Chapter 18
Food Patterns and Nutrient Intake in Relation to Childhood Obesity

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Introduction

Childhood and adolescence are pivotal periods in human life characterized, among others by intense metabolic rate, continuous body growth and development, physical and psychological changes, and the onset of habits that will probably continue in later ages. All these characteristics may confer high vulnerability in relation to the risk of obesity development in predisposed subjects. Body composition and psycho-social changes determine nutritional requirements as well as dietary and physical activity behavior variability but, at the same time, these latter and other environmental and behavioral factors could also influence the former (Rodríguez et al. 2004). Among all risk factors that are known to modulate obesity development and its persistence into adulthood, diet composition and food patterns are among the main environmental determinants of energy balance along different periods of life (Rodríguez and Moreno 2006) (Fig. 18.1).

Although energy imbalance has to be a constant and basic cause of overweight, fat deposition does not always occur in the case of excess energy availability. Energy balance homeostasis and body composition maintenance are both regulated by a complex net of neuro-hormonal and metabolic processes which strongly preserve an individual resilience in maintaining weight. Variations in any component or physiological determinant of this balance are compensated with other changes that modify energy expenditure or energy intake in order to re-establish energy equilibrium. Exogenous obesity develops when energy intake exceeds energy expenditure during long periods of time, leading to slow accumulation of body fat. Even a small maintained daily energy imbalance can result in significant weight gain. The “energy gap” is the small positive energy imbalance that causes body fat increase after compensating energy changes have failed attempting to maintain body weight. Metabolically, it is very easy to achieve a continuous positive energy balance in our “obesogenic” environment (abundant food supply and sedentary lifestyle), especially after negative energy balance

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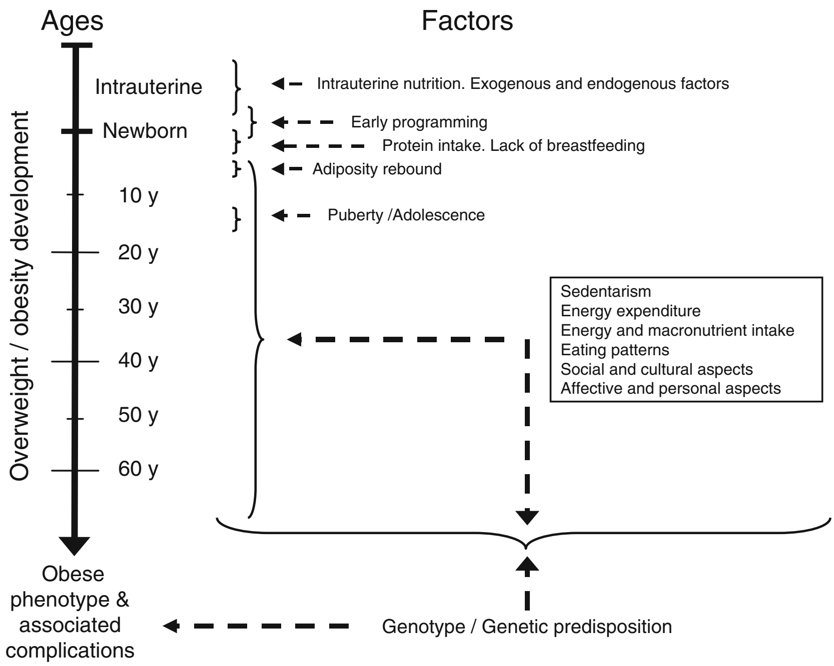

Fig. 18.1 Potential factors influencing obesity development along different periods of life. Adapted from Rodríguez and Moreno (2008)

periods due to human predisposition to store energy. Longer-term neuro-endocrine signals depend on the magnitude of energy stores and, when adipose tissue mass has decreased, hunger is activated to restore the loss by stimulating food intake and inhibiting thermogenesis. In contrast, the response to energy excess is relatively weak and compensatory food intake decreases are not complete.

In spite of simple theoretical relations between positive energy balance and obesity development, no consistent information exists about which is the strongest environmental factor influencing body fatness in children and adolescents (Gibson and Neate 2007; Gillis et al. 2002; Guillaume et al. 1998; Moreno and Rodríguez 2007; Rodríguez and Moreno 2006, 2008; Veugelers and Fitzgerald 2005). Excessive global energy intake due to easy and continuous food accessibility, consumption of energy-dense foods (Alexy et al. 2004; Atkin and Davies 2000; Berkey et al. 2000; Bogaert et al. 2003; Gazanniga and Burns 1993; Hassapidou et al. 2006; McGloin et al. 2002; Ong et al. 2006; Parizkova and Rolland-Cachera 1997; Scaglioni et al. 2000; Skinner et al. 2004), excessive percentage of energy intake from fats (Alexy et al. 2004; McGloin et al. 2002) or high macronutrient consumption (for example, excessive protein intake) (Parizkova and Rolland-Cachera 1997; Scaglioni et al. 2000), contemporary eating patterns (Berkey et al. 2004; Bowman et al. 2004; Bray et al. 2004; Colapinto et al. 2007; Ello-Martin et al. 2005; Field et al. 2004; Fisher et al. 2007; Francis et al. 2003; Gillman et al. 2000; James et al. 2004; Kral et al. 2007; Ludwig et al. 2001; Moreno et al. 2005; Niemeier et al. 2006; Orlet Fisher et al. 2003; Phillips et al. 2004; Rolls et al. 2000; Sen 2006; Serra et al. 2003; Toschke et al. 2005; Welsh et al. 2005) (elevated consumption of bakery foods, sweetened beverages, sweets or low-quality foods, the low consumption of fruit and vegetables, big portion size intake, daily meal patterns and daily energy intake distribution) are all considered potential contributors of the "obesity epidemic". Nowadays, diet aspects and eating behaviors are also strongly influenced by environmental, socio-cultural, economic, affective and marketing factors (food advertising and promotion). People eat frequently away from home (French et al. 2001; Schmidt et al. 2005), there are time limitations with respect to eating and meal preparation (Bowman et al. 2004;

Rolls et al. 2000), children eat alone without family supervision (Gillman et al. 2000; Sen 2006) (sometimes watching television) and children with both parents at work eat in school dining halls. The food industry has responded to this social demand by increasing convenience foods and prepared meals that could also be associated with the increase in the prevalence of overweight (Berkey et al. 2004; Bowman et al. 2004; Bray et al. 2004; Field et al. 2004; French et al. 2001; James et al. 2004; Ludwig et al. 2001; Orlet Fisher et al. 2003; Phillips et al. 2004; Rolls et al. 2000; Schmidt et al. 2005; Welsh et al. 2005). In this context, this chapter reviews the potential contribution of energy, nutrient intake, eating patterns and other dietary intake factors on overweight prevalence.

Methodological Challenges in Studying Children's Diets

Instrumentation Issues in Measuring Children's Diets

Accurate assessment of dietary intake in obese children is of major concern in population-based nutrition research, given the dramatically increased prevalence of childhood obesity together with the growing list of obesity-related comorbidities as well as psychological consequences. This issue is also of obvious relevance within clinical settings where dietary intakes of children are being monitored. Potential methodological problems that are most clearly documented in adults include obesity-related underreporting, selective underreporting of undesirable foods, and biased reporting associated with other psychosocial characteristics of individuals. Surprisingly little is known on how to obtain accurate measures of dietary intake in obese and normal weight children. Thus dietary instrumentation in obese children is a topic that urgently requires attention by researchers in nutrition.

Assessment of diet in normal- and overweight children, either directly or by adult proxy, introduces some special methodological challenges, in addition to some of the well-known ones. For instance, the average age at which children develop cognitive skills required for self-reporting of diet differs cross-culturally and between individuals, and the minimal age at which children are able to conceptualize time frames used in dietary instruments (e.g. 24 h, 1 week, 1 month) is not well established. The ability of children under 10 years to give valid responses to food frequency questionnaires covering periods of more than a day is questionable because of difficulties in estimating frequences and averages. The need for adult assistance in dietary reporting is also driven by the limited scope of the child's experience and knowledge of recipes and food composition (e.g. fat content of milk). It may be safely assumed that adults reporting their young children's intakes are likely to be affected by social desirability biases as the desire to report that their children consume healthy diets (USDA 2005). Finally, it should be pointed out that in countries where most children attend after-school care and daycare centers that provide one or more meals, parental proxy reports are likely to be inadequate. For instance, in Swedish pre-schools children may have as many as three meals a day at the daycare center (breakfast, lunch and mid-day snack). In such settings, it is unlikely that valid data can be collected without the support of the personnel at the daycare.

Adolescents, on the other hand, are frequently asked to report their own diets by recall or questionnaire. Challenges in dietary assessment of adolescents include: rapidly changing eating habits due to growth; unstructured consumption of snacks and skipping meals, eating away from home frequently; and high prevalence of dietary restraint, particularly among girls. In addition, similar to the situation among adults, overweight and obesity in adolescents has been associated with underreporting of intake: up to 40% of energy may not be reported in obese adolescents (Bandini et al. 1990). Energy underreporting also increases with age across adolescence (Livingstone and Robson 2000). Obesity-related underreporting by food record has also been documented in Swedish adolescents (Bratteby et al. 1998).

Food frequency questionnaires (FFQs) have been developed for adolescents (Rockett et al. 1997; Vereecken et al. 2005) and in the near future electronic and web-based tools will have increasing appeal within this age group. Research in school settings has many advantages in terms of data collection (Rockett et al. 1997; Vereecken et al. 2005). However, there are difficulties within the school setting, including competing time constraints from school curricula resulting in limited time for recruitment, adequate explanation of study forms and procedures, and data collection. Alternative approaches and settings that appeal to young people are needed (Coufopoulos et al. 2001; Frank 1994). It is unclear which methods may minimize or avoid some of the biased reporting related to overweight and restrained eating that are known to exist in this age group (Frank 1994).

Summary

In summary, while a general underreporting bias exists in free-living subjects describing their diets, regardless of weight status, all evidence points to this problem being magnified in the obese, including children and adolescents. Although existing data suggest that it is possible to obtain valid intake data from sufficiently motivated obese adults (Lindroos et al. 1999), obesity-related underreporting biases have been reported for most of the commonly used dietary assessment instruments, and relatively little focus has been placed on how to solve this problem. Given the known importance of obesity for a number of health outcomes, it is critical to develop instruments that can rank and differentiate obese and non-obese individuals of all ages with respect to dietary intakes.

Other Methodological Challenges

Problems of instrumentation are accompanied by other methodological concerns when studying potentially etiological roles of diet in childhood obesity. One problem is that the importance of food choice may be obscured when studying diets at the macronutrient and micronutrient levels. It may be easier to communicate advice about healthy foods than giving recommendations about nutrients. A second problem is that many confounding factors may be present, which bias observed associations between nutrients and obesity. These include age, physical activity, socio-economic status, and other socio-cultural factors such as gender and ethnicity. To give an example, failure to consider physical activity when studying associations between energy intake and body mass index (BMI) might result in an underestimation of the association due to influence of lean, athletic subgroups of children. Similarly, poorer reporting accuracy and more underreporting in less educated or socially disadvantaged groups might obscure an association between energy intake and obesity.

Finally it should be pointed out that study design is a key factor when interpreting associations between dietary intake and obesity. Cross-sectional survey data, in which anthropometric measures and dietary assessments are conducted simultaneously, cannot be assumed to reflect causal associations and may be affected by problems of reversed causality, where diets have already changed as a consequence of obesity or weight gain. Prospective designs are often assumed to alleviate this problem by observing diet at one point in time in relation to subsequent weight gain or incidence of obesity. However, this design does not take into account the fact that diet may change over time. Studies of concurrent change in both diet and obesity are frequently undertaken in efforts to address these design issues. The next two sections will offer an overview of different types of studies that have been used to describe associations between dietary intake and obesity in children. We will start with examples from the literature describing energy and nutrient composition of diets in relation to obesity and continue to describe studies of dietary patterns. Because some of the individual publications describe both nutrients and diet patterns, we have combined a summary of all cited studies in Table 18.1.

Table 18.1 Characteristics of cross-sectional and prospective studies relating food patterns and nutrients with body composition

Age group/sample size	Methods	Dietary and energy expenditure variables studied	Reference
	Cross-sectional		
7–12 y/2,440	Diet history	EI, g and E% protein, carb and fat, animal protein, foods	Rolland-Cachera and Bellisle (1986)
15–17 y/64	5-d food record (child)	EI, g + E% protein, carb, fat, fatty acids, micronutrients, foods	Ortega et al. (1995)
1.5–4.5 y/1,444	4-d weighed record	EI, E% fat, protein and carb	Davies (1997)
15 y/50	7-d record/DLW (child)	EI	Bratteby et al. (1998)
6–12 y/955	3-d record	EI, fat, SFA, cholesterol, protein and fiber in g and g/kcal	Guillaume et al. (1998)
1.5–4.5 y/77	4-d weighed record, DLW (parents)	TEE, BMR, PAL, EI, E% fat, protein and Carb	Atkin and Davies (2000)
7–11 y/530	Diet history	EI, EI/BMR, E% protein, carb, fat, E% meals	Maffeis et al. (2000)
4–16 y/181	Diet history	EI, fat in g, E% and RNI%, SFA in g and RNI%	Gillis et al. (2002)
5–8 y/114	7-d weighed record, DLW	EI, TEE, E%+g fat, carb, protein	McGloin et al. (2002)
15–16 y/37	Diet history, DLW	EI, EI/TEE	Sjöberg et al. (2003)
8th grade + 4th grade/3,000	FFQ, self reported weight and height	EI, E% fat and sugar, sweetened soft drinks, sweets, breakfast	Andersen et al. (2005)
11–14 y/512	3-d weighed record	EI, g, E% and g/kg body weight of protein, carb and fat, g of starch, intake of micronutrients and foods	Hassapidou et al. (2006)
6–14 y/142	2x24-h recall + 1d record	EI, g and E% of fat, atty acids, proetin, carb. and intake of fiber and micronutrients, foods	Aeberli et al. (2007)
4 y/153	7-d recod	E% fat, carb, sucrose, n-3 fatty acids	Garemo et al. (2007)
4 y/1,780	3-d record		Jouret et al. (2007)
10–11 y/4,289	Diet history	SES. Dietary intake and habits, meal behaviors (with family, watching TV, fast food restaurants)	Veugelers and Fitzgerald (2005)
7–18 y/1,294	7-d weighed record, BMI, 7-d physical activity diaries	Nutrient intake, non-milk sugars, soft drinks. PAL	Gibson and Neate (2007)
3–11 y/748	7-d food portion record, physical activity questionnaire	Portion size, foods (energy-dense, nutrient-poor)	Lioret et al. (2009)
5–6 y/4,370	Diet history. BMI	Meal frequency. Foods, macro- and micronutrients	Toschke et al. (2005)
9–14 y/16,202	Semiquantitative food frequency questionnaire. Self reported weight and height	Frequency of family dinners. Foods	Gillman et al. (2000)
12–15 y/5,014	Diet history. Self reported weight and height	Frequency of family dinners.	Sen (2006)

(continued)

Table 18.1 (continued)

Age group/sample size	Methods	Dietary and energy expenditure variables studied	Reference
7–12 y/4,746	Semiquantitative food frequency questionnaire. Measured weight and height	Frequency of fast food restaurant use. Energy and food intake. Demographic and behavioral data	French et al. (2001)
8–9 y/137 and 13–15 y/243	Location of major fast food outlets. Measured weight and height	Presence and distance of fast food outlets	Crawford et al. (2008)
2–5 y/1,160	24-h recall	Demographic descriptors. Food comsumption (including beverage). Physical activity	O'Connor et al. (2006)
5–14 y/3,049	24-h recall	Energy intake. Sucrose intake. Beverages	Parnell et al. (2008)
	Prospective		
8 y, follow-up at 12 y/112	Diet history	EI, protein, carb, fat in g and E%, simple carb in g	Maffeis et al. (1998)
Birth, 1 y, 5y171 newborn, 147 at 5-y follow-up	Infant feeding practice retrosp. 1 y, FFQ + 24-h recall	EI, EI/kg, weigt and BMI at birth, 1 y and 5 y, E% protein, carb, fats, SFA, monounsaturated, polyunsaturated FA	Scaglioni et al. (2000)
9–14 y/>10,0001 y follow-up	FFQ	EI, g of fat, fiber	Berkey et al. (2000)
Birth to 15 y/150 (of 500)	3 d weighed rec. At2, 4, 6 y and 4-d rec at 8, 11, 13 and 15 y	EI, g and E% protein, carb, fat, skinfolds, E% SFA	Magarey et al. (2001)
6–9 y / 41 children in 12-month follow-up	3-day food record	EI, E% protein, fat, carb + fatty acids	Bogaert et al. (2003)
5, 7–9 y	Repeated 3-d records at 5 y, 7 y, questionnaire at 4.5 y	Diet at 5 and 7 y: food groups from which dietary pattern scores were derived	Johnson et al. (2008)
6–8 to 13–17 y/50	7-d record	Energy density ED by total diet and excluding different fractions of diet	McCaffrey et al. (2008)
From birth to 7 y/8,234	Food frequency cuestionnaire at 30 and 38 months. Infant feeding at 6 months. Weight and BMI increases	Social and family characteristics. Intrauterine and perinatal factors. Behavioral patterns	Reilly et al. (2005)
Non-hispanic white girls 5–9 y/137	Three 24-h recalls within a 2–3-week period. Especific snacking and TV viewing questionnaires. Increase in BMI	Snacking frequency, TV viewing patterns, snacking while watching TV. Fat intake from energy-dense snacks	Francis et al. (2003)
2–8 y/70	24-h recall 3-d record and food records. BMI changes and adiposity rebound	%E from macronutrient. Energy density intake. Food group intakes	Skinner et al. (2004)
3–6 y/49	3-d record in children born at low or high risk for obesity based on maternal pregnancy BMI. Children BMI and abdominal circumference changes	Beverage (milk, fruit juice and drinks, sodas, soft drinks) consumption patterns	Kral et al. (2007)
2–18 y (at least 10 years of long-term participation)/228	Weighed dietary records. BMI changes	Fat intake patterns. %E from macronutrient. Energy density intake. Food group intakes	Alexy et al. (2004)

(continued)

Table 18.1 (continued)

Age group/sample size	Methods	Dietary and energy expenditure variables studied	Reference
11.7 y until 19 months later/548	Frequency questionnaire. BMI	Sugar-sweetened drinks	Ludwig et al. (2001)
11–21 to 18–27 y/9,919	Food intake questionnaire. BMI and weight gain	Fast food consumption. Breakfast skipping	Niemeier et al. (2006)
8–12 y non-obese premenarcheal girls until 4 y after menarche/196	Annual controls. Food intake questionnaire. BMI and percentage of body fat	Foods. Energy dense snacks	Phillips et al. (2004)
9–14 y between 1996 and 1998/14,977	Food frequency questionnaire. BMI	Snacks	Field et al. (2004)
9 y black and white girls to 19 y/2,379	3-day food record and food-patterns questionnaire; annually in the first 5 years and then in years 7, 8, and 10	Food consumption (including fast food) and nutrient intake	Schmidt et al. (2005)
7–11 y during one school year/644	Three 3-d recalls on drinks consumption: BMI and abdominal circumference	Carbonated drinks	James et al. (2004)

All studies included weight, height (measured or self-reported), *EI* daily energy intake; *ED* energy density energy/grams; *E%* percent of energy; *TEE* total energy expenditure; *DLW* doubly labeled water; *SES* socio-economic status; *y* year; *d* day

Energy and Nutrient Intake in Obese vs. Non-Obese Children

This section offers examples of research describing the association between composition of the diet and childhood obesity, based on different dietary instruments and study designs. We have identified studies reporting on energy, fat, protein and sucrose in relation to current obesity and prospective weight development in children and adolescents. Those studies also describing diet in terms of patterns will be reviewed in the section on "Food Consumption Patterns as Obesity Risk Factors".

Energy and Energy Intake

The literature on energy intake (EI) in obese vs. non-obese children includes examples of negative associations, positive associations and non-associations, using cross-sectional and prospective designs. For instance, negative associations between EI and obesity have been found in a number of cross-sectional studies (Bratteby et al. 1998; Hassapidou et al. 2006; Sjöberg et al. 2003). In one of these studies, the association was negative in girls but not in boys, a difference attributed to sex influences on underreporting (Sjöberg et al. 2003). Although it is often assumed that such associations are artifacts of obesity-related underreporting, low physical activity seems likely to be part of the explanation (Berkey et al. 2000).

In contrast, several studies have provided evidence of positive associations between energy intake and obesity. In one study using diet history, children and adolescents with obesity had significantly higher EI than non-obese children, independent of physical activity patterns and other dietary covariates (Gillis et al. 2002). In one study from UK with 7–18 year old children, a positive relation between EI based on 7-day food records, physical inactivity and BMI was found as well as a negative association between physical activity and BMI (Gibson and Neate 2007). In a French study of overweight vs. normal weight boys, the 3-day food records revealed higher EI in the overweight group (Jouret et al. 2007). In a large study ($n = 10{,}769$) of 9–14 year old children in the US with a 1-year follow-up, positive associations were found between EI as well as physical inactivity and weight gain (Berkey et al. 2000). Interestingly, in one longitudinal study of Hispanic children with a history of weight gain, it was observed that a further weight gain was suppressed in children who decreased their EI while also increasing their physical activity level (Butte et al. 2007).

Finally, it must be noted that a number of cross-sectional and prospective studies have not detected any relation between EI and overweight/obesity (Aeberli et al. 2007; Andersen et al. 2005; Maffeis et al. 1998; Maffeis et al. 2000; Rolland-Cachera and Bellisle 1986). One of these studies however found a positive relation only when studying EI at dinner meals (Maffeis et al. 2000).

Differences in studies can potentially be attributed to numerous methodological differences. Measurements of EI in epidemiological settings are known to be inexact (Willett 1998). One explanation for inconsistent associations with childhood obesity includes random and systematic reporting errors. These included differences in precision of different instruments and obesity-related underreporting. Another explanation is that children and adolescents with obesity have lower physical activity levels and many truly have low expenditures. Finally, if BMI reduction is being attempted during the dietary reporting period, lack of positive associations can be attributed to "reverse causation". Studies, typically small ones, using doubly labeled water to validate energy intakes have been less ambiguous than dietary surveys in their results, indicating that underlying positive associations may be attenuated by underreporting, while also confirming that voluntary energy expenditure may also be reduced in obese children (Atkin and Davies 2000; Bandini et al. 1990; Bratteby et al. 1998; McGloin et al. 2002).

Fat and Fat Type

The literature on dietary fat intake in obese vs. non-obese children is also mixed and may further depend on whether fat is measured in the absolute or as a percent of total energy (E%). For instance, in a cross-sectional study including adolescents, there was a positive association for E% of fat but not for intake of fat in grams per day (Ortega et al. 1995); however, the opposite, significant positive associations for fat in grams but not in E% has also been reported (Gillis et al. 2002). In other cross-sectional studies positive relations have been found both for absolute and energy adjusted intakes of fat (Guillaume et al. 1998; McGloin et al. 2002). In a prospective study where children were followed from birth to 15 years, energy adjusted fat was positively associated with subscapular skinfold but not with BMI or triceps skinfold (Magarey et al. 2001). In one study a positive association for fat intake was found for boys but not for girls (Jouret et al. 2007). On the contrary, following children over a 10 year period, BMI-SDS was highest in the group of children with the lowest fat intake pattern (Alexy et al. 2004). However a number of studies have reported no associations between dietary fat and childhood obesity (Aeberli et al. 2007; Andersen et al. 2005; Atkin and Davies 2000; Berkey et al. 2000; Davies 1997; Maffeis et al. 1998; Rolland-Cachera and Bellisle 1986; Scaglioni et al. 2000).

The mechanism of dietary fat in the promotion of obesity is traditionally believed to be mediated by the high energy density and its facilitating effect on positive energy balance. It has been argued that energy density is a determinant of energy intake more important than dietary fat per se, and a number of studies, almost all in adults, have confirmed this (Newby 2007). One study in children found no relation between energy density of total diet and subsequent changes in fat mass but, when energy density excluding beverages was analyzed, there was a positive relation between dietary energy density and change in % of body fat (McCaffrey et al. 2008). Seven years earlier, in the baseline study, positive associations were found between absolute and energy adjusted fat intake and obesity, but no such information was given for the follow-up (McCaffrey et al. 2008; McGloin et al. 2002). Other studies have focused on the type of fat rather than on the amount of fat as a more relevant factor in childhood obesity. For instance, one study in obese children and adolescents observed that they consumed not only more fat but more saturated fat, independent of total energy intake and physical activity level (Gillis et al. 2002). It has also been reported that the ratio between n-6/n-3 polyunsaturated fatty acids (linoleic acid, C18:2 n-6, and alpha-linolenic acid, C18:3 n-3, and long-chain metabolites) may be a factor in early obesity (Ailhaud et al. 2006; Karlsson et al. 2006). However, very little has been published about dietary intake differences in n-6/n-3 ratio in children. One study in 4-year-old children with adequate intake of n-3 fatty acids showed lower body weight than those with lower intake of n-3 fatty acids (Garemo et al. 2007). In summary, although there is evidence that total fat and high fat foods are associated with childhood obesity, the current trend is to examine specific types or attributes of dietary fat that may promote obesity, rather than total fat per se.

Protein

Longitudinal studies of feeding during first post-natal months and early childhood have demonstrated positive relation between protein intake and body size and adiposity (Rolland-Cachera et al. 1995; Scaglioni et al. 2000). Positive associations between protein intake during weaning and transition to the family diet and various indices of obesity at age 7–8 years have also been reported (Gunther et al. 2007; Skinner et al. 2004). Rolland-Cachera et al. (1995) proposed in the mid 1990s that high protein intake in infancy and early childhood was associated with obesity and with earlier adiposity rebound. Timing of and BMI at adiposity rebound (AR) are significantly related to persistent obesity (Dietz 1994; Freedman et al. 2001; He and Karlberg 2002; Whitaker et al. 1998). Other studies have shown sex-specific associations or no associations at all between protein intake in infancy and AR. There was an association between a higher protein intake between 12 and 24 months and higher BMI at AR in girls, but not in boys, and there was no consistent relation with timing of AR (Gunther et al. 2006). In another study, no association was found between high protein intake and early AR (Dorosty et al. 2000).

In cross-sectional studies percent of EI from protein has been shown to be higher among overweight children and adolescents (Aeberli et al. 2007; Azizi et al. 2001; Ortega et al. 1995; Rolland-Cachera and Bellisle 1986) but with no significant differences for absolute protein intakes.

A possible methodological complication in studies of protein intake and obesity is that protein may be underreported less than the rest of the diet, due to social desirability factors. In fact when protein is estimated as a percent of total energy there is evidence that it is proportionally overreported, as a consequence of corresponding underreporting of the fat and carbohydrate fractions (Heitmann and Lissner 1995; Lissner et al. 2007). To our knowledge this has not been studied in children, but might explain in part the inconsistent findings reported in adolescents, whose dietary reporting biases are likely to be similar to those in adults.

Sucrose

In the twenty-first century, sugar has become a prime suspect in the search for an obesogenic dietary composition pattern in children. Sucrose occurs both as intrinsic and added in foods and is often used as a surrogate for added sugar. In cross-sectional studies, positive associations have been found between intake of sucrose and BMI in young children (Garemo et al. 2007). There are examples of cross-sectional and prospective studies showing no associations at all between sugar intake and body fatness (Andersen et al. 2005; Buyken et al. 2008), while negative associations were found in two studies (Overby et al. 2004; Parnell et al. 2008).

Both cross-sectional (Gibson and Neate 2007) and prospective studies (Ludwig et al. 2001) about sucrose consumption in children show that consumption of calorically sweetened beverages increases the risk for obesity (Olsen and Heitmann 2009). Proposed mechanisms are that sugar from beverages can lead to a disruption in regulation of EI and satiety (physiological satiety mechanisms are not triggered and energy compensation is not functional), and liquid carbohydrates may cause lower thermogenesis. On the other hand, in a recent meta-analysis of randomized controlled studies, no association between consumption of sugar sweetened beverages and weight gain was found (Forshee et al. 2008).

Other Aspects of Nutrient Composition

There are many other aspects of nutrient intake that will be covered in the section on diet patterns. Breastfeeding is a key factor that can potentially be studied in terms of energy/nutrient content, but which is usually studied as a qualitative or semiquantitative exposure. Similarly, investigations of nutrient intake in children after infancy may benefit from observing nutrients within the context of specific meals. Nutrient content of breakfast foods are believed to differ from that of foods consumed during the rest of the day. Such information, together with differences in breakfast consumption between obese and non-obese children (documented in next section), may clarify the protective association between breakfast consumption and obesity. In this context it should be also considered that certain combinations of nutrients may be more obesogenic than others. For instance, in one prospective study, an energy-dense, high-fat and low fiber diet was followed by higher gain of fat mass from 5/7 years to 9 years (Johnson et al. 2008). However, combinations of nutrients may be more easily studied in terms of food patterns; in the same study, consumption of fast food yielded similar predictive information (Johnson et al. 2008).

It has been suggested that diets of low nutrient density and high energy density are relatively less costly (Drewnowski and Specter 2004) and dietary factors may represent one mechanism explaining the persistent socio-economic gradient in childhood obesity. Socio-economic factors are not only important for diet composition but also for risk of being obese (Guillaume et al. 1998; Rolland-Cachera and Bellisle 1986). Morevover, it has been shown that parental BMI, which is also associated with socio-economic status, may be more important for childrens' weight status than intake of fat, carbohydrate or EI (Maffeis et al. 1998, 2000; Magarey et al. 2001). Socio-ecomomic status has many components that may contribute to childhood obesity and diet may be a key component but available dietary methodology and ways of defining socio-economic status make it difficult to quantify a specific contribution of diet.

Summary Regarding Nutrient Composition and Childhood Obesity

The literature does not allow us to draw firm conclusions regarding nutrient composition and childhood obesity (Newby 2007; Rodríguez and Moreno 2006). Therefore, we turn to the evidence for food patterns which may be more promising, possibly because of better potential for accurate reporting of qualitative aspects of diet (e.g. breakfast, fast food).

Food Consumption Patterns as Obesity Risk Factors

Eating patterns are strongly associated with socio-cultural and economic characteristics of the population, and influenced by a large number of factors affecting personal and family environments. Various factors interact with each other contributing to the establishment of an obesogenic environment which increase the probability of being obese in predisposed subjects: favorable economic conditions, constant food availability, fashionable eating habits, poor family supervision, influence of TV advertisements on food selection, low price but non healthy food industry offers, poor family-social cultural level and parents knowledge about healthy habits. In spite of this hypothetic list of contemporary social factors influencing prevalence of overweight in the population, the real contribution of each one and the main exogenous cause (eating vs. physical activity patterns) remains unknown. The aim of this part of the chapter is to review food consumption patterns in relation with obesity development.

Meal Frequency and Daily Distribution of Meal

At similar energy intakes, a low meal frequency has been classically associated with overweight. In adults, four or more eating episodes per day was related to a lower risk of obesity in comparison with subjects who reported three or fewer eating episodes per day (Ma et al. 2003); and, in children, to eat few meals a day (three or fewer) may also facilitate weight gain compared with four, five or more daily meals (Toschke et al. 2005).

With respect to daily distribution of meals, obese children seem to eat less energy at breakfast, skip breakfast more frequently and consume a higher percentage of energy at dinner (Bandini et al. 1990; Livingstone and Robson 2000; Moreno et al. 2005; Serra et al. 2003). A prospective study of 9,919 adolescents and adults (age range 11–27 years) has recently shown that decreases in breakfast consumption and skipping breakfast predicted increased BMI and weight gain during this period of life (Niemeier et al. 2006). Moreover, healthy habits as a family breakfast have been associated with regular and courteous intakes in the morning (Serra et al. 2003), and the frequency of family dinner has been inversely related to fried foods and soda drinks consumption (Gillman et al. 2000).

Food Portion Size

Intake of large portion sizes of some food items (snacks, soft drinks, french fries, hamburgers, etc.) is frequently observed. Children's energy intake increases when larger portions are offered because satiety signals fail to reduce intake in response to this increment in food consumption (Colapinto et al. 2007; Fisher et al. 2007; Rolls et al. 2000; Sen 2006). Children have reported preference for larger portions of high-energy foods and smaller portions of vegetables; and, as consequence, this behavior can promote high energy intake and lower diet quality (Colapinto et al. 2007; Fisher and Kral 2008; Fisher et al. 2007). Despite increases in food portion sizes, children fail to reduce consumption by satiety signals that compensate for the feeling of "fullness" (Ello-Martin et al. 2005; Rolls et al. 2000). Growing children are not able to self-regulate their intakes in a correct way; however, in infants and small children, portion size does not affect daily energy intake (Bowman et al. 2004). Associations between portion size and overweight status in children have been described, but usually in cross-sectional studies (Fisher and Kral 2008; Lioret et al. 2009); nevertheless, this fact has not been observed in longitudinal studies looking for the risk of overweight development in children eating big portion sizes.

Family Control of Children's Eating

To eat alone without family supervision is by itself a potential risk factor for overweight development. A "family breakfast" has been associated with a regular intake in the morning (Serra et al. 2003) (while a "family dinner" has been related both to a decrease of fried foods and soda drinks consumption (Gillman et al. 2000) and reduced odds of becoming overweight after 3 years of follow-up (Sen 2006)). To eat while watching TV is very common when children are alone and it also increases the risk of overweight in children (Veugelers and Fitzgerald 2005). Results from a cross-sectional study of 4,298 students, aged 10–11 years, from Nova Scotia (Canada), showed that children were at increased risk of overweight depending on whether they bought lunch at school (odds ratio (OR) = 1.39), ate supper while watching television more than 5 times per week (OR = 1.44) or their parents were separated or divorced (OR = 1.21). The children were less likely to be overweight if they ate supper together with the family more than 3 times per week (OR = 0.68) or if their parents completed university education (OR = 0.67) (Veugelers and Fitzgerald 2005). However, no data from longitudinal studies are available describing the independent effect of eating alone or eating while watching TV on children's obesity development.

Fast Food Restaurant Consumption

When eating in fast food restaurants, children tend to consume a large amount of food and to choose high-energy foods (Colapinto et al. 2007). Both the frequency of fast food consumption and the amount of energy intake from fast foods are increasing due to a variety of factors: big portion sizes, palatable and cheap foods, the attractiveness of fast food and easy access to restaurants attractive for children and adolescents. In these fun and attractive restaurants with a wide supply of big portion sizes, children's taste perception is also influenced by branding of foods and beverages (Robinson et al. 2007). Consumption of fast food seems to have an adverse effect on dietary quality (Bowman et al. 2004; Schmidt et al. 2005). Children and adolescents who eat fast food will consume more total energy, total fat, saturated fat, carbohydrates, sodium, added sugars, and sugar-sweetened beverages; and less fiber or milk and fewer fruits and non-starchy vegetables (French et al. 2001). Therefore, excessive fast food intake may displace the consumption of other more nutritious foods.

Despite these findings, longitudinal studies have not found associations between food portion size or fast food intake and the risk of overweight development in children. In a recent study, neither the density of fast food outlets in the local neighborhood (number of outlets within a 2-km buffer around participants' homes) nor the proximity to a fast food restaurant (distance to the nearest outlet) increased the risk of obesity (Crawford et al. 2008)

Snack Consumption

"Snacks" are defined as other eating episodes out of meals, generally smaller and less structured (Gatenby 1997). The percentage of children and adolescents consuming snacks in industrialized countries and the contribution of snacking to total daily energy and fat intake have increased during the last decades (Francis et al. 2003). So, we could think that this behavior could be related to the higher prevalence of obesity due to its low nutritional value and high energy density, but research findings are not conclusive (Moreno and Rodríguez 2007; Rodríguez and Moreno 2006; Rodríguez et al. 2004). However, when snacking is associated with sedentary activities, it has been associated with unhealthy body composition changes in girls (Francis et al. 2003). Nevertheless, in large and well designed longitudinal studies based on initially non-obese children, snack consumption is not a clear predictor of weight gain among children and adolescents (Field et al. 2004; Phillips et al. 2004). In a longitudinal study performed in a cohort of 196 initially non-obese premenarcheal girls, the consumption of energy dense snacks did not seem to influence weight status or fatness change over the adolescent period (Phillips et al. 2004). Results from another prospective trial in 8,203 girls and 6,774 boys, 9–14 years of age, suggested that although snack foods may have low nutritional value, they were not an important independent determinant of weight gain among children and adolescents (Field et al. 2004).

Beverage Consumption

Beverage intake among children has also increased in the recent decades, increasing sugar caloric contribution (O'Connor et al. 2006; Wang et al. 2008).Theoretically, children's metabolism fails to reduce food consumption to compensate for the caloric contribution of sweetened drinks and, on the other hand, sweeteners such as high-fructose corn syrup contribute to an increased weight gain due to their influence on lipogenesis, insulin secretion or leptin production (Bray et al. 2004). This is one of the contemporary food consumption patterns that showed by itself a predictive influence on overweight prevalence in few longitudinal studies (Berkey et al. 2004; James et al. 2004; Ludwig et al. 2001; Welsh et al. 2005). Results from prospective cohort studies performed in children and adolescents showed that there was a positive relationship between the consumption of sugar-sweetened beverages and overweight/obesity development (Berkey et al. 2004; James et al. 2004; Ludwig et al. 2001; Welsh et al. 2005); however, a recent meta-analysis and other simultaneous longitudinal studies have found that the association between sugar-sweetened beverage consumption and BMI or weight gain is not fully convincing, based on the current body of scientific evidence (Forshee et al. 2008; Kral et al. 2008; O'Connor et al. 2006; Parnell et al. 2008).

To Eat High-Quality Foods and Food Variety

Palatability of high energy density food promotes more energy intake and compensatory eating responses may not be sufficient to suppress hunger or to delay eating in children predisposed to develop obesity (Bowman et al. 2004; French et al. 2001; Rolls et al. 2000; Schmidt et al. 2005). However, eating low-energy-dense foods (such as fruits, vegetables, and soups) maintains satiety while reducing energy intake (Bowman et al. 2004; Rolls et al. 2000). Social and taste acceptance, eating behaviors and the satiety value of several types of food tend to promote or suppress energy intake.

Individuals who consume the greatest variety of foods from all food groups have the most adequate nutrient intake (Krebs-Smith et al. 1987). It has been described both in adults and in children that dietary variety obtained from vegetables was inversely associated with body fatness; while conversely, dietary variety obtained from sweets, snacks, condiments and carbohydrates was directly associated with body fatness (McCrory et al. 1999; Miller et al. 2008; Receveur et al. 2008). Other studies have shown an association between TV/video viewing and adverse dietary practices and low diet quality (Miller et al. 2008). In our environment, less than 20% of children consumed the recommended number of portions of vegetables and fruits (Serra et al. 2003).

Summary Regarding Food Patterns and Childhood Obesity

For eating patterns, controversial results have been reported from longitudinal studies with no conclusive evidence of an association between diet habits and obesity development later in life (Moreno and Rodríguez 2007; Reilly et al. 2005; Rodríguez and Moreno 2006, 2008; Veugelers and Fitzgerald 2005). Prospective cohort studies have only found associations between obesity development and specific behaviors such as sugar-sweetened beverage consumption or skipping breakfast (James et al. 2004; Ludwig et al. 2001; Niemeier et al. 2006). Snacking, fast food and big food portion size consumption have not been consistently related to obesity development in longitudinal studies despite these dietary habits are associated with an excessive intake of energy, total fat, saturated fat, carbohydrates, added sugars, and sugar-sweetened beverages (Moreno and Rodríguez 2007; Reilly et al. 2005; Rodríguez and Moreno 2006, 2008; Veugelers and Fitzgerald 2005).

Available evidence is in general supportive of current diet recommendations, i.e. lower fat and sugar, higher fruit and vegetable consumption (Ells et al. 2008). However, better methods are needed to study diet–disease relationships, particularly in children.

Conclusions

Measuring diet is problematic in obese populations of any age and there is a clear need to develop and improve dietary instruments. The situation in children is further complicated by many factors, e.g. growth. However, with available methodologies, it has been possible to identify certain “obesogenic” dietary characteristics in children. Prospective longitudinal designs provide stronger evidence for causal associations than cross-sectional designs but unfortunately there are not many studies using this approach.

The evidence regarding obesogenic macronutrients is weak and conflicting. Considering the reviewed dietary patterns those showing more evidence on the relationship with childhood obesity development are consumption of sugar sweetened beverages and skipping breakfast. Potentially, a cluster of these and other dietary patterns could be involved in the development of obesity in children.

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