REVIEW

Obesogenic diets in European children – from nutrients to upstream factors

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ABSTRACT

Introduction: Poor nutrition is a major contributor to the overall burden of disease. Worldwide, nutrition-related diseases have become a major health concern, reportedly causing a loss of over 56 million years of healthy life for European citizens in the year 2000. Childhood obesity is one of these major health problems.

Methods: The IDEFICS/I.Family studies (9), funded in the 6th and 7th European Framework Programme, investigated ways to improve young people's health and to tackle the problem of obesity. This publication provides an overview of selected results derived from these studies: we will stress dietary factors in European children as one major aspect of the complex aetiology of childhood obesity, and offer a broader comment on the role of contemporary food systems.

Results: Parental socioeconomic status, children's media consumption and current marketing strategies employed by the food industry were associated with a low-quality diet and unhealthy food intake in European children.

Conclusion: Present evidence calls for policy interventions to facilitate healthy diets of European children and adolescents. Prevention strategies for childhood obesity should address upstream factors including aggressive food marketing to children, the failure of self-regulation of the food industry, and socioeconomic disadvantages.

Keywords: BIG FOOD, CHILDHOOD OBESITY, FOOD CHOICE, FOOD MARKETING, MEDIA CONSUMPTION

INTRODUCTION

In recent years, it has become evident that differences in nutrition play an important role in explaining variations in health across Europe, and that poor nutrition is a major contributor to the overall burden of disease. Worldwide, nutrition-related diseases have become a major health concern, reportedly causing a loss of over 56 million years of healthy life for European citizens in the year 2000 *(1)*. The World Health Organization (WHO) has estimated that diseases caused by diet-related risk factors and physical inactivity account for 19% of global deaths and 7% of global disability-adjusted life years (DALYs) *(2)*. Recent research has contributed to the evidence that unhealthy dietary behaviour and insufficient physical activity are positively associated with obesity, especially in children *(3, 4)*. European policy-makers have acknowledged the need for action to tackle the obesity epidemic, having established the High Level Group on Nutrition and Physical Activity and the European Platform on Diet, Physical Activity and Health in 2005 *(5)*, adopting the European Charter on Counteracting Obesity at the WHO European Ministerial Conference (Istanbul, 2006), as well as the Vienna Declaration on Nutrition and Noncommunicable Diseases in the Context of Health 2020 *(6)*, and the Minsk Declaration on the Life-course Approach in the Context of Health 2020 *(7)*. Recently, the WHO Report of the Commission on Ending the Childhood Obesity Epidemic *(8)* gave recommendations for future research and policy measures.

In this paper, we will give an overview of results from the European, "Identification and Prevention of Dietary and

Lifestyle-induced Health Effects in Children and Infants" (IDEFICS)/I.Family studies *(9, 10)* on children´s lifestyle behaviours and health status. We will focus on various aspects of dietary behaviour and food choice and thereby stress one major facet of the complex aetiology of childhood obesity throughout (as illustrated in Fig. 1). We discuss characteristics of children´s diet and eating behaviours in relation to childhood obesity, together with the main determinants of children´s dietary behaviour, for example: social gradient, media and marketing. These latter determinants are often referred to as upstream factors *(11)* that need to be addressed when attempting to promote healthy dietary behaviours. We conclude by highlighting some policy implications, especially with regard to the commercial factors driving the availability of less healthy foods and drinks.

METHODS

The IDEFICS/I.Family studies were funded in the 6th and 7th European Framework Programme. I.Family builds on the IDEFICS study by involving the families of children already recruited during the IDEFICS baseline (T0) and follow-up survey (T1). In 2007/2008, 16 228 children aged between two and 9.9 years from Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden participated in the baseline survey. Two years later, we examined 13 596 children of whom 11 041 (68% of T0) had participated previously. Participants who were overweight or less educated, reported low well-being, or came from single parent families were more likely to drop out *(10)*.

In a second follow-up, I.Family examined 9 617 children plus their parents; 7 105 (52% of T1) of these children already participated in the IDEFICS surveys, now between the ages of seven and 17 years. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. Approval by the appropriate ethics committees was obtained by each of the centres undertaking fieldwork.

The IDEFICS/I.Family studies investigated biological, behavioural, social and environmental factors that influence diet and health. Dietary behaviour was assessed using two instruments: an eating habits questionnaire *(12)* that included a food frequency questionnaire; and a 24-hour dietary recall *(13, 14)*. Assessing dietary behaviour in small children raises methodological problems mainly due to proxy reports — these have been discussed elsewhere *(15)*. In addition, since diet cannot be considered as a one-dimensional exposure we looked at various aspects of dietary behaviour including different approaches for derivation of dietary patterns. We also considered physical activity and a range of other familial factors in our analyses to better capture the complex interplay between lifestyle factors and childhood obesity. As major determinants of dietary behaviour, we measured three indicators of socioeconomic status: net household income; occupation categorized according to the European Socioeconomic Classification (ESeC) *(16)*; and education according to the International Standard Classification of Education (ISCED) *(17)*. Children's television viewing habits (including the exposure to TV commercials for the Swedish sample) *(18-20)* and so-called pester power behaviours were assessed using questionnaires. Furthermore, sensory tests were carried out to assess the children's taste preferences *(21)*. All studies from the IDEFICS/I.Family cohort that addressed the aspects listed in Fig. 1 are included in this review. Tables 1–4 include lists of the respective exposure and outcomes investigated, the measurement method, the applied statistical methods, the sample size, and point estimates for each study.

OVERVIEW OF RESULTS

CHARACTERISTICS OF CHILDREN'S DIET

In order to characterize and evaluate dietary habits in European children, we investigated (a) their adherence to common dietary recommendations, (b) their sugar intake, (c) the energy density of their food, and (d) dietary patterns within families in the IDEFICS/I.Family cohort (Table 1).

Habitual intake distributions of energy and macronutrients were estimated and compared with the German, Swiss and Austrian (D-A-CH) reference values (nutritional guidelines including age-specific reference values, commonly accepted for European populations). This analysis revealed that only two thirds of the IDEFICS/I.Family children met the guidelines for relative intake of carbohydrates and fat *(22)* and only 7% met the recommendation for water intake.

In all countries except Estonia, sugar made up more than 20% and up to 30% (Germany) of children's total energy intake *(23)* (where sugar intake was defined as all mono- and disaccharides, irrespective of whether added or naturally occurring). The intake of total sugars, as well as consumption of foods and drinks rich in added sugar, were found to be higher on weekends compared to weekdays, suggesting that this is a modifiable risk factor. However, we did not find a difference between weekdays and weekends for total energy intake.

Energy density (in kcal/g) describes the calories consumed per day divided by the total intake in grams, excluding non-caloric beverages. As expected, children consuming diets with

low energy density had a lower total energy intake per day but consumed higher quantities of food and beverages compared to children with high energy density *(13)*. The diet of children with low energy density was healthier: in comparison to children with high energy density, these children consumed less fat, and had lower intake of cereal products, sugar and sugar products; whereas they consumed more protein and carbohydrates, and had a higher intake of fruits & vegetables and dairy products. Furthermore, school-age children tended to consume diets with a higher energy density than pre-school children.

In contrast to this analysis of single dietary exposures, investigation of dietary patterns provides a more comprehensive picture of an individual's overall diet. We assessed dietary patterns of children and their parents, and the resemblance between them *(14)*. Three dietary patterns comparable in children and parents were identified: a "sweet and fat" pattern roughly characterized by a higher-than-average intake of sugar and sweets, animal or processed fats, sweetened beverages, sweetened milk and dairy products; a "refined cereals" pattern roughly characterized by a higher-than-average intake of cereals based on refined products or with a high proportion of sugar or fat, plant-based fats and oils and non-caloric and non-processed beverages and an "animal product" pattern roughly characterized by higher-than-average intake of meat (all types), meat alternatives, mixed dishes mainly based on cereals, legumes, potatoes, fruit and vegetables. Energy intake was lowest in the animal product pattern. Associations were observed between parental dietary patterns and children's dietary patterns. The likelihood of the child being allocated to the sweet and fat pattern, the refined cereals pattern, and the animal products pattern was higher if the mother or the father was allocated to the same dietary pattern. Availability of soft drinks during meals further increased the likelihood of children being allocated to the sweet and fat pattern and decreased the likelihood of children being allocated to the refined cereals and animal product patterns.

In general, we found that children´s water intake was too low, relative to dietary recommendations. Furthermore, children´s sugar intake and overall energy density seemed to be too high. Since the home food environment was an important predictor for their dietary behaviour this might be one way to change children´s dietary behaviour, albeit downstream from the forces that shape the availability and promotion of different food and drinks.

ASSOCIATIONS OF DIETARY BEHAVIOUR AND CHILDHOOD OBESITY

One aim of the IDEFICS/I.Family studies was to examine how dietary behaviour influences children's health and especially the risk of childhood obesity (Table 2). We observed a positive association of age- and sex-adjusted standard score of the body mass index (BMI z-score), with total daily food intake (grams/day), and with total energy intake (kcal/day). However, the latter was a more important predictor of unhealthy weight development in children than total daily food intake *(24)*. In a longitudinal analysis of the IDEFICS cohort, energy intake adjusted for age, height and sex was positively associated with BMI z-score, even after accounting for objectively measured physical activity *(25)*.

In our investigations, different dietary patterns were associated with different health outcomes. One dietary pattern that was rich in raw vegetables, cooked vegetables (including boiled and not fried potatoes and legumes), whole cereals, fresh fruit, milk and breakfast cereal (the latter three without added sugar), was identified to be associated with a lower risk of being overweight/obese two years later *(12)*. This suggests that a diet rich in vegetables and wholemeal cereals may help to counteract childhood overweight/obesity. We also identified the so-called Mediterranean dietary pattern (characterized by higher-than-average consumption frequencies of vegetables and legumes, fruits and nuts, cereals and all kinds of fish as well as lower-than-average consumption frequencies of dairy products, meat and processed meat) to be inversely associated with childhood obesity in our cohort. However, this dietary pattern was, surprisingly, very common in Swedish children and less common in children living in Mediterranean countries *(26)*. This is in line with the finding that the Swedish children in our cohort were less likely to be overweight/obese compared to children from Italy, Cyprus and Spain *(27)*.

In accordance with WHO recommendations *(28)*, plant-based foods and a reduction of simple sugars should be promoted as well as nutrient-dense foods instead of highly processed, energy-dense foods. Promotion of plain water as the main source of fluids for children, instead of sugar-sweetened beverages, is also recommended in order to reduce childhood obesity.

SOCIAL GRADIENT AND CHILDREN'S DIET

As stated in the first section, parents influence their children's diet through their own diet and through the family food environment they create. But it is also widely accepted that not only health awareness and health behaviour, but also diet quality of adults is influenced by their socioeconomic status (SES) *(29)*. Therefore, SES has to be considered as a potential determinant of children's diet (Table 3).

Investigation of the cross-sectional association between parental education level and frequency of children's consumption of obesity–related foods revealed that children from families with low and medium education levels had higher odds of frequently

consuming high-sugar and high-fat foods, compared to children from families with high parental education levels *(30)*.

In a further cross-sectional analysis, various country-specific dietary patterns were identified *(31)*. It is noteworthy that one dietary pattern was common across all countries, consisting mainly of processed food (e.g. pizza, hamburger, candy bars and puddings). In all countries except Sweden this dietary pattern was associated with lower parental education, income, and occupational position.

In a subsequent longitudinal analysis, at baseline and follow-up the following dietary patterns were identified: "processed" (higher-than-average consumption frequencies of snacks and fast food), "sweet" (higher-than-average consumption frequencies of sweet foods and sweetened beverages) and "healthy" (higher-than-average consumption frequencies of fruits, vegetables and whole meal products) *(32)*. Children with highly educated parents and from the highest household income category were more likely to fit the healthy pattern at both time points. Consistently, at both time points, children with lower educated parents were more likely to fit the sweet pattern compared to children with highly educated parents. In addition, at both time points children of migrant parents were more likely to fit the processed pattern compared to children of non-migrant parents.

In a similar analysis, social vulnerabilities such as migrant status, social network, family structure and employment status were investigated extending the classical definition of SES *(33)*. The higher the number of social vulnerabilities, the more likely children were to fit the processed pattern and less likely to fit the healthy pattern at both time points.

To sum up, different approaches to the data all led to the same conclusion: low parental SES has a negative impact on children´s diet. There is an urgent need to make it easier for low SES groups to access healthier diets, and to involve them in developing strategies to tackle childhood obesity.

MEDIA AND CHILDREN'S DIET

Since there is good evidence that consumption of unhealthy foods and sugar-sweetened beverages is related to childhood obesity *(34–36)*, the recent WHO report on ending childhood obesity *(28)* calls for a reduction in exposure of children to marketing of these products. Interventions limiting media use to ensure appropriate television/screen viewing may offer the dual benefit of reducing sedentary activity and reducing exposure to unhealthy advertised food products. We investigated the extent to which these exposures contribute to the obesogenic environment for European children, and summarize a number of relevant findings below (Table 4).

As noted above, children's sugar consumption is a modifiable risk factor for childhood obesity *(23)*. However, frequent consumption of foods with high sugar content is not necessarily related to a child's preference for sweet taste, as determined experimentally *(21)*. In fact, we found that taste preferences for sugar and fat in blind tests were stronger correlates of weight status than parental reports of children's usual consumption frequencies *(21)*.

In the IDEFICS study, screen behaviours that were positively associated with overweight children were: hours spent in front of the television; having a television in the bedroom; and watching television while eating meals *(20)*. These behaviours were also associated with a propensity to consume high-fat and high-sugar food items, independent of objectively measured taste preference for sweet and fat *(20)*. Moreover, children with taste preferences for both high-sugar and high-fat items appear prone to be overweight *(21)*. Exploiting two questions that were only asked in the Swedish questionnaire, we found that in the Swedish IDEFICS cohort, screen habits were associated with sugar-sweetened beverages, independent of parental norms *(18)*. Interestingly, Sweden is a country where sugar intake is relatively low and commercial television targeting children is restricted.

TV habits of children in the IDEFICS study were related prospectively to increases in weight- to-height ratio, and were also associated with consumption of sugar-sweetened beverages *(19)*. Children's food purchasing requests to their parents were correlated with both weight status and propensities to consume foods high in sugar and fat, although corresponding prospective associations with being overweight or obese were not consistently observed *(37)*.

In summary, we found strong evidence that children's screen behaviours were correlated with both diet and BMI at the baseline survey. However, after two years, associations between TV exposure and increases in sugar-sweetened beverage consumption were weaker *(19)*. This may reflect difficulties in obtaining unbiased information on dietary exposures and limitations in screen time as an indicator of energy requirements. The association between screen time and weight status was not dependent on taste preferences, implying that television may impact on children's intake of high-sugar and high-fat foods without modifying their personal taste preferences for sugar and fat. Children's various so-called pester power behaviours, for example asking for foods while at the supermarket, and parental acquiescence to these requests, are widely believed to promote

weight problems. However, it seems that children who ask for foods seen on TV were specifically affected, as measured by changes in BMI and diet quality indicators *(37)*. In conclusion, sedentary screen behaviours, preferences for sweet and fat tasting foods, and asking for foods seen on television were more consistently associated with adverse weight indicators, compared to parental reports of their children's food frequencies.

DISCUSSION: FOOD MARKETING, CHILDREN'S DIETS AND POLICY IMPLICATIONS

The results presented above are considered largely from a biological and/or behavioural perspective as was done in the original publications and the discussions provided there. In the following, we comment on what we believe is the most significant factor from a broader, policy-oriented perspective: the way contemporary food systems influence what food ends up on children's plates. Whilst poor dietary habits cause ill health and obesity, we need to look further upstream to understand the causes of poor diets.

In line with a number of other policy documents, including those led by the WHO *(28)*, we would underline the availability and marketing of processed foods, with their greater energy density than whole and home-prepared foods. This factor clearly relates to the dominant role of a few large companies in supplying food to consumers. In 2011, the national top five food retailers' market share exceeded 60% in 13 EU member states *(38)*. There are obvious commercial reasons why large food companies are oriented toward processed foods and drinks. While whole foods offer few opportunities to create a standardized product, processed products can be packaged, branded and marketed by a company. Moreover, to produce whole foods does not require the key capacities commanded by modern business corporations, such as research facilities or specialized factory production lines. For the same reason, large companies do not undertake concerted, consistent marketing campaigns to promote whole foods; as has been found in many other studies *(39)*, most marketing efforts are dedicated to energy-dense, processed foods and drinks.

As indicated in the aforementioned findings, processed foods and drinks tend to be more harmful for health than whole foods. Again, there are some straightforward reasons for this. To increase shelf-life and improve flavour, manufacturers use fats, sugar and salt, and reduce water content. They rely on consistent, storable ingredients — wheat, sugar or vegetable oils, for example, or extracts and concentrates from fruits/vegetables. This also reduces water and fibre content. These factors mean that processed foods tend to be more energy-dense, high in fat, salt, added sugar and rapidly absorbed carbohydrates; equally, they tend to be less nutrient-dense and low in fruit and vegetable content.

The results of the IDEFICS/I.Family studies demonstrate the damaging effects of the ubiquitous availability and marketing of processed foods. As noted above, the children we studied tend to eat foods that are too energy-dense *(13)*, and were significantly influenced by television advertising *(18, 37)*.

Governments and public health organizations have, so far, pursued two main strategies to deal with these problems. Many public health initiatives have been based around information provision and social marketing. As part of the IDEFICS intervention, we also tried to encourage children and families to make different food choices. As with other initiatives, we found this had only small effects *(40)*. In general, the problem is not that consumers lack knowledge, but rather that contemporary food environments make it hard to act on this knowledge, especially when families are suffering under disadvantageous socioeconomic circumstances, and facing many sources of pressure. This helps to explain our finding, which is consistent with virtually every study in this area, that children from lower SES backgrounds tend to have low-quality diets and poorer health outcomes *(32)* (for further discussion see *(41)*).

In addition, both the EU and some of its Member States have taken measures to promote so-called voluntary self-commitments (VSCs) by food and drink companies. Many of these efforts have focussed on the problem of companies' marketing of high-fat/salt/sugar foods to children. The EU Pledge is one high-profile European initiative *(42)*. Companies that sign the pledge commit not to advertise products to children under 12 years old unless they fulfil specific nutritional criteria. One major problem is that this commitment ignores those aged between 12 and 18 years old. Another problem is that the nutritional criteria are not very restrictive. The German non-governmental organization (NGO) Foodwatch examined the products that these companies were marketing to children in terms of WHO criteria for a balanced diet *(43, 44)*. They found that only 10% of marketed products met this guideline *(34–37, 44)* (see also *(45–47)*). A further problem is whether the pledge is actually kept. For example, the most recent official evaluation of the EU Pledge found that, out of 75 websites by the signatory companies featuring so-called advergames (computer activities or games), 23 of these were designed to appeal primarily to under 12 year olds *(42)*. Many more will

also be attractive to younger children, or aimed primarily at teenagers.

The poor outcomes of such VSC measures should not be surprising. Food and drink companies are caught by their own business models. Profit-making companies cannot afford to ignore strategies that their competitors are using to increase sales and market share. Marketing processed foods and drinks to children is one such strategy. In the absence of statutory regulation that applies to all market actors, companies have no choice but to promote unhealthy products to children.

Addressing these upstream factors is hard work. At the least, we would argue that much stricter controls on marketing to children are needed. These might be statutory, or it might be possible to extend the current inefficient VSCs to create truly binding commitments; for example, if these were independently monitored by NGOs such as Foodwatch. Since such measures are often presented as restrictive, we would like to conclude by pointing out how such regulations would create important freedoms. Strict limits on marketing to children would enable food and drink corporations to act in more socially responsible ways. Such limits would also free children from commercial influences that they do not understand and cannot resist. Not least, limiting marketing would help free parents – especially those parents who face the burdens of lower SES – from pressures to buy products that pose clear risks to their children's health.

CONCLUSIONS

The IDEFICS/I.Family studies provide novel insights and significant depth of research into childhood obesity. Both studies also support a growing consensus about the causes of obesity. These implications are far-reaching, especially in those countries and regions where rates of overweight and obese children are high or increasing.

The evidence presented in this paper supports policy interventions that will touch on diverse aspects of families' lives. This is achieved not by asking people to choose differently or deliberate more about health-related behaviours, but rather by altering the environmental and structural factors that constrain and facilitate contemporary lifestyles. In particular, we have suggested that efforts to address childhood obesity must look to the causes of poor diets. These include aggressive marketing to children, the failure of self-regulation of the food and drink industry and the corrosive effects of socioeconomic disadvantages that ensure that healthy diets are, for many families, hard to achieve and maintain.

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FIGURES AND TABLES

FIG. 1. ADDRESSED ASPECTS RELATED TO DIETARY BEHAVIOUR AND FOOD CHOICE OF EUROPEAN CHILDREN EXTRACTED FROM THE COMPLEX AETIOLOGY OF CHILDHOOD OBESITY.

TABLE 1. SUMMARY OF STUDIES DESCRIBING THE CHARACTERISTICS OF CHILDREN'S DIET

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Variable of interest	Estimates	
Börnhorst et al. (2014)	24HDR	**Usual intake**	**Mean**	
Estimation of usual intake distributions using measurement error correction methods (n=8611)		Energy intake (kcal/day)	1546.2	
		Water intake (kcal/day)	1216.7	
		Fat intake (% of total energy intake)	32.3	
		Carbohydrates intake (% of total energy intake)	52.1	
		Protein intake (% of total energy intake)	15.7	
Svenson et al. (2014)	24HDR	**Country**	**Mean (% of total energy intake)**	
Descriptive analyses of country-specific percentage of sugar intake (n=9497)		Belgium	28	
		Estonia	19	
		Germany	30	
		Hungary	28	
		Italy	21	
		Spain	23	
		Sweden	22	

TABLE 1. SUMMARY OF STUDIES DESCRIBING THE CHARACTERISTICS OF CHILDREN'S DIET

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Variable of interest		Estimates	
Hebestreit et al. (2014)	24HDR	**Dietary characteristics**		**Stand. β-estimate**	***p*-value**
Association between dietary characteristics (exposures) and ED (kcal/g, outcome) using LMM (6– < 10 yrs; n=4613)		Total energy intake (kcal/day)		0.405	< 0.0001
		Total food intake (g/day)		-0.096	< 0.0001
		Fat intake (% of total energy intake)		0.310	< 0.0001
		Protein intake (% of total energy intake)		-0.129	< 0.0001
		Carbohydrate intake (% of total energy intake)		-0.222	< 0.0001
		Cereal products (g/day)		0.165	< 0.0001
		Sugar and sugar products (g/day)		0.085	< 0.0001
		Fruit and vegetables (g/day)		-0.199	< 0.0001
		Dairy products (g/day)		-0.059	< 0.0001
Hebestreit et al. (2017)	24HDR, FFQ	**Exposures (parental DP and soft drink availability)**	**Outcomes (children's DP)**	**OR**	**95% CI**
Association between DP of parents (Sweet and Fat (SF), Refined Cereals (RC), Animal Products (AP)) as exposures and DP of children (SF, RC, AP) as outcomes using k-means and GLMM (n=1607 for mother-child dyads, n=763 for father-child dyads) and of impact of soft drink availability		Mother in SF, soft drinks available vs mother not in SF, soft drinks not available (ref)	Child in SF vs not (ref)	2.78	1.80, 4.28
		Mother in RC, soft drinks not available vs mother not in RC, soft drinks not available (ref)	Child in RC vs not (ref)	2.48	1.43, 4.27
		Mother in AP, soft drinks not available vs mother not in AP, soft drinks not available (ref)	Child in AP vs not (ref)	2.16	1.59, 2.92
		Father in SF, soft drinks available vs father not in SF, soft drinks not available (ref)	Child in SF vs not (ref)	4.26	2.16, 8.41
		Father in RC, soft drinks not available vs father not in RC, soft drinks not available (ref)	Child in RC vs not (ref)	2.05	1.22, 3.45
		Father in AP, soft drinks not available vs father not in AP, soft drinks not available (ref)	Child in AP vs not (ref)	2.48	1.62, 3.79

24HDR: 24-H dietary recall, CI: confidence interval, DP: dietary pattern, ED: energy density, GLMM: generalized linear mixed models, LMM: linear mixed models, OR: odds ratio, yrs: years, ref: reference group.

TABLE 2. SUMMARY OF STUDIES INVESTIGATING THE ASSOCIATIONS OF DIETARY BEHAVIOUR AND CHILDHOOD OBESITY

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Exposures	Estimates	
Hebestreit et al. (2014)	24HDR	**Dietary intake**	β-estimate	***p*-value**
Association between dietary intake (exposures) and BMI z-score (outcome) using LMM (n=8544)		Total daily food intake (g/day; 1 unit ~ 100g)	0.027	$p < 0.0001$
		Total energy intake (kcal/day; 1 unit ~ 100 kcal)	0.032	$p < 0.0001$
Hebestreit et al. (2016)	24HDR		β-estimate	**99% CI**
Association between Δresidual energy intake per year (1 unit ~ 100 kcal/year, exposure) and ΔBMI z-score per year (outcome) using LMM and LM (n=2753)		Δresidual energy intake per year (1 unit ~ 100 kcal/year, exposure)	0.014	0.001, 0.027
Pala et al. (2013)	FFQ	**Vegetables and wholemeal consumption tertiles (ref: 1st tertile)**	**OR**	**95% CI**
Association between vegetables and wholemeal consumption tertiles (exposure, ref: 1st tertile) and overweight/obesity (outcome, ref: thinness/normal weight) using mixed effects logistic regression (n=8223)		2nd tertile	0.69	0.57, 0.84
		3rd tertile	0.64	0.51, 0.80
Tognon et al. (2014)	24HDR	**Country**	**Percentage of adherence (score > 3) to a Mediterranean-like diet on work days (%)**	
Descriptive analysis of country-specific adherence to Mediterranean-like diet score (range: 0–7, outcome) (n=7940)		Sweden	37.6	
		Estonia	33.0	
		Hungary	34.3	
		Belgium	35.5	
		Germany	29.4	
		Italy	49.3	
		Spain	34.3	
		Cyprus	29.6	

24HDR: 24-H dietary recall, BMI: body mass index, CI: confidence interval, FFQ: food frequency questionnaire, LM: linear model, LMM: linear mixed model, yrs: years

TABLE 3. SUMMARY OF STUDIES INVESTIGATING THE ASSOCIATION BETWEEN THE SOCIAL GRADIENT AND CHILDREN'S DIET

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Exposures	Outcomes	Estimates	
Fernandez et al. (2013)	FFQ	**Parental education (low, medium, high)**	**Consumption frequency**	**OR**	**95% CI**
Analysis of association between parental education (exposure) and food consumption frequencies (outcomes) using logistic regression (n=14 462)		Low parental education vs high (ref)	Vegetables (highest tertile vs middle and lowest tertile (ref))	0.56	0.47, 0.65
		Low parental education vs high (ref)	Fried potatoes (highest tertile vs middle and lowest tertile (ref))	2	1.72, 2.31
Fernandez et al. (2014)	FFQ	Additive socioeconomic status score	**Country-specific "Processed" component**	β-estimate	**95% CI**
Analysis of associations between socioeconomic status score (including education, parental occupation, household income, range: 3–15) and "Processed" dietary component obtained using PCA stratified by country and LM (n=14 233)			"Processed" component (Belgium)	-0.035	-0.053, -0.018
			"Processed" component (Cyprus)	-0.056	-0.078, -0.033
			"Processed" component (Estonia)	-0.037	-0.056, -0.019
			"Processed" component (Germany)	-0.036	-0.05, -0.022
			"Processed" component (Hungary)	-0.069	-0.082, -0.055
			"Processed" component (Italy)	-0.063	-0.077, -0.049
			"Processed" component (Spain)	-0.045	-0.065, -0.025
			"Processed" component (Sweden)	-0.005	-0.024, 0.013
Fernandez et al. (2015)	FFQ	**Socioeconomic variables**	**DP at T0/T1**	**OR**	**95% CI**
Prospective analysis of association between socio-economic variables and DP ("Healthy", "Processed", "Sweet") using k-means and logistic regression (n=9301)		Mother high-educated vs low-educated (ref)	"Healthy" DP at both time points vs all other combinations (ref)	1.61	1.28, 2.04
		Father highly educated vs father low educated	"Healthy" DP at both time points vs all other combinations (ref)	1.51	1.20, 1.90
		Highest household income category vs lowest	"Healthy" DP at both time points vs all other combinations (ref)	1.31	1.12, 1.53
		Mother highly educated vs low educated (ref)	"Sweet" DP at both time points vs all other combinations (ref)	0.65	0.47, 0.89
		Father highly educated vs low educated (ref)	"Sweet" DP at both time points vs all other combinations (ref)	0.73	0.54, 0.99
		Migrant parents vs non-migrant parents	"Processed" DP at both time points vs all other combinations (ref)	1.24	1.05, 1.46
Iguacel et al. (2016)	FFQ	**Number of social vulnerabilities at T0 (0–6)**	**DP at T0/T1**	**OR**	**99% CI**
Analysis of associations between social vulnerability and DP ("Healthy", "Processed", "Sweet") using multinomial mixed models (n=9301)		3–6 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T0)	1.78	1.21, 2.62
		2 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T0)	1.71	1.31, 2.23
		1 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T0)	1.19	0.98, 1.45
		3–6 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T1)	1.65	1.17, 2.32
		2 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T1)	1.35	1.07, 1.71
		1 vs 0 vulnerabilities (ref)	"Processed" DP vs "Healthy" DP (ref) (T1)	1.18	0.99, 1.55

24HDR: 24-H dietary recall, CI: confidence interval, DP: dietary pattern, FFQ: food frequency questionnaire, LM: linear model, PCA: principal component analysis, yrs: years, ref: reference group.

TABLE 4. SUMMARY OF STUDIES INVESTIGATING THE ASSOCIATION BETWEEN MEDIA AND CHILDREN'S DIET

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Exposures	Outcomes	Estimates	
Lanfer et al. (2012)	FFQ, sensory tests	**Child's preference for sweet taste**	Weekly consumption frequency of sweet foods	**Mean**	***p*-value**
Mean weekly consumption frequency of sweet foods comparing children with low vs high sweet preference (n=1696)		Low sweet preference		32	0.97
		High sweet preference		32	
Association between taste preference and overweight/obesity using logistic regression (n=1696)		Child's taste preference	Overweight/obesity (ref: thinness/ normal weight)	**OR**	**95% CI**
		High vs low fat preference (ref)		1.8	1.3, 2.5
		High vs low sweet preference (ref)		1.5	1.1, 2.1
Lissner et al. (2012)	FFQ	**Television habits**		**OR**	**95% CI**
Association between television habits and overweight/obesity, fat consumption score and sugar consumption propensity using logistic regression (n=15 144)		Child regularly eats meals while watching TV vs does not (ref)	Overweight/obesity (ref: thinness/ normal weight)	1.28	1.16, 1.42
		Child watches TV at least 60 min/day vs does not (ref)	Overweight/obesity (ref: thinness/ normal weight)	1.21	1.10, 1.33
		Child has a TV or video/DVD in bedroom vs has not (ref)	Overweight/obesity (ref: thinness/ normal weight)	1.3	1.17, 1.44
		Child regularly eats meals while watching TV vs does not (ref)	4th fat consumption score quartile (ref: 1st quartile)	1.49	1.34, 1.65
		Child watches TV at least 60 min/day vs does not (ref)	4th fat consumption score quartile (ref: 1st quartile)	1.43	1.29, 1.57
		Child has a TV or video/DVD in bedroom vs has not (ref)	4th fat consumption score quartile (ref: 1st quartile)	1.2	1.07, 1.35
		Child regularly eats meals while watching TV vs does not (ref)	4th sugar consumption score quartile (ref: 1st quartile)	1.93	1.72, 2.16
		Child watches TV at least 60 min/day average vs does not (ref)	4th sugar consumption score quartile (ref: 1st quartile)	1.84	1.66, 2.05
		Child has a TV or video/DVD in bedroom vs has not (ref)	4th sugar consumption score quartile (ref: 1st quartile)	1.74	1.54, 1.97
Olafsdottir et al. (2014)	FFQ	**Screen habits**	**Consumption of SSB (ref: less than 1 time a week)**	**OR**	**95% CI**
Association between screen habits and consumption of SSB using logistic regression (n=1733)		TV viewing (1 unit ~ 1 h/day)	Consumption of SSB at least 1–3 times a week	1.5	1.2, 1.9
		Total screen time (1 unit ~ 1 h/day)	Consumption of SSB at least 1–3 times a week	1.4	1.2, 1.6
		Exposure to commercial TV (ref: not exposed)	Consumption of SSB at least 1–3 times a week	1.6	1.3, 2.1
		Parent not or partly limiting exposure to TV commercial (ref: limiting)	Consumption of SSB at least 1–3 times a week	1.9	1.4, 2.6

TABLE 4. SUMMARY OF STUDIES INVESTIGATING THE ASSOCIATION BETWEEN MEDIA AND CHILDREN'S DIET

Reference and short analysis description (incl. exposures, outcomes, statistical method, sample size)	Dietary assessment method	Exposures	Outcomes	Estimates	
Olafsdottir et al. (2014)	FFQ	**Screen activities**		**OR**	**95% CI**
Prospective association between screen activities and outcomes: weight for height increase, increase in SSB using logistic regression (n=11038)		TV viewing time (1 unit ~ 1 h/day) (2– < 6 yrs)	Increase in weight for height between T0 and T1 (highest quintile vs all others (ref))	1.32	1.14, 1.52
		TV viewing time (1 unit ~ 1 h/day) (6– < 10 yrs)	Increase in weight for height between T0 and T1 (highest quintile vs all others (ref))	1.24	1.13, 1.35
		Total screen time (1 unit ~ 1 h/day) (2– < 6 yrs)	Increase in weight for height between T0 and T1 (highest quintile vs all others (ref))	1.22	1.09, 1.36
		Total screen time (1 unit ~ 1 h/day) (6– < 10 yrs)	Increase in weight for height between T0 and T1 (highest quintile vs all others (ref))	1.16	1.09, 1.24
		TV viewing time (1 unit ~ 1 h/day) (2– < 6 yrs)	Increase in SSB between T0 and T1 (ref: no increase)	1.3	1.15, 1.48
		TV viewing time (1 unit ~ 1 h/day) (6– < 10 yrs)	Increase in SSB between T0 and T1 (ref: no increase)	1.11	0.99, 1.24
		Total screen time (1 unit ~ 1 h/day) (2– < 6 yrs)	Increase in SSB between T0 and T1 (ref: no increase)	1.21	1.09, 1.33
		Total screen time (1 unit ~ 1 h/day) (6– < 10 yrs)	Increase in SSB between T0 and T1 (ref: no increase)	1.08	0.996, 1.16
Huang et al. (2016)	FFQ	**Children's requests for items he/she saw on TV (never/sometimes/often/ my child hardly watched TV) (T0)**		**OR**	**95% CI**
Association between children's food purchasing requests and outcomes: obesity, sugar consumption score, fat consumption frequency using logistic regression and LM (T0) (n=13 217)		Often vs sometimes (ref)	Obesity (> 95th percentile) (T0)	1.19	1.03, 1.37
				β-estimate	***p*-value**
		Often vs sometimes (ref)	Sugar consumption score (T0)	1.72	< 0.0001
		Often vs sometimes (ref)	Fat consumption score (T0)	1.74	< 0.0001
Association between children's food purchasing requests and outcomes: obesity, sugar consumption score, fat consumption frequency using logistic regression and LM (T1) (n=7820)		**Children's requests for items he/she saw on TV (never/sometimes/often/ my child hardly watched TV) (T0)**		**OR**	**95% CI**
		Often vs sometimes (ref)	Obesity (> 95th percentile) (T1)	1.15	0.84, 1.59
				β-estimate	***p*-value**
		Often vs sometimes (ref)	Sugar consumption score (T1)	0.45	> 0.05
		Often vs sometimes (ref)	Fat consumption score (T1)	0.68	< 0.05

24HDR: 24-H dietary recall, CI: confidence interval, FFQ: food frequency questionnaire, SSB: sugar-sweetened beverages, T0: first survey, T1: first follow-up, yrs: years, ref: reference group.