a body weight of 40 kg utilizes about 6 g glucose over baseline requirements. Monitoring blood glucose before and at termination of exercise and at hourly intervals during episodes of prolonged strenuous activity is recommended[4]. If the blood glucose level should go below 1000 mg/l during the period of exercise, 15 g carbohydrate (10 g for younger children) may be administered as readily absorbed sugar[4]. For vigorous activity expected to last longer than 30 min, an additional 15 g carbohydrate may be necessary.

Fibre

Adequate nutrition for type 1 diabetes includes a high fibre content[27,31]. The intake of legumes, vegetables, fruit, fibre-rich cereals and wholegrain products should be encouraged as for the general population. Fibre-containing foods provide vitamins, minerals and other substances important for good health. Moreover, a high-fibre diet is associated with better glucose control in type 1 diabetes[38]. Optimal fibre intake recommended for the general population is 3·3 g/1000 kJ (14 g/1000 kcal)[27].

Sweeteners

Sugar alcohols (erithritol, isomalt, lactitol, maltitol, mannitol, sorbitol, etc) have lower energy than glucose (8·4 kJ/g; 2 kcal/g) and cause a lower increase in postprandial glucose response than glucose or sucrose[27]. Their use appears to be safe, although there is no clear evidence that they may cause reduced glycaemia or energy intake.

Other non-nutritive sweeteners (acesulfame K, aspartame, neotame, saccharin and sucralose) may be used also by children with diabetes[39].

Fat

A recent study conducted in the USA demonstrated that fat intake is higher in adolescents with type 1 diabetes than in those without diabetes, and fat intake exceeds recommendations (Fig. 2) [40]. Another study showed that dietary fat intake predicted a 1-year change in body fat in girls with type 1 diabetes (Fig. 3) [41]. Clear evidence is available that individuals with diabetes have a cardiovascular risk equivalent to that of non-diabetic individuals with pre-existing CVD[42]. Although the most important factor in the development of vascular complications is the glycation process, the role of lipids is also important. High TAG levels are an independent predictive factor of both renal and retinal complications in patients with type 1 diabetes[43,44]. Moreover, LDL-cholesterol levels are independent risk factors of diabetic nephropathy, whereas total cholesterol is associated with persistent microalbuminuria[45,46]. Finally, clinical studies have shown that serum levels of advanced glycation endproducts (AGE), for instance, a complex and heterogeneous group of proteins, formed by non-enzymic glycation in a series of reactions, are correlated with clinical stages of diabetes complications such as retinopathy and nephropathy[47,48]. Children and adolescents with diabetes and high serum TAG or LDL-cholesterol had significantly higher serum levels of fluorescent AGE[49]. The observed effect may be caused by a loss of optimal regulation of lipid metabolism. It could suggest a link between TAG and the formation of AGE.

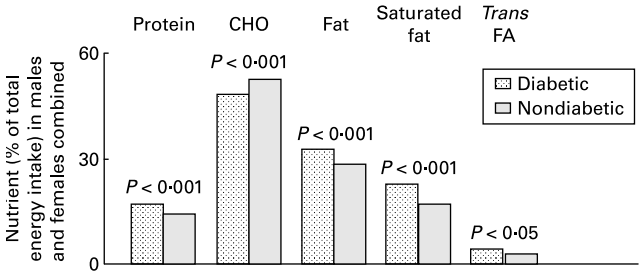

Fig. 2. Self-reported diet composition in adolescents with and without type 1 diabetes[40]. CHO, carbohydrate; FA, fatty acids.

The relationship between fat intake and fat gain, as well as fat intake and cardiovascular risk factors, emphasizes the need to maintain total fat ≤30 % of total enrgy intake in children and adolescents with diabetes, as well as to maintain the composition of fat intake within desirable limits: saturated fat <7 % of total energy; dietary cholesterol <24 mg/1000 kJ (<100 mg/1000 kcal); *trans*-fatty acids taken in minimal amounts (Fig. 3)[27,31]. Children with diabetes should be encouraged to increase their *n*-3 PUFA (mainly contained in fish) and MUFA intake (mainly with olive oil), given the demonstrated benefits on lipid metabolism and the lipoprotein profile[27,31,50]. Finally, moderate intake of plant sterol and stanol esters may contribute to reduce the absorption of dietary and biliary cholesterol and could contribute to limit cholesterol circulating levels also in children with diabetes[51].

Protein

Also as regards protein, children and adolescents with diabetes should respect dietary recommendations for the population (15–20 % of total energy)[27,31]. Good-quality protein (meat, poultry, fish, eggs, milk, cheese and soya) provide all nine indispensable amino acids and are highly digestible. A daily intake of >0·8 g protein/kg body weight is adequate[27]. In case of early stages of chronic kidney disease, total protein intake should be reduced, ranging between 0·8 and 1 g protein/kg body weight[27]. Intake lower than 0·8 g/kg is recommended in the later stages of kidney disease.

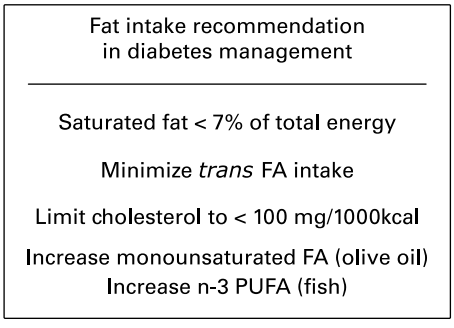

Fig. 3. Fat intake recommendation in type 1 diabetes[27,31].

Vegetarian diet

A small fraction of individuals living in industrialized countries have a vegetarian diet, although vegetarianism is becoming more popular. Several studies have shown that a plant-based diet high in fibre-rich foods, such as vegetables, fruits, cereals, whole grains and legumes, is inversely related to BMI, overweight and obesity, blood pressure, blood lipids, cancer, heart disease and all-cause mortality[52–57]. Recent data suggest that diabetes care has benefited from a vegetarian diet[58,59]. In fact, a low-fat plant-based diet influences nutrient intake and body composition in several ways that may, in turn, affect insulin sensitivity. First, dietary energy density and energy intake are reduced in a low-fat, high-fibre diet. The weight-reducing effect of the vegan diet is probably responsible for a substantial proportion of its effect on the reduction of the HbA1C[58–60]. Second, reductions in total fat intake and in the proportion of dietary saturated to unsaturated fat as well as the increased intake of low-glycaemic-index and high-fibre foods increase insulin sensitivity[59,60].

Few data are available in children with type 1 diabetes having a vegetarian diet. Kontessis *et al.* demonstrated that a vegetarian diet is able to improve microalbuminuria in normotensive, normoproteinuric children with type 1 diabetes[61]. Moreover, the American Dietetic Association and the Dietitians of Canada suggest that well-balanced vegetarian diets are healthy and adequate from a nutritional standpoint and have health benefits for the prevention and treatment of certain pathologies[62]. Type 1 diabetes is potentially one of these.

Age at risk for low nutritional compliance

The young child

Controlling blood glucose of preschool children with type 1 diabetes is a big challenge for parents. Young children are very insulin sensitive and they have highly variable and unforeseeable physical activity and nutrition patterns. Considering this, it is very difficult to maintain constant and satisfactory regulation of blood glucose levels. In general, mealtime is usually considered by parents the most difficult part of their child's care[63]. Physiologically the young child has transient food preferences, emotional lability, behavioural resistance, and increasing independence seeking. All these features affect adherence to the diabetes dietary recommendations of the child. A recent study showed a correlation between certain disruptive child mealtime behaviours (children leaving the table at mealtimes, complaining during meals, spitting out their food), children's dietary adherence and average blood glucose control[64]. Interestingly, some ineffective/coercive parenting strategies (coaxing, interrupted commands, physical prompts and feeding) were identified. Helping parents cope and educating them to adopt successful parenting behaviours could improve mealtimes and allow the child to learn and follow a structured feeding schedule, which is desirable for long-lasting efficacy in diabetes care.

The adolescent

Adolescence is a delicate phase of life. Adherence to metabolic control by adolescents with type 1 diabetes is a big challenge for both physician and parents. The important endocrine changes during puberty, rapid growth, changes in body composition and body fat distribution, as well as the physiological increase in insulin resistance, together with psychological maturation and changes of lifestyle, eating habits and social interactions, all heavily affect glucose metabolism. A combination of factors other than the difficulty in blood glucose control promotes fat gain in some adolescents with diabetes, especially females[65]. Unfortunately, poor eating habits are common in these adolescents and are associated with insulin misuse, poor glycaemic control and the development of microvascular complications[66]. Moreover, the cumulative incidence of eating problems continues to increase beyond the teen years and this is strongly associated with poor physical health conditions, which increase the risk of morbidity and mortality[66]. There are three main factors associated with unhealthy weight control in adolescents with type 1 diabetes: (a) increased emphasis on food, eating patterns and regulation of dietary intake for diabetes management purposes; (b) increased emphasis on and concern about weight regulation; and (c) quality of family functioning and support[66,67]. Maintaining structure and routine of family meals seems to serve as a protective function for adolescent girls with diabetes. Family meals may be helpful for role-modelling healthy eating patterns and for the early detection of emerging eating disorders.

Conclusions

Insulin-dependent diabetes requires maintaining lifelong healthy eating habits. Age- and sex-specific recommendations proposed for the general population are usually valid also for children and adolescents with type 1 diabetes. Attention to diet composition, especially to macronutrient and fibre content, as well as to eating patterns is crucial. The risk for all the complications of diabetes, besides mortality, is increased in obese diabetics. Therefore, it is important that an individual with diabetes maintains normal body weight, much more so than an individual without diabetes. Unfortunately, controlling weight could lead to very dangerous behaviours, especially in adolescent girls, such as insulin misuse or eating disorders. New tools should be available to the physician to efficaciously deal with these emerging problems. Further studies that analyse the relationship between diabetes and appetite regulation, insulin resistance cofactors, postprandial glucose disposal after mixed meals that differ in composition and energy intake and new behaviour-based intervention programmes might contribute to improve the efficacy of intervention and metabolic regulation in these patients.

Conflict of interest statement

None of the authors has any conflicts of interest to report.

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Child nutrition and growth: butterfly effects?

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The international symposium organised by the Danone Institute as a pre-congress satellite of the European Nutrition Societies Congress, in Paris, in July 2007, brought together experts of child nutrition and behaviour. These experts coming from several countries of Europe and North America shared their views on the impact of numerous factors affecting child eating and health in present-day developed societies. Topics included nutritional influences during foetal life, early life development of food likes and dislikes, neophobia, ability for energy regulation, impact of media and advertisement, etc. Most contributions addressed the obesity epidemics and the problems associated with body weight control. Other aspects of child health were also considered, for example the nutritional challenge of adequately feeding children with type 1 diabetes. The nine speakers were asked to underline practical strategies to improve nutrition in early life, so as to maximise health, growth and quality of life in today's environment. The present paper is a summary of the ideas expressed by the experts, highlighting agreements, convergences, and occasional disagreements between expert opinions.

Nutrition: Child: Growth: Body weight control

The recent symposium organised by the Danone Institute International as a satellite to the FENS 2007 Congress brought together distinguished scientists from many areas of the world with expertise in several areas of research and care related to child growth and health. A central theme to most of the talks was body weight control in growing children although other health issues were considered. The talks highlighted the crucial importance of nutritional factors following and before birth. They revealed how the foetus, the infant, and the child are exposed to countless influences from foods ingested by the pregnant mother or by the young person at various stages of development. Our speakers all agreed on the paramount importance of nutritional factors for child development and weight control but clearly had differing, if not diverging opinions about the relative contribution of critical factors: the mother, the family, the society, the environment and particularly the school environment, genetics, economics, and others. Prevention and treatment of overweight also elicited varied opinions.

Curiously, in spite of the very different geographic origins of our speakers, not much clash occurred that could be attributed to different influences in various parts of the developed world (Europe and North America). It is as if our children, who benefit the best conditions in history to enjoy a harmonious and healthy growth, were under the influence of a host of more or less visible sources of trouble that negatively affected their health, inducing unprecedented frequencies of nutrition-related conditions such as overweight and diabetes. Are we dealing with a special case of the "butterfly effect" that has been demonstrated under different situations: even the smallest effects such as the seemingly random deviations in the flight of a butterfly in one part of the world can trigger major weather catastrophes such as tornadoes or tsunamis in other parts of the world. Some of our speakers actually did mention the butterfly effects and their collective contribution to our symposium suggests that we might be dealing with a number of wandering butterflies whose flights interact in perhaps inextricable manners. It does seem obvious that the effects of such interactions do create catastrophes in terms of child health and development worldwide. Our speakers, after describing the particular kinds of individual or social factors they were experts in, were invited to suggest a few ideas of practical solutions that could be used to understand the impact of butterfly wanderings in their fields and potentially correct their deleterious effects.

This was done, and at the end of our one-day symposium we had a large number of ideas that did temper the sensation of helplessness commonly found in the scientific and lay literature dealing with the present epidemic of overweight and other nutrition-related problems in young people all over the world. This final chapter of the proceedings of the symposium will review these suggestions and try to identify how they could be used, in isolation or in combination, to prevent nutrition-related problems in early life and perhaps even correct them before the child develops into an adult with poor quality of life and faces the numerous long-term complications originating from early life conditions.

Genetics, foetal and neonatal influences

Our first speaker, Dr Luc Marlier, presented work on newborns showing that prenatal sensory influences had an

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impact on orientation responses to olfactory stimulation. Taste buds as well as olfactory receptors are functional in the third semester of pregnancy. The foetus therefore gets exposed to a variety of taste and smell stimuli that depend on the mother's diet. Prenatal exposure affects postnatal responses to a variety of olfactory stimuli. In Dr Marlier's words, culture is present in the amniotic fluid. It has been clearly showed that human newborns orient to the odour of the amniotic fluid and the colostrum. A few hours after birth, infants of mothers who ingested anis-smelling substances during pregnancy, orient to anis-smelling stimuli. In contrast, infants of women who did not ingest anis-smelling substances reject anis stimuli four days after birth. Garlic and alcohol intake by pregnant women could likewise affect the newborn's responses. Even pre-term infants respond to olfactory stimuli such as vanilla by increasing their respiratory rate. These fascinating observations clearly demonstrate that sensory responses can be affected by prenatal influences originating from the mother's food choices; however they do not tell us whether such responses can affect food preferences, food choices, or food intake in the offspring. Clearly, more research is needed in this field. The data are nevertheless extremely precious and converge with other recent evidence highlighting the importance of early life events.

The notion that genetic factors were crucial in every aspects of a person's life is well-known if not universally accepted. The nature-nurture argument has raged for decades and is not solved today. It has even gained in complexity in recent years as the new developments in genetic research have allowed an improved appreciation of the impact of genes on particular traits. We now know that very few individual characteristics depend on a single gene and that most are affected by a variety of genes. In addition, the importance of "epigenetic" factors has been demonstrated. Genes are expressed in certain environments and remain unexpressed in others. The critical factors of the environment that permit or inhibit the expression of genes also remain to be identified in many aspects of growth and health. This is why much research is devoted today to early life factors, among which dietary conditions. Nutritional influences during pregnancy could be some of the critical factors allowing the expression of certain genes. More ambitious hypotheses even include the nutritional status of the mother-to-be before she becomes pregnant. Such factors affect a number of events occurring in early life, some of which are becoming increasingly recognised as determining the future health and development of the child. Birth weight is the subject of much very stimulating research as it has become evident that both low and high birth weight can predict future weight control problems and other diseases.

We already see a multitude of butterflies interacting over the unborn infant to influence future life events. Genes, mother's dietary and health status, epigenetic factors, among others, set the scene for the infant's first moments of life and already determine important aspects of the young person's chances to enjoy a healthy development. Although it remains difficult to counteract the influence of genes, awaiting future understanding of genetic and epigenetic effects, it seems possible to act on young women's nutritional status before and during pregnancy. Public health authorities and professionals know how difficult it is to make young persons, including future mothers, adopt a healthy lifestyle. Individual and social factors can either help or create problems. Some of such factors were addressed by our other speakers.

The impact of society: cognitive schemas

Beyond infancy, children have to learn to survive in a given society. In rich developed societies, recent decades have seen marked changes in many aspects of lifestyle. While energy needs are decreasing due to increasingly sedentary work and leisure activities, the food supply has increased in amount, variety and convenience. For reasons that have to do with both sensory appeal and nutritional input, foods that are rich in energy, high in fat and/or sugar, are easily accepted and ingested by children. It is clearly more difficult to have children accept foods generally regarded as "healthier", such as vegetables, fruits, fish, etc. This is a clear problem for parent, educators, and health professionals. Where can we find hope? How can we make our children more willing to try and perhaps enjoy such healthy foods, rather than overindulging in high energy substances that can create weight control or health problems in those with the wrong genetic background or unfavourable life circumstances? In a society, children and adults have particular cognitive attitudes or schemas about substances that can be ingested as foods. Such schemas can influence behaviours to a large degree and were the topic of Dr Patricia Pliner's talk. Dr Pliner defined such schemas as mental structures that represent organised knowledge about a given type of stimulus, and in particular foods. They affect expectations about familiar and unfamiliar foods. Knowing how cognitive schemas work can help us improve our children's acceptance of diverse and unfamiliar foods.

One type of behaviour found in numerous children in developed countries, in Europe as well as in America, is called "neophobia" and is characterised by a refusal expressed by the child to accept objects, among which foods, that are unfamiliar or novel. Most (but not all) children, between the ages of 2 and 10 years, are affected by more or less severe neophobia. Some cultures might be more permissive and expose young children to a broader variety of food stimuli, thereby making more foods seem familiar to the child. Studies should be carried out on this issue and it would be interesting to compare how easy (or how difficult) it is in different countries of the developed world to induce acceptance or even liking for a broad variety of foods including those that have a low appeal to many children. In all countries, nevertheless, some proportion of children do exhibit neophobia and strongly reject many foods that their parents regard as "healthy".

Children use "cognitive schemas" to evaluate foods. When a novel or unfamiliar food is presented, many children have the cognitive schema that it will not taste good. Convincing the child that the schema does not apply to this novel food and that this food is an "exception" to the general schema could facilitate the child's willingness to taste the food and have a chance to realise that its taste is not indeed unpleasant. Another strategy could be to convince the child that the food actually does not belong in the novel, unknown category, but rather is a familiar food. The trick to achieve such a cognitive change in the child is to use what Paul Rozin has called a locally familiar "flavour principle"[1]. In every culture, certain

foods, spices, or other salient flavour substances are used in many staple foods. Every child learns early in life that foods with such flavour characteristics are both tasty and safe. Examples are chilli in Mexico, tomato and olive oil in Mediterranean countries, curry in India. Children who have observed adults and peers enjoy foods with those culture-specific flavour principles are willing to ingest them and, following experience of the taste and post-ingestive consequences of intake, readily develop strong preferences for foods that are typical of their own cultures.

Observations of migrant populations have revealed that food traditions survive longer after people have moved to a different country than other types of original cultural traditions. A novel food that is presented under the "disguise" of an accepted flavour principle is more likely to be accepted and perhaps liked than a food that is experienced as a totally unknown object whose sensory characteristics might be unpleasant. Role models are also important: witnessing significant others enjoy the food can encourage the child to test the food. The mother is the best model.

A more challenging strategy would be to change the child's cognitive schemas about novel foods and create expectations that novel foods can indeed be good-tasting, appealing and safe. Although research is rare about the mechanisms that could induce such a change, it has been shown that exposing the child to good-tasting novel foods does increase the willingness to try novel foods. Early exposure to a broad variety of foods may make the child less neophobic: variety of food choices made available to a young child can create cognitive schemas that novel foods actually taste good.

Clearly, more research is needed about neophobia in children and its cultural, geographic differences. What is known however is that neophobia usually decreases as the child grows up and has disappeared in most by age 12 years. Some children actually exhibit little or no neophobia but the reasons that account for the specific intensity of the symptom in different individuals remain to be elucidated. Genetic, epigenetic, socio-cultural or family factors could interact and exert still unknown levels of influence.

The special problem of fruit and vegetable intake

The specific case of fruits and vegetable intake was addressed by Dr Hans Brug. This is obviously a case of clear disagreement between recommendations and behaviours. Only about 17·6 % of eleven year-olds in Europe do comply with the recommended daily intake of five fruits or vegetables a day. Dr Brug analysed the reasons for the discrepancy and the strategies that could help bridge the important gap between recommended and actual intake. Three crucial determinants that could be modifiable to a certain extent are motivation, ability and availability. The motivation to ingest vegetables is usually low in young people because their sensory characteristics are not those that appeal to children (sweetness, fatness, softness, etc.) and the same is true to a lesser degree of many fruits.

Children's responses to the taste of fruits and vegetables could be improved via a number of strategies of demonstrated efficiency: mere exposure, pairing the vegetable with other foods of high palatability (sensory-sensory learning), social modelling could be used. The ability of the parents and/or caregivers to propose, prepare, cook vegetables in a more pleasant way could be improved and the importance of doing so could be highlighted by public information campaigns. Environmental opportunities should also be improved. One problem with vegetables is their price and the time needed to cook them. Dr Brug recommends intervention programs involving both school-based and family activities. The ultimate goal is to teach children to like fruits and vegetables, which requires that children are exposed to them in situations that are experienced as pleasant, safe, and free of conflict. This obviously involves large social and economic changes, so that ability and availability will in fact modify children's attitudes and motivations to these foods.

Dr Wardle extended the argument to underline that the problem is probably different for fruits and vegetables, since most children like fruits (at least some of them) while they dislike vegetables. This probably has to do more with sensory factors (sweetness, texture, etc.) than with availability or price. The innate acceptance of sweetness and rejection of bitterness can orient children's food choices for many years in early life. Another potentially critical factor is the energy density of foods. According to a physiological reinforcement theory, energy rich foods, or in other words foods with a high energy density, are easily accepted by children because such foods provide the high input of energy that growing children need. Given the high frequency of child overweight, it seems that our children do get plenty of energy to meet their high needs and many actually get too much. In such a case, the same physiological homeostatic theory could predict that once the energy needs are met, then children should turn away from high energy density foods and appreciate foods with lower energy content but higher nutrient density. Obviously this is not what happens. Even the notion of "sensory specific satiety" would predict that children would turn to different types of foods after ingesting plenty of high sugar, high fat foods, but this again does not happen, perhaps due to the immense variety of available energy rich sweet or savoury foods.

Under such a situation, Dr Wardle proposed her strategies for facilitating acceptance of fruits and vegetables by children. She believes in family influence and in the parent-child or child-sibling relationships that can provide useful role models. In these efforts, with the same level of exposure, some children are less responsive than others and exhibit high levels of neophobia (fussiness). Dr Wardle exposed evidence that the intensity of neophobia might be determined by genetic factors. Studies of same sex twin pairs showed that monozygotic twins aged 4–5 y had higher correlations of their food likes than dizygotic twins. A study of 5406 twin pairs revealed that the score on a neophobia scale at age 10 y was higher in mono than dizygotic twins. The neophobia score is a strong predictor of acceptance of vegetables in children. The heritability of neophobia could be as high as 0·78. If neophobia and rejection of vegetables is determined by genetic factors, then what can be done?

Understanding the causes of such a rejection response is a first step. Clearly, sensory factors are important and fussier children could happen to be more sensitive to the bitter or sour taste of some vegetables or other foods. Some children may be more prone to digestive disorders than others and the association of salient sensory cues from unfamiliar foods could become associated to unpleasant post-ingestive

disorders, such as nausea. Clearly we need more information about what makes some children fussier than others and more research is needed. What seems obvious, given the level of acquired knowledge, is that fruits and vegetables should be available often, both on the family table and at school meals. Making them palatable is important, even though this may require time and culinary skills. They could also be offered as snacks in a pleasant way. Social facilitation by witnessing significant role models ingest the foods may be an efficient strategy to induce long-term progresses in acceptance. They should be prepared and presented in a way that will make them acceptable to children, and the high sensitivity of some children to bitter, for example, should not be antagonized by threats or constraints.

Food choices and energy regulation

The foods children enjoy and accept are a very important aspect of their ability to obtain a healthy nutritional status. Another problem, which was briefly alluded to above, is the amount of food children are willing to eat. There is supportive scientific evidence that children are rather apt at adjusting their energy intake to their energy needs. Pioneer works by Leann Birch[2] and others, have established that young children are able to adjust their energy intake according to what they have ingested in the previous hours. The "pre-load paradigm" has shown that after ingesting a high energy pre-load, pre-schoolers spontaneously eat less than after the intake of a low energy pre-load. It is also generally held that adults and elderly persons are less able to achieve such a corrective adaptation of their intake, although the very few studies that have looked at this problem usually report large inter-individual variations in the ability to adequately compensate for the energy ingested previously. It also seems that it is easier to compensate for a low energy preload (by eating more at the next occasion) than for an excess of energy (by eating less at the next occasion).

Today, the question of the ability of humans to adequately compensate for energy variations in intake is still a debated issue. Most data indicate that compensation or adjustment is approximate at best, and can be very poor in many people. Infants and children may be better than adults, but they progressively lose this precious ability to respond to their internal cues signalling energy needs as they grow and learn to eat according to externally determined social rules. It would be very useful to maintain and even improve the energy compensation abilities in most people. Dr Susan Johnson reviewed the literature dealing with this extremely important topic and highlighted that several factors can affect results of energy adjustment studies: age, gender, previous learning, environmental factors and experimental design, among others. Research over the years confirms the large inter-individual differences even in young children and the age-related decline in the ability to adjust energy intake to needs. When no age-related difference is reported, it is because adjustment is just very poor in everybody[3]. When there is compensation, it is not perfect and generally biased toward over rather than undereating. The constant availability of palatable, convenient, low cost, energy rich foods may counteract any compensation ability a child could exhibit under less permissive circumstances.

Dr Johnson underlined the very important influence of the number of occasions to eat on total energy intake: children eat in response to opportunity[4]. How much is served (portion size) and how often food is available could be two important factors affecting the ability of a person, including a child, to effectively adjust energy intake as a function of energy needs. Supportive evidence highlights the strong impact of environmental influences, regardless of innate or genetically determined characteristics: portion size, meal frequency and duration, exposure to food cues in the environment and particularly in the media, etc. More research is needed on the effects of these factors, both in isolation and in interaction.

Clinical practice

Dr Silvia Scaglioni is a clinician dealing with obese children. She offered some practical advice that could be useful to both parents and health professionals. Dr Scaglioni underlined the crucial role of parents in providing healthy foods but recognised the increasing difficulty of this task in our obesogenic environment in which inexpensive high energy density food is constantly available. Among the behaviours that can induce problems is the too frequent offering of foods to children in response to stress or as a reward. Dr Scaglioni advocates judicious parental modelling of good eating practices, both in terms of food choices and eating frequency. In her view, both parents of an overweight child should participate in the efforts to improve the child's behaviour. They should be made aware of the long term consequences of child obesity. While information is important, it is not sufficient to modify behaviours. Therefore long term programmes of behavioural changes are to be developed, integrating the child's own suggestions.

One strategy is to ask the overweight child what he/she would advise another overweight kid to do in order to lose weight. Principles of sound behavioural modification techniques should be applied: small steps at a time, small obtainable goals, progressively more ambitious changes and goals, constant and positive support from the family, etc. Dr Scaglioni suggested that instructing mothers before delivery about child growth and nutrition would be useful. It would be particularly important to help overweight mothers-to-be and women with eating behaviour problems to solve these problems as much as possible before the child is born. This obviously requests a strong level of support and organisation not only from health professionals but from the society as a whole.

Education in practice

Dr Jana Parizkova is also a great believer in education of parents as well as children. She presented data from her country, the Czech Republic, underlining something that is also well known in other countries: well educated people are usually leaner and healthier than people with low education levels. Mothers' education level has impact on the foetus and later on, on the infant during the first few months of life. Parents' education level is linked with breastfeeding and with the amount of physical activity that the child is encouraged to engage in, as confirmed by a recent study of about 10 000 Czech children. A key factor in addressing the

obesity epidemics, according to Dr Parizkova, is to educate the mothers.

We are grateful to Dr Parizkova to have reminded us that our present cogitations can be traced back to the thinking of the great Czech pedagogue Comenius who, in 1632, already proposed the basic advice we are still desperately trying to convince our contemporaries to adopt: the body energy balance depends on both healthy adequate eating and sufficient physical activity. Comenius's wise advice has been supported, rather than weakened, by later research but over the last 400 years we have not succeeded in creating a society in which behaviours allowing an adequate energy balance could be willingly practiced by all, adults and children.

Dr Parizkova presented data showing that spas for obese children could be an excellent place to teach them adequate behaviours, including food choices, eating frequency, and physical exercise. Interesting medium-term results have recently been reported by other teams[5] confirming Dr Parizkova's observations. Such studies show that, under appropriate circumstances, children and adolescents can in fact be taught to behave in a weight-control friendly way. The problem is that the society they return to after they have lost considerable amounts of weight does not support the healthy behaviours that they have learned to perform under a totally different environment. Here again, parental support is of paramount importance.

Pathologies in normal weight children: the example of type 1 diabetes mellitus

Dr Claudio Maffeis is a paediatrician who addressed the many problems associated with type 1 diabetes mellitus in children. This severe disease, with heavy long-term threats on health and quality of life, is more and more frequent in children and appears at an increasingly earlier age. Although it is not directly caused by overeating, as is type 2 diabetes mellitus found increasingly often in young individuals, the problem of adequate nutrition is an extremely important aspect of treatment of type 1 diabetes mellitus in children and adolescents. Type 1 diabetes mellitus has a known genetic basis which is facilitated by environmental triggers, among which inappropriate nutritional conditions. It is generally held that encouraging an optimal nutrition in children, both in terms of food choices and energy intake, can reduce the rates of heavy complications in later life. Nutrition exerts its beneficial (or detrimental) effects by affecting glucose control. Public health authorities in developed countries, such as the American Diabetes Association, advocate nutrition therapy as a crucial part of treatment. The nutritional needs of growing children should be covered both in terms of quantity and quality. Dr Maffeis underlined that the severe health consequences of type 1 diabetes: inflammation and lipotoxicity contributing to the development of the metabolic syndrome, micro and macroangiopathy, etc. Such complications can get extremely difficult to cope with if they are allowed to develop from early life.

In order to maintain the pleasure of eating, which is essential for obtaining long-term compliance to the demanding diet, an individualised approach to dietary advice is recommended, as already suggested by Dr Scaglioni. Dr Maffeis advocates a complex treatment that includes both dietary aspects and physical activity. Obviously, carbohydrate intake has to be monitored, as patients with type 1 diabetes cannot secrete insulin and cannot benefit from physiological glycemic control. The large amount of knowledge recently acquired about the glycemic index and the glycemic load should allow parents to facilitate food choices in order to optimize the child's glycemic levels[6]. Again, the important contribution from family members was stressed, in particular the interactions between family members at mealtimes.

One of the main problems of treating children and adolescents with type 1 diabetes is the commonly poor adherence to several aspects of treatment, such as insulin injections and dietary advice. While children are extremely sensitive to taste factors, as already underlined by previous speakers, adolescents also want and need to join groups of peers. Given the generally poor eating practices of this age group, adolescents with type 1 diabetes might be exposed to very bad influences that must be acknowledged, understood and neutralised as much as possible. This is an extremely difficult medical problem with potential critical consequences for the patients and for society as a whole. More research is clearly needed on the conditions of a better compliance with dietary recommendations in early life as this can affect many other future health consequences than body weight control.

Young people and food advertising

Our last speaker addressed a topic that is not frequently examined in scientific conferences: that of advertising and market research dealing with children consumers. Ms Immaculata Garcia Alvarez confirmed that young people are exposed to much encouragement to consume high energy density foods by the media, particularly television. Most television commercials targeted at children are about foods (56 %) and 46 % are about high fat, high sugar items. Only 4 % deal with foods that could be considered part of the traditional "Mediterranean diet". The impact of such advertisements on food choices and behaviours remains uncertain however, as no correlation was found between the percentage of food advertisement and the overweight rate in children populations. Ms Garcia Alvarez believes that the strategies used to affect food choices in advertisement could be used to encourage the intake of "healthy" foods, using the same message contents: having fun, ideal families, associating certain foods with characters or individuals that children admire, etc. Given the very high costs of advertising in the media, it appears difficult to see how governments or public health authorities could compete with the food industry to encourage healthy food choices.

As also underlined by Ms Garcia Alvarez, recent societal changes have facilitated inadequate changes in the way children are fed: both parents work long hours, they have little time and energy to prepare "Mediterranean" type family meals, they experience guilt over this, and often show excessive permissiveness for questionable behaviours as nibbling. One problem comes from the fact that traditional cooking practices are no longer transmitted over generations, and that many places where children are fed such as school cafeterias propose unpalatable foods. This has made convenient inexpensive snack foods even more attractive.

Some experts openly speak of a toxic environment. It is unlikely that recent social changes could or should be reversed.

The way forward is in the direction of more social changes that would require a convergent involvement of all significant actors: parents, educators, public health authorities, industry, media, etc. The relative importance of every party's responsibility is the subject of fierce argument among experts and the lay public. Scapegoats are frequently designated: the food industry, school cafeterias, the media, etc. Such discussion could go on forever, while our children are getting fatter and more vulnerable to nutrition-related diseases. While many of our speakers underlined the crucial importance of the family and especially the mother, it remains clear that motherly influence occurs in a given society that also exerts strong impact on individual behaviours. Societal factors may impose very difficult conditions to individual goodwill; conversely, some of the individual's responsibility has to do with creating the societal conditions in which children grow up.

Conclusions: a few practical considerations

Our symposium lasted one very full day. Many aspects of child nutrition were addressed but, obviously, many were not even alluded to. For example, the nutrient imbalance experienced by infants at weaning, when the high-fat mother's milk is suddenly replaced by a very high protein diet[7], has not been discussed. The influence of low or high birth weight is another determining factor of many future health and weight control consequences. So, acknowledging that many important aspects were not included in our analysis of children's feeding conditions in developed societies, a few practical ideas were expressed and discussed by our speakers.

While genetic factors are clearly important, epigenetic influences should be studied and optimised. This involves providing high quality information to the public and in particular to women of child-bearing age. Pre-pregnancy nutritional status of mothers-to-be deserves consideration. Events occurring during pregnancy are of unquestioned importance. Early life nutritional events can influence food choices and eating behaviours later on. Exposing children to a variety of healthy palatable foods under convivial circumstances could create good habits. While everyone agreed that the mother, and more broadly the family, had a crucial impact, the role of societal factors was also recognised. The influence of peers, school, the media and the food industry was recognised by all, although the relative contribution of each could be discussed. Society as a whole has a central role in making the conditions of availability of healthy food choices and opportunities for physical exercise accessible to all, including to families with low income and limited capacity to understand complex nutritional information.

Conflict of interest statement

Dr Bellisle received honoraria from the Institute as an organiser of the symposium, as a speaker and as an invited editor for the special issue of the journal. The author has no conflicts of interest to report.

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