Nutrition 106 (2023) 111893

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Food portion sizes and their relationship with energy, and nutrient intakes in adolescents: The HELENA study

Sondos M. Flieh [a], María L. Miguel-Berges [a,b,*], Inge Huybrechts [c,d], Christina Breidenassel [e,f], Evangelia Grammatikaki [g,h], Cinzia Le Donne [i], Yannis Manios [g,j], Kurt Widhalm [k,l], Dénes Molnár [m], Peter Stehle [e], Anthony Kafatos [n], Jean Dallongeville [o], Cristina Molina-Hidalgo [p], Sonia Gómez-Martínez [q], Marcela Gonzalez-Gross [f,r], Stefaan De Henauw [s], Laurent Béghin [h,t], Mathilde Kersting [u], Luis A. Moreno [a,b,r,v], Esther M. González-Gil [a,r,v]

[a] Growth, Exercise, Nutrition and Development Research Group, Faculty of Health Sciences, University of Zaragoza, Zaragoza, Spain
[b] Instituto Agroalimentario de Aragón, Zaragoza, Spain
[c] International Agency for Research on Cancer, Lyon, France
[d] Department of Public Health, Ghent University, Ghent, Belgium
[e] Department of Nutrition and Food Sciences, University of Bonn, Bonn, Germany
[f] ImFINE Research Group, Department of Health and Human Performance, Faculty of Physical Activity and Sport, Universidad Politécnica de Madrid, Madrid, Spain
[g] Department of Nutrition and Dietetics, School of Health Science and Education, Harokopio University, Athens, Greece
[h] University Lille, Inserm, Centre Hospitalier Universitarie Lille, Clinical Investigation Center, Lille, France
[i] Council for Agricultural Research and Economics, Research Centre for Food and Nutrition, Rome, Italy
[j] Institute of Agri-Food and Life Sciences, Hellenic Mediterranean University Research Centre, Heraklion, Greece
[k] Department of Gastroenterology and Hepatology, Medical University of Vienna, Vienna, Austria
[l] Austrian Academic Institute for Clinical Nutrition, Vienna, Austria
[m] Department of Pediatrics, Medical School, University of Pécs, Pécs, Hungary
[n] Faculty of Medicine, University of Crete, Crete, Greece
[o] Department of Epidemiology and Public Health, Institut Pasteur de Lille, Lille, France
[p] Evaluacion funcional y fisiologia del ejercicio, Ciencia y Tecnologia de la Salud Department of Physiology, Faculty of Medicine, University of Granada, Granada, Spain
[q] Immunonutrition Research Group, Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition, Spanish National Research Council, Madrid, Spain
[r] CIBER Fisiopatología de la Obesidad y Nutrición, Instituto de Salud Carlos III, Madrid, Spain
[s] Department of Public Health and Primary Care, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium
[t] University Lille, Inserm, Institute for Translational Research in Inflammation, INFINITE, Lille, France
[u] Research Department of Child Nutrition, Pediatric University Clinic, Ruhr-University Bochum, Bochum, Germany
[v] Instituto de Investigación Sanitaria Aragón, Zaragoza, Spain

ARTICLE INFO

Article History:
Received 21 June 2022
Received in revised form 19 September 2022
Accepted 19 October 2022

Keywords:
Food portion size
Dietary intake
Macronutrient
Micronutrient
Adolescent

ABSTRACT

Objectives: This study aimed to investigate the associations between portion sizes (PSs) from different food groups and energy, as well as nutrient intakes in European adolescents.
Methods: A sample of 1631 adolescents (54.2 % girls) were included from the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional (HELENA) study. Mean food PS was calculated by dividing the total intake of the items by the number of eating occasions of these consumed items. To determine the key items for analysis, foods were ranked by frequency of consumption. A one-way between-groups analysis of covariance was used to test for significant differences in means across tertiles. A multivariable linear regression analysis was carried out, adjusting for age, sex, maternal education, body mass index, and using country as a level.

The HELENA study received funding from the European Community Sixth RTD Framework Program (Contract FOODCT-2005–007034), and . Esther M. González-Gil holds a Juan de la Cierva-Formación grant from the Spanish Government (FJCI-2017–34967). The HELENA study was approved by ethics committees in all countries, and followed good clinical practice, ethical guidelines of the Declaration of Helsinki 1964 (revision of 2000), and legislation on clinical research in humans in each country involved in the study. The ethical approval code from the coordinator center was 03/2006, and the date of approval is February 2006 as obtained from the ethical committee of clinical research in Aragon, Spain. Informed consent was obtained from all participants in the study. The data presented in this study are available for further scientific analysis upon request from the coordinator of the HELENA study.

*Corresponding author. Tel.: +34 638234634.
E-mail address: mlmiguel@unizar.es (M.L. Miguel-Berges).

https://doi.org/10.1016/j.nut.2022.111893

Results: Energy intake increased with elevated intakes of energy-dense foods. Large portions of rice and other grains, starch roots and potatoes, and meat substitutes, nuts, and pulses were associated with increased carbohydrate and fiber intake. Larger portions of cheese and butter and animal fat were significantly associated with a higher fat intake. Lower intakes of some vitamins and micronutrients were noticed with consumption of larger portions of high energy-dense foods, such as desserts and pudding, margarine and vegetable oil, and butter and animal fat.

Conclusions: Large food PSs may be associated with positive energy, as well as macro- and micronutrient intake. Moreover, the findings from this study may help the future development of dietary guidance in general and specific to PSs, and support targeted strategies to address intakes of certain nutrients in European adolescents.

Introduction

Childhood and adolescence are both critical periods during which rapid cognitive development and physical growth occurs [1]. During childhood, nutritional demands increase, and adequate energy intake along with the consumption of nutrient-dense foods are essential [2]. However, being overweight or obese from energy-dense, low-nutrient content diets is a critical and growing worldwide problem [3].

Dietary habits undergo many changes during a lifespan with regard to dietary diversity, nutrient intake, and portion size (PS) [4]. A portion is how much food one chooses to eat for a meal or snack, or the amount of food to eat or serve to an individual for a single eating occasion [5]. Increased PSs of food and energy-dense drinks commonly served are considered a major component of the food environment contributing to the excess of energy consumed and the development of obesity [6]. In children and adolescents, larger food PSs have been associated with the increased intake of specific nutrients and/or a decrease in intake of some micronutrients as a result of the composition of the food itself. For example, when children consume large PSs of sugary sweets, total sugar increased but the intake of many micronutrients decreased [7].

However, children with excess energy consumption may suffer from nutrient deficiency [8]. Moreover, unsuitable nutritional profiles in terms of food, as well as macro- and micronutrients, during adolescence is associated with adverse health outcomes later in adult life [2]. For example, the regular consumption of cow milk is very important during childhood due to its high content of protein, fat, calcium, and vitamin D to maintain good health [9]. Of note, vitamins and micronutrient deficiencies, such as vitamin D, calcium, and iron, can lead to a wide range of health problems, such as hyperparathyroidism, rickets, osteomalacia [10], and anemia [11], in children and adolescents.

Most European countries met under half of the World Health Organization's (WHO) recommended nutrient intake (e.g., iron, calcium, vitamin D, and vitamin C); thus, widespread nutrition issues could exist across Europe [8]. Macronutrient compliance to recommended nutrient intake was poor globally, but micronutrient compliance was slightly better, although girls and children age >10 y showed less attainment [8]. On the other hand, selected micronutrient intake has been examined in Central and Eastern European countries, but these countries lacked intake information across all ages, particularly in children, compared with other European countries [12]. Also, a recent review showed that less than a third of European countries reported the energy and nutrient intakes of children and adolescents [13].

Most studies focus on the effect of PS from energy-dense foods on energy intake and body mass index (BMI) to manage the obesity epidemic [5,14], but the effect of food PS on nutrient intake is usually not addressed. Knowledge of adolescents' association between PS and intake of energy and macro- and micronutrients is essential to monitor trends and nutritional interventions. Therefore, the present study aimed to examine the relationship between food PS from various food groups and the intake of macro- and micronutrients.

Methods

Study design

The analysis was conducted using data from the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS), which is a cross-sectional multicenter study (2006–2007) focused on the evaluation of nutritional status in European adolescents [15]. Recruited adolescents were age 12.5 to 17.5 y from 10 European cities: Heraklion and Athens (Greece), Dortmund (Germany), Ghent (Belgium), Lille (France), Pécs (Hungary), Rome (Italy), Vienna (Austria), Stockholm (Sweden), and Zaragoza (Spain) [15].

The main objective of the HELENA-CSS was to obtain reliable and comparable data from randomly selected European adolescents (n = 3528; 52.3% women), using widely relevant health- and nutrition-related parameters, including dietary intake, food choices and preferences, serum vitamin and mineral status, lipid and glucose metabolism, immunologic markers, anthropometric measurements, physical activity, and fitness and genetic markers [16]. The inclusion criteria were participants age <17.5 y or >12.5 y who were free from any acute infection lasting <1 wk before the inclusion process, and not concurrently involved in another clinical trial.

The study was approved by the research ethics committees in each involved city, and followed the ethical guidelines of the Declaration of Helsinki 1964 (revision of Edinburgh 2000) [17]. Moreover, written informed consent was obtained from participating adolescents and their parents [17].

Study sample

Of the total sample of the HELENA-CSS, the present study included 1631 adolescents (54.2% girls). The specific inclusion criteria were participants who twice completed a 24-h recall with plausible intake. In this study, data on complete nutritional intake from eight European countries (Greece, Germany, Belgium, France, Italy, Austria, Sweden, and Spain) have been included. Approximately 1198 adolescents were excluded from the study, because they did not meet the inclusion criteria. Adolescents considered overreporters (n = 173; 4.9%) and underreporters (n = 526; 14.9%) according to the approach by Goldberg et al. [18] were excluded from this analysis.

Sociodemographic data

The education level of the adolescents' mothers was obtained using the International Standard Classification of Education [19], and reported as primary education, lower secondary education, higher secondary education, and higher education/university degree. In this study, the two lowest levels were merged into one group called lower level, in addition to medium and higher level.

Dietary assessment

The HELENA Dietary Assessment Tool (HELENA-DIAT) was used to assess adolescents' dietary consumption. This software is a self-administered, computerized 24-h recall, which was developed and originally validated in Flemish adolescents and then in the HELENA-CSS [20]. The HELENA-DIAT is based on previous day assessments of the intake from six meal occasions (breakfast, morning snack, lunch, afternoon snack, evening meal, and evening snack). The two nonconsecutive 24-h recalls were performed on 1 convenient weekday and 1 weekend day. A well-trained dietitian was present to assess the adolescent in case they needed help to complete the dietary 24-h recall.

A total of 800 photographs were available in the HELENA-DIAT program. Participants were able to select one of the amounts in a photograph or indicate that they had consumed more or less than the amount appearing on the computer. In addition, the adolescents were able to type the consumed amount for each food item in a text box. Moreover, participants had the option to remove or modify the selected items at any time. For foods that could be measured with household tools, such as cups, several portions appeared on the screen, so participants could select the consumption amount by clicking directly on the portion. In cases of foods usually eaten in combination with other items, such as French fries and mayonnaise, a reminder box was shown on the screen to include this item [20].

Dietary assessment of energy and macro- and micronutrients

First, all consumed foods and beverages were selected autonomously by participants from a standardized food list in the HELENA-DIAT. Then, the consumed food amounts were translated into nutrients using the German Food Code and Nutrient Data Base (Bundeslebensmittelschlüssel, version II.3.1), which includes 12 000 coded foods and approximately 158 nutrient data available for each product [21]. The multiple-source method was used to estimate the usual nutrient intake, including occasionally consumed foods, to eliminate day-to-day influence within individual variability and random error in the recalls [22]. When the multiple-source method was applied, the dietary data provided average energy intake in (kilojoules and kilocalories), as well as average intake of macronutrients (carbohydrates, proteins, and fat in g) and micronutrients (vitamins A, E, C, and B12, and calcium, iron, sodium, potassium, and zinc in mg; vitamin D in μcg) [23].

Portion size calculation

PS was established by dividing the total intake of items in grams included in the food group and consumed in the 24 h-recall by the number of eating occasions of these consumed items. In this study, the average amount of PS was calculated from the two days included in the 24-h recall by each eating occasion. For instance, if an individual consumed 30 g of bread for breakfast on the first day and 30 g for breakfast on the second day, then their PS at breakfast from this food item was 30 g. If the individual consumed 60 g of bread only for breakfast and not for any other meal, their PS was 60 g. Several studies of food PS effect on overweight children and adults have used the same methodology [24,25]. Thus, these data represent per-consumer, not per-capita, averages, and show the average change on PS for those who consume a certain item. Therefore, to analyze a specific food group, only participants who consumed this food group were included in the analysis.

Selection of foods and nutrients

Based on the European food groups classification system, approximately 4179 food and beverages, in the form of recipes or as individual foods, were aggregated into food groups [26]. To determine the key items for analysis, foods were ranked by frequency of consumption (i.e., number of eating occasions). In our study, we excluded foods that were very infrequently consumed from the analysis. Furthermore, the daily diet was divided into 11 food groups based on the nutritional composition of the food groups: 1) water; 2) bread and cereal; 3) grains and potatoes; 4) fruit; 5) vegetables; 6) milk, milk desserts, and yogurt; 7) cheese; 8) meat/fish/eggs/nuts and vegetarian substitutes; 9) spread and cooking fat; 10) low-nutrient, energy-dense foods (e.g., chocolate, sugar products, biscuits, pies, savory snacks, creams, confectionery); and 11) low-nutrient, energy-dense drinks (e.g., carbonated soft drinks, juices).

Milk products and cheese were allocated to different food groups because of the important difference in fat content. However, three food groups were excluded from the analysis (products for special nutrition use, soya beverages, and alcoholic drinks) due to infrequent consumption (>85 % of sample did not report consumption). For the analysis, we considered energy-adjusted intakes of macronutrients (carbohydrate, protein, fat), fiber, total sugars, vitamins (vitamins C, B12, A, D, and E), and minerals (calcium, iron, sodium, potassium, and zinc). These nutrients were selected due to their public health importance in the diets of European adolescents, as highlighted in a previous analysis using data from the same cohort [27] and in other studies [28,29].

Statistical analysis

Normality was assessed using the Kolmogorov–Smirnov test. The descriptive analysis of mean and SD for general characteristics and lifestyle data are presented, and Student's t and ^{2} (for categorical variables) tests were used to compare means of continuous variables by sex.

PS data for each food item were split by tertiles to create relatively small (T1), medium (T2), and large (T3) PS categories. To avoid bias caused by differences in energy intake, all nutrients' intakes were energy adjusted per total intake percentage for macronutrients (carbohydrate, protein, fat, and sugar) and per 10 megajoule (MJ) for micronutrients (vitamins and minerals). Therefore, energy-adjusted values were calculated using the nutrient-density method, which involved computing the amount of PS in each food group consumed daily per 10 MJ of daily energy intake. The nonsignificant differences between sex for PS intake from food groups and nutrient intake using the Student t test justify why the analysis was not separated by sex.

Mean values for each of the macro- and micronutrients were compared across PS tertiles (T1 vs T2 vs T3) for the days on which portions of a particular food were consumed. A one-way between-groups analysis of covariance was used to test for significant differences in means across tertiles adjusting for sex, age, and BMI, and using maternal education as a covariable. A Tukey posthoc comparison test was used for normal distribution ($P < 0.05$). Moreover, Kruskal–Wallis tests with Mann–Whitney U-test comparisons were used for data not normally distributed ($P < 0.05$).

To assess the relation between the amount of PS from food groups and energy, as well as macro- and micronutrients, a multivariable linear regression analysis was carried out, with food PS amount as independent variables and nutrient intake as the dependent variable, adjusted for age, sex, maternal education, and BMI, and using country as a level. Finally, to reduce the probability of type 1 errors, the Holm–Bonferroni adjustment method was applied manually to significant results by ordering them from the smallest to the largest P value, testing the smallest probability, and applying a simple equation (i.e., alpha / (number of tests performed–rank after ordering + 1). If the first test was significant, the second smallest probability was tested, and so on. When the first nonsignificant test was generated, the procedure ended. This method is more powerful than the single-step Bonferroni.

All analyses were carried out using IBM-SPSS (version 25; SPSS Inc.; Chicago, IL). $P = 0.05$ was used to represent statistical significance for all tests.

Results

General characteristics of study participants and portion size characteristics

Sample descriptive characteristics, lifestyle data, energy, and nutrient intake are presented in Table 1 by sex. In general, boys had significantly higher percentages of being overweight and obese than girls (18.8% combined and 14.2%, respectively; $P < 0.001$. With regard to total energy and macro- and micronutrients, boys had a significantly higher mean intake than girls ($P < 0.005$). Median PS in grams consumed and categorized by their corresponding tertiles of small (T1), medium (T2), and large (T3) for foods groups and subgroups included in this study are described in Table 2.

Associations between nutrient intake and portion-size tertiles of food groups

Supplementary Table S1 describes the mean daily nutrient intakes by tertiles of PS food groups consumed by European adolescents. Mean carbohydrate intakes were higher when larger tertile portions of desserts and puddings were consumed. With regard to protein, a higher mean intake was noted when large tertile portions of meat substitutes, nuts, and pulses, as well as cakes, pies, and biscuits were consumed. Lower mean fat intakes were observed when large tertile portions of rice and other grains; fruit; milk, yogurt and milk beverages; and meat substitutes, nuts, and pulses were consumed, but a higher mean fat intake was noted when larger tertile portions cheese, eggs, butter and animal fat, and cake, pies, and biscuits were consumed. Dietary fiber mean intakes were lower when a larger PS tertile of bread and rolls was consumed.

Higher vitamin A consumption was noted when a larger tertile portion meat and poultry was consumed. Vitamin D mean intake was higher when larger tertile portions of cheese and sauces and creams were consumed. Vitamin E mean intake decreased when larger tertile portions of fruit and vegetable juices were consumed. With regard to vitamin B12, a high mean intake was noted when

Table 1
Baseline demographic characteristics, lifestyle data, total energy, and nutrient intake for study sample of adolescents ages 12.5 to 17.5 y

General characteristics	All participants (N = 1631) Boys (n = 747)	Girls (n = 884)	*P* value
Age, y, mean (SD)	14.7 (1.3)	14.7 (1.2)	0.145
Body mass index, kg/m^2, mean (SD)	20.8 (3.5)	20.8 (3.3)	0.131
Body mass index categories, n (%)			
Underweight	45 (6.1)	75 (8.5)	< **0.001**
Normal weight	562 (75.1)	683 (77.3)	
Overweight	107 (14.4)	103 (11.7)	
Obesity	33 (4.4)	23 (2.5)	
Maternal education, n (%)			
Low	231 (32.2)	257 (30.6)	0.202
Medium	211 (29.4)	278 (33.2)	
High	275 (38.4)	304 (36.2)	
Total energy, Kcal/d, mean (SD)	2690.6 (438.7)	2133.6 (302.8)	< **0.001**
Carbohydrate, g/d, mean (SD)	323.8 (70.3)	261.7 (51.7)	< **0.001**
Protein, g/d, mean (SD)	103.1 (23.5)	79.5 (15.9)	< **0.001**
Fat, g/d, mean (SD)	105.9 (25.3)	85.1 (18.2)	< **0.001**
Total sugar, g/d, mean (SD)	150.5 (57.4)	123.8 (45.2)	< **0.001**
Fiber, g/d, mean (SD)	20.1 (6.1)	18.0 (5.3)	< **0.001**
Vitamin A retinol equivalent without beta carotene, mg/d, mean (SD)	1.1 (0.4)	1.0 (0.4)	**0.002**
Vitamin D, µg/d, mean (SD)	2.2 (0.9)	1.9 (0.8)	< **0.001**
Vitamin E, mg/d, mean (SD)*	10.6 (2.9)	9.3 (2.3)	< **0.001**
Vitamin C, mg/d, mean (SD)	110.2 (61.9)	108.6 (56.5)	**0.035**
Vitamin B12, mg/d, mean (SD)	6.4 (2.1)	5.1 (2.1)	< **0.001**
Calcium, mg/d, mean (SD)	874.2 (471.3)	689.6 (374.9)	< **0.001**
Iron, mg/d, mean (SD)	14.4 (3.5)	11.8 (2.8)	< **0.001**
Sodium, mg/d, mean (SD)	2641.5 (737.3)	2110.7 (595.6)	< **0.001**
Potassium, mg/d, mean (SD)	3007.3 (766.9)	2532.9 (602.4)	< **0.001**
Zinc, mg/d, mean (SD)	13.5 (2.9)	10.7 (2.1)	< **0.001**

Boldface values indicate significance, *P* value < 0.05. Differences of mean values by sex were considered using student's *t* test analysis for continuous variables and ^{2} for categorical variables.
*Only alpha tocopherol.

Table 2
Median food portion size consumed according to corresponding tertiles of total intake for food groups and subgroups in this study

Food groups	Tertile medians, g* T1	T2	T3	Interquartile range
Bread and cereals				
Bread and rolls	64	100	154	90
Breakfast cereals	28	42	63	35
Grains and potato				
Rice and other grains	90	150	210	120
Starch roots, potatoes	80	120	193	113
Pasta	120	180	270	150
Fruit	130	180	280	150
Vegetables	46	91	163	117
Milk, milk desserts, and yogurt				
Milk, yoghurt, and milk beverages	187	287	450	263
Desserts and puddings (milk-based)	55	80	130	75
Cheese	24	40	67	43
Meat/poultry/fish/eggs				
Meat and poultry	71	150	274	203
Fish	60	120	173	113
Eggs	17	50	85	68
Meat substitutes, nuts, and pulses	20	44	120	100
Spread and cooking fat				
Margarine and vegetable oil	8	15	29	21
Butter and animal fat	10	17	30	20
Low-nutrient, energy-dense food				
Cakes, pies, biscuits	47	88	150	103
Savory snacks	20	35	50	30
Sugar, honey and jams, chocolate	22	47	90	68
Sauces and creams	30	55	91	61
Low-nutrient, energy-dense drinks				
Carbonated soft/isotonic drinks	250	400	650	400
Fruit and vegetable juices	200	300	450	250

*Medians of portion weights (g) from food groups according to small (T1), medium (T2), and large (T3) food portion-size tertiles.

larger tertile portions of eggs and cake, pies, and biscuits were consumed, and a lower mean intake was noted when larger tertile portions of starch roots and potatoes, as well as vegetables, were consumed.

With regard to iron, the mean intake increased when larger tertile portions of eggs, as well as meat substitutes, nuts, and pulses were consumed, and decreased with the consumption of larger tertile portions of bread and rolls and butter and animals fat. Calcium mean intake was lower when large tertile portions of sugar, honey, and jams were consumed. Moreover, sodium mean intake was lower when larger tertile portions of milk, yoghurt, and milk beverages, as well as meat substitutes, nuts, and pulses were consumed. With regard to potassium mean intake, larger portions of fish, eggs, and meat substitutes, nuts, and pulses were noted when consuming larger tertile portions. Mean intakes of zinc were higher when larger tertile portions of meat substitutes, nuts, and pulses were consumed, and a lower mean intake was noted with the consumption of a larger tertile portion of vegetables and fruit and vegetable juices.

Association between food portion size and nutrient intake

Tables 3, 4, and 5 show the association between food PS and nutrient intake in this selected sample of European adolescents. With regard to macronutrients and fiber, large portions of breakfast cereals, cheese, and eggs were inversely associated with carbohydrate intake, but large portions of rice and other grains, starch roots and potatoes, and carbonated soft drinks were significantly associated with increased carbohydrate intake. Larger portions of milk, yoghurt, and milk beverages, as well as fish were significantly associated with increased protein intake. Larger portions of cheese and butter and animal fat were significantly associated with a higher fat intake. On the other hand, fish and fruit and vegetable juice PSs were inversely associated with fat intake. Sugar intake increased when larger portions of sugar, honey, and jam were consumed. Finally, larger portions of rice and other grains, vegetables, and meat substitutes, nuts, and pulses were significantly associated with a higher fiber intake.

With regard to vitamins and micronutrient intake, vitamin A intake increased when larger portions of vegetables, as well as sauces and cream, were consumed, but larger portions of bread and rolls; milk, yoghurt, and milk beverages; dessert and pudding; and sauce and cream were associated with higher vitamin D intake. Larger portions of starch roots and potatoes, as well as meat and poultry, were associated with a higher intake of vitamin E. Larger portions of vegetables and fruit and vegetable juices were associated with a higher vitamin C intake. Last, larger portions of milk, yoghurt, and milk beverages; cheese; and meat and poultry were associated with a higher vitamin B12 intake, but larger portions of milk, yogurt, and milk beverages were associated with a higher calcium intake.

With regard to minerals, larger portions of breakfast cereals, rice and other grains, vegetables, meat and poultry, and eggs were associated with a higher iron intake, but larger sugar, honey, and jam PSs were associated with a lower intake of iron. Sodium intakes decreased when larger portions of bread and rolls, breakfast cereals, and meat and poultry were consumed. On the other hand, PSs of rice and other grains and carbonated soft drinks were inversely associated with potassium intake, but larger milk, yogurt, and milk beverages, as well as meat and poultry, PSs were

Table 3
Association between portion size from various food groups and energy-adjusted intake of macro- and micronutrients using multiple linear regression model: macronutrients (carbohydrate, protein, fat, total sugar, fiber)

Food groups, g	Carbohydrate, %TE			Protein, %TE			Fat, %TE			Total sugar, %TE			Fiber, g/10 MJ		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI		β	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Bread and rolls	−0.121*	−0.173	−0.068	0.279	−0.426	0.985	0.289	−0.014	0.593	−0.016	−0.044	0.011	−0.219	−1.430	1.147
Breakfast cereals	−0.113*	−0.160	−0.067	−0.964*	−0.442	−0.980	0.318	−0.726	0.091	−0.001	−0.006	0.004	−0.324	−0.752	0.104
Rice and other grains	0.188*	0.101	0.275	0.956	0.099	1.075	0.441	−0.193	1.201	−0.015	−0.061	0.032	0.969*	0.796	1.341
Starch roots, potatoes	1.061*	1.010	1.113	−0.961*	−0.827	−1.695	−0.765*	−1.280	−0.251	0.018	−0.003	0.039	1.652	−0.914	1.317
Pasta	−0.005	−0.094	0.084	1.407	−0.054	1.868	−0.046	−1.444	1.352	0.001	−0.032	0.034	−0.299	−1.335	0.736
Fruit	−0.574*	−0.854	−1.295	1.676	−0.963	1.315	1.231	−1.441	1.903	−0.001	−0.018	0.015	−0.636	−1.376	0.105
Vegetables	0.303	−0.351	0.957	0.688	0.014	1.362	0.852	−0.547	1.250	−0.003	−0.008	0.002	0.267*	0.089	0.445
Milk, yoghurt, and milk beverages	0.691	0.246	1.136	0.908*	0.273	1.543	1.103	−0.164	1.371	−0.015	−0.033	0.002	−0.766	−1.869	0.337
Desserts and puddings (milk-based)	0.521	0.936	1.106	1.092	0.571	1.812	0.867	0.794	1.939	−0.011	−0.052	0.030	0.504	−1.175	1.182
Cheese	−0.565*	−0.953	−0.176	−0.596*	−0.996	−0.197	0.269*	1.135	1.403	0.008	−0.008	0.024	0.182	−0.003	0.367
Meat and poultry	−1.528	−0.897	1.159	−0.439	−1.745	0.133	−1.908	−0.680	−1.136	−0.063	−0.114	−0.012	−1.589*	−0.588	−1.589
Fish	0.082	−0.239	0.402	0.489*	0.182	0.796	−0.690*	−0.971	−0.406	−0.011	−0.155	0.134	−1.095	−0.656	1.466
Eggs	−0.117*	−0.159	−0.075	0.043	−0.716	0.801	0.127	−0.190	0.444	−0.003	−0.029	0.024	−1.551	−1.056	0.955
Meat substitutes, nuts, pulses	0.076	−0.234	0.387	0.129	−0.214	0.472	0.338	−0.323	0.998	1.074	1.030	1.117	0.556*	0.876	1.236
Margarine and vegetable oil	−0.026	−0.058	0.006	0.265*	0.114	0.416	−0.033*	−0.058	−0.023	−0.400	−0.018	0.010	0.645*	0.289	1.001
Butter and animal fat	−0.029	−0.065	0.006	−0.365	−0.704	−0.026	0.080*	0.053	0.106	−0.900	−0.029	0.011	0.111	−0.694	0.917
Cakes, pies, biscuits	−0.077	−0.868	0.715	0.873	−0.009	1.754	0.132	−1.587	1.851	−0.008	−0.022	0.007	1.001*	0.575	1.428
Savory snacks	−0.005	−0.036	0.026	−0.266	−1.257	0.726	−0.119	−0.471	0.233	0.400	−0.026	0.034	−1.223	−1.004	−0.442
Sugar, honey, jams, chocolate	0.183	−0.508	0.874	−0.193	−1.101	0.716	0.394	−1.138	1.927	0.062*	0.023	0.101	0.117	−1.111	1.346
Sauces and creams	0.148	0.043	0.253	0.121	−0.096	0.338	0.276	0.050	0.502	−0.003	−0.006	0.001	−0.367	−0.825	0.092
Carbonated soft/isotonic drinks	0.575*	0.274	0.876	0.031	−0.494	0.555	1.506	−0.086	1.099	0.284	−0.003	0.003	0.376	0.076	0.676
Fruit and vegetable juices	−0.584*	−0.319	−1.848	−0.966*	−1.606	−0.326	−0.277*	−1.278	−0.276	−0.300	−0.023	0.018	0.979*	1.661	1.296

%TE, energy adjusted per total intake percentage; β, regression coefficient; CI, confidence interval.
Adjusted for confounders: Age, sex, maternal education, body mass index, and using country as level. Boldface values indicate significance accepted after Holm−Bonferroni adjustment method.
*Significant results.

Table 4
Association between portion size from various food groups and energy-adjusted intake of macro- and micronutrients using multiple linear regression model: Vitamins (A, D, E, C, and B12)

Food groups, g	Vitamin A, mg/10 MJ			Vitamin D, μg/10 MJ			Vitamin E, mg/10 MJ			Vitamin C, mg/10 MJ			Vitamin B12, mg/10 MJ		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI		β	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Bread and rolls	−0.013	−0.025	−0.001	0.677*	0.433	0.920	0.941	0.267	1.615	0.484	−0.002	0.970	0.961	−1.250	1.172
Breakfast cereals	0.001*	−0.011	0.003	0.888	−0.404	−1.372	−0.021	−0.305	0.264	−0.016	−0.081	0.049	0.680	−0.369	1.728
Rice and other grains	0.004	0.000	0.009	−0.291	−0.958	1.679	−1.537	−1.649	−0.414	−0.027	−0.215	0.161	−0.121	−1.088	−0.155
Starch roots, potatoes	−0.745	−0.001	0.000	−1.764	−0.106	1.577	0.781*	0.369	1.193	−0.598*	−0.833	−0.362	0.367	−1.061	1.794
Pasta	−0.005	−0.016	0.007	0.544	−0.237	1.325	1.625	−1.953	0.203	0.776	0.190	1.363	1.156	0.402	1.909
Fruit	−0.001	−0.003	0.000	1.746	−1.194	1.686	1.328	0.277	1.378	0.038	−0.004	0.080	−1.971	−1.855	1.912
Vegetables	0.151*	0.000	0.000	−0.911	−1.332	−0.489	0.089	−0.029	0.207	0.010*	0.017	1.102	−1.286*	−1.007	−0.565
Milk, yoghurt, and milk beverages	−0.001	−0.003	0.002	0.207*	0.306	1.108	−0.184	−1.115	0.746	−0.113	−0.248	0.022	1.303*	0.352	1.254
Desserts and puddings (milk-based)	−0.001	−0.006	0.003	0.421*	0.199	0.643	0.083	−0.555	0.72	−0.130	−0.392	0.131	−0.383	−1.222	0.456
Cheese	0.002	0.000	0.003	0.275	−0.826	1.376	0.304	0.082	0.527	0.019	−0.008	0.046	0.813*	0.943	1.682
Meat and poultry	0.003	−0.001	0.006	−0.582	−0.791	1.627	1.014*	0.328	1.701	0.076	−0.079	0.232	0.042*	0.444	1.639
Fish	−0.003	−0.010	0.004	−0.035	−0.189	0.119	−0.478	−0.843	−0.114	0.032	−0.644	0.708	−0.164	−0.473	0.146
Eggs	−0.003	−0.008	0.002	−0.685	−1.468	1.098	−0.596*	−0.991	−0.201	0.051	−0.218	0.32	1.272	−0.982	0.527
Meat substitutes, nuts, pulses	−0.003*	−0.004	−0.001	−0.699	−1.134	0.735	−0.220	−0.185	0.141	0.053	−0.095	0.202	−0.820	−1.278	1.638
Margarine and vegetable oil	−0.653	0.000	0.000	0.252	−0.088	0.593	0.014	−0.035	0.063	0.026	−0.001	0.053	−0.958	−1.891	−0.025
Butter and animal fat	0.000	−0.001	0.002	0.754	−0.215	1.722	−0.201	−0.343	−0.059	0.026	−0.129	0.181	−0.445	−2.537	1.648
Cakes, pies, biscuits	0.455	0.000	0.001	0.828	−1.983	3.639	−0.184	−0.414	0.046	−0.134	−0.280	0.013	3.110	−0.233	6.460
Savory snacks	0.320	0.009	0.055	−1.271	−0.139	−0.403	0.693*	0.230	1.157	0.673	0.060	1.285	1.096	−1.289	1.482
Sugar, honey, jams, chocolate	−0.800	−0.022	0.006	1.909	1.866	1.952	−0.265	−0.595	0.065	0.075	−0.007	0.156	−1.060	−1.441	−0.677
Sauces and creams	0.001*	0.001	0.002	0.949*	1.636	1.262	−0.032	−0.104	0.040	0.009	−0.046	0.064	0.299	−0.495	1.093
Carbonated soft/isotonic drinks	0.006	0.001	0.012	−1.692	−1.752	1.368	−0.349	−1.723	1.025	−0.009	−0.064	0.046	0.312	−1.790	1.413
Fruit and vegetable juices	−0.003*	−0.004	−0.001	1.271	−0.604	2.146	−1.453*	−1.961	−0.945	0.279*	0.452	1.105	1.857	−1.117	1.831

β, regression coefficient; CI, confidence interval.
Adjusted for confounders: Age, sex, maternal education, body mass index, and using country as level. Boldface values indicate significance accepted after Holm−Bonferroni adjustment method.
*Significant results.

Table 5
Association between portion size from various food groups and energy-adjusted intake of macro- and micronutrients using multiple linear regression model: Minerals (calcium, iron, sodium, potassium, and zinc)

Food groups, g	Calcium, mg/10 MJ			Iron, mg/10 MJ			Sodium, mg/10 MJ			Potassium, mg/10 MJ			Zinc, mg/10 MJ		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI		β	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Bread and rolls	0.002	−0.026	0.031	−0.191	−0.646	0.736	−0.024*	−0.031	−0.016	−0.003	−0.039	0.033	0.060*	0.194	1.127
Breakfast cereals	0.037	0.008	0.067	0.443*	0.169	1.317	−0.006*	−0.011	0.000	−0.001	−0.018	0.016	0.000	−0.002	0.002
Rice and other grains	0.053	0.000	0.106	0.904*	0.134	1.674	−0.009	−0.023	0.004	−0.063*	−0.089	−0.037	−0.009*	−0.013	−0.005
Starch roots, potatoes	0.105*	0.064	0.146	−1.943*	−0.928	−1.958	0.000	−0.006	0.006	0.011	−0.002	0.025	0.005	−0.001	0.011
Pasta	−0.031	−0.124	0.061	1.322	−1.088	0.731	−0.038	−0.065	−0.012	−0.134	−0.250	−0.018	−0.004	−0.013	0.005
Fruit	0.003	−0.047	0.053	−1.722	−0.079	1.636	0.164	−0.044	0.371	0.007	−0.004	0.018	−0.002	−0.008	0.004
Vegetables	−0.009	−0.017	−0.001	0.955*	0.532	1.377	0.001	−0.001	0.003	0.000	−0.001	0.001	−0.001	−0.003	0.000
Milk, yoghurt, and milk beverages	0.015*	0.010	0.021	−1.637	−0.666	−1.608	0.001	−0.009	0.011	0.038*	0.029	0.047	−0.003	−0.010	0.003
Desserts and puddings (milk-based)	−0.023	−0.042	−0.004	−0.468	−1.642	1.706	−0.018*	−0.029	−0.007	0.003	−0.012	0.018	0.004	0.000	0.008
Cheese	0.000	−0.002	0.002	−0.973	−1.045	−0.902	0.000	−0.001	0.001	−0.004	−0.008	0.000	0.001	0.002	1.001
Meat and poultry	−0.003	−0.042	0.037	0.665	0.877*	1.452	−0.009*	−0.011	−0.007	0.023*	0.009	0.037	0.003*	0.005	1.002
Fish	0.020	−0.023	0.063	1.060	−0.283	1.395	0.002	−0.002	0.005	−0.011	−0.025	0.004	−0.002	−0.004	−0.001
Eggs	0.010	−0.012	0.032	0.720	0.387*	1.058	0.005	−0.003	0.013	0.004	−0.017	0.025	0.004*	0.006	1.001
Meat substitutes, nuts, pulses	−0.110	−0.029	0.007	0.254	−1.014	1.522	0.000	−0.001	0.001	0.009	0.003	0.015	−0.001	−0.003	0.001
Margarine and vegetable oil	0.000	0.000	0.021	0.281	−0.427	0.988	−0.712	−0.002	0.002	−0.008*	−0.012	−0.004	−0.002*	−0.003	−0.001
Butter and animal fat	−0.002	−0.013	0.008	0.400	−1.413	1.692	0.200	−0.002	0.005	−0.002	−0.009	0.004	0.002	0.000	0.004
Cakes, pies, biscuits	0.300	−0.015	0.021	−0.355	−0.833	0.122	−0.001	−0.005	0.003	0.011	−0.001	0.023	−0.600*	−0.010	−0.002
Savory snacks	0.023	−0.031	0.076	0.890	1.152	1.571	0.100	−0.004	0.006	−0.026	−0.053	0.001	−0.006	−0.020	0.007
Sugar, honey, jams, chocolate	0.900	−0.034	0.052	−1.917	−0.351*	−1.483	0.001	−0.003	0.004	0.004	−0.025	0.032	1.120	−0.008	1.016
Sauces and creams	0.006	0.000	0.012	0.984	0.480*	1.488	−0.001	−0.001	0.000	−0.002	−0.004	0.001	0.000	−0.001	0.001
Carbonated soft/isotonic drinks	−0.021	−0.055	0.012	0.932	−0.635	2.500	0.001	−0.009	0.011	−0.025*	−0.040	−0.010	0.003	0.001	0.005
Fruit and vegetable juices	0.076	−0.034	0.186	0.799	0.479	1.120	0.039	0.010	0.067	0.009	−0.013	0.031	−0.009	−0.016	−0.002

β, regression coefficient; CI, confidence interval.
Adjusted for confounders: Age, sex, maternal education, body mass index, and using country as level. Boldface values indicate significance accepted after Holm−Bonferroni adjustment method.
*Significant results.

associated with a higher potassium intake. Zinc consumption increased with larger portions of bread and rolls, meat and poultry, and eggs.

Discussion

The present study describes the associations between food PSs and intake of energy, as well as macro- and micronutrients, in adolescents. Previous HELENA and other European studies found that carbohydrate and fat intake were similar to those of the European food-based dietary guidelines [30], but protein intake was twice as high [27,31]. The findings of our study are in line with those of the current dietary guidelines by the WHO [32] and the European food-based dietary guidelines [30], which recommend choosing cereals, roots, fruit and vegetables, nuts and seeds, and dairy products as a principal source for carbohydrates intake. These food groups have higher fiber (except dairy) content, and are considered low carbohydrate-content food and low glycemic index, in addition to having higher water content [30,32].

In our study, we found that protein intake increased when PSs of fish, as well as meat substitutes, nuts, and pulses, increased. These food groups are considered a good source of protein [33]. Of note, large portions of cakes, pies, and biscuits, as well as sauces and creams, were associated with a higher protein intake due to the contents of milk, cheese, eggs, and sometimes nuts in their ingredients. Moreover, we found that protein intake decreased when large portions of rice and starch roots, fruit, margarine and vegetable oil, and butter and animal fat were consumed. In general, animal protein has high saturated fat and cholesterol content, but plant protein sources are high in fiber and carbohydrates [34]. Therefore, the increase in protein consumption was influenced by the specific protein food source, resulting in different macro- and micronutrient contents [35].

Lower intakes of fat were observed when larger portions of dessert and pudding; margarine and vegetable oil; sugar, honey, jam; and fruit and vegetable juice were consumed. A possible explanation for this finding is the sugar−fat see-saw phenomenon (i.e., when energy percentages from sugar intakes increase, fat intakes decrease) [36]. Of note, the findings of this study support the current dietary guidelines from the WHO [32] and the European food-based dietary guidelines [30], which recommend replacing butter, lard, and ghee with oils rich in polyunsaturated fatty acid, in addition to limiting the consumption of baked and prepackaged snacks and foods, such as cakes, pies, cookies, and biscuits that contain high trans-fat [37]. The importance of this dietary guidance must be taken into account carefully, because the reduction of energy coming from saturated fat (mainly trans-fat and sugar) may be difficult to achieve in children and adolescents due to inappropriate dietary habits [38,39].

Previous studies found that European adolescents had lower dietary fiber intake compared with the WHO recommendation of 25 g/d, mainly due to high intakes from animal sources [40,41]. The present study showed that dietary fiber intakes decreased with increasing PSs of bread and rolls, suggesting that the consumed foods within this category were not whole grain, unlike what European public health authorities [30] recommend (i.e., choose whole grain breads, pulses, and nuts for digestive health), which is in line with our findings.

In our study, we found that large portions of margarine and vegetable oil, as well as butter and animal fat, were associated with lower intakes of several vitamins, such as vitamins C and B12, and minerals, such as calcium, iron, potassium, and zinc. One possible explanation is that when fat content increases, water-soluble vitamin content (including niacin, folate, and vitamins B12 and C) decreased, as well as minerals (e.g., iron, and potassium) [42]. In addition, fat and oil itself are not a source of these nutrients, but only a source of fatty acids and vitamin E [43]. Of note, low consumption of energy-dense foods has been found to be associated with better nutritional quality of a diet, including higher intakes of fiber and micronutrients, in addition to a better balance of macronutrients [44].

A U.S. dietary survey of children and adolescents noted an association between some dietary sources of sugar with intakes of folate, calcium, and iron, as well as that the source of added sugars resulted in different dietary patterns [45,46]. For example, iron intakes decreased when more sweets, sugar-sweetened beverages, and sweetened grains products were consumed, and increased with higher intakes of nonsweetened cereals. In our study, large portions of meat substitutes, nuts, and pulses were associated with higher intakes of iron, potassium, and zinc. As expected and given the nutritional composition of this food group, their higher level of protein, fiber, folate, iron, potassium, and zinc could help address some dietary shortness that affects developed and developing countries [47]. Of note, plant proteins and plant-based meat alternatives have been in the top 10 global food trends since 2014. Obtaining a greater proportion of protein intake from plant sources, such as nuts, whole grains, and legumes, in addition to unsaturated plant oils, could help address some current health and environmental challenges [48].

The same results as those in our study have been found in Irish children and adolescents. Their vitamin D intake increased when large portions of cheese were consumed, but iron intakes were significantly increased on days that larger portions of baked beans were eaten [7]. Of note, when dietary energy-dense food consumption in children and adolescents increased, intakes of vitamins A, C, D, and B12, as well as folate, riboflavin, calcium, potassium, zinc, sodium, and iron, were decreased [44].

Among the possible explanation of our results is food displacement. For instance, adolescents who consumed large portions of dessert and puddings had decreased intakes of many macro- and micronutrients on days these portions were consumed. Dessert and puddings cannot be responsible for decreased micronutrient intake per se, but possibly the consumption of large portions from this food group displaced other, more nutrient-dense, snacks, such as fruit or vegetables, from the diet on those days. Moreover, larger food PSs may be associated with the increased intake of a nutrient as a consequence of the composition of the food itself. For example, larger portions of cheese were associated with significantly increased vitamin D intakes on days they were consumed. Finally, food fortification or enrichments may play an important role in increasing the intake of special nutrients, such as increasing vitamin D intake when large portions of bread and rolls were consumed.

The current analysis has several strength points. First, the data are based on two 24-h recalls of food intake that were collected from a wide geographic spread with large cultural dietary diversity. To our knowledge the work is novel for its focus on examining a wide range of foods rather than just energy-dense foods, which are typically more involved in discussions on food PS. The main limitation of the current work is that self-reported questionnaires were used to collect the food consumption data; therefore, a recall bias must be considered. Moreover, a high percentage of under- and overreporters were detected, and the exclusion could have introduced a secondary selection bias to this work. The intake data for vitamin D are difficult to assess, because of the high amount of fortified foods that was not included in the food databases, in addition to skin production from sunlight exposure.

Conclusions

The present study describes the association between food PS and nutrient intake in adolescents on days the foods were consumed. Large food PSs may be associated with positive energy and nutrient intake. Large portions of rice and other grains, starch roots and potatoes, and meat substitutes, nuts, and pulses were associated with increased carbohydrate and fiber intake. Larger portions of cheese and butter and animal fat were significantly associated with a higher fat intake. Lower intakes of some vitamins and micronutrients were noted when larger portions of high energy-dense foods, such as desserts and pudding, margarine and vegetable oil, and butter and animal fat, were consumed. The present work identifies which large food PSs may be associated with positive nutrient intake. Moreover, the findings from this study may help the future development of dietary guidance in general and specific to PS, and support targeted strategies to address the intake of certain nutrients in adolescents.

Acknowledgements

The authors are grateful for the support provided by school boards, headmasters, teachers, school staff, and communities, and the efforts of all study nurses and data managers. The HELENA Study Group consists of Luis A. Moreno (coordinator); Luis A. Moreno, Fréderic Gottrand, Stefaan De Henauw, Marcela González-Gross, Chantal Gilbert (core group members); Anthony Kafatos (President), Luis A. Moreno, Christian Libersa, Stefaan De Henauw, Sara Castelló, Fréderic Gottrand, Mathilde Kersting, Michael Sjöstrom, Dénes Molnár, Marcela González-Gross, Jean Dallongeville, Chantal Gilbert, Gunnar Hall, Lea Maes, Luca Scalfi (steering committee); and Pilar Meléndez (project manager). From the Universidad de Zaragoza (Spain): Luis A. Moreno, José A. Casajús, Jesús Fleta, Gerardo Rodríguez, Concepción Tomás, María I. Mesana, Germán Vicente-Rodríguez, Adoración Villarroya, Carlos M. Gil, Ignacio Ara, Juan Fernández Alvira, Gloria Bueno, Olga Bueno, Juan F. León, Jesús Mª Garagorri, Idoia Labayen, Iris Iglesia, Silvia Bel, Luis A. Gracia Marco, Theodora Mouratidou, Alba Santaliestra-Pasías, Iris Iglesia, Esther González-Gil, Pilar De Miguel-Etayo, Mary Miguel-Berges, Isabel Iguacel, and Azahara Rupérez. From the Consejo Superior de Investigaciones Científicas in Spain: Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez, Ligia Esperanza Díaz, Javier Romeo, Ana Veses, Belén Zapatera, Tamara Pozo, and David Martínez. From the Université de Lille 2 in France: Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, and Juliana Von Berlepsch. From the Research Institute of Child Nutrition Dortmund, Rheinische Friedrich–Wilhelms–Universität Bonn in Germany: Mathilde Kersting, Wolfgang Sichert-Hellert, and Ellen Koeppen. From Pécsi Tudományegyetem, University of Pécs, in Hungary: Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs. Angster, Enikö Nagy, Orsolya Kovács, and Judit Répasi. From the University of Crete School of Medicine in Greece: Anthony Kafatos, Caroline Codrington, María Plada, Angeliki Papadaki, Katerina Sarri, Anna Viskadourou, Christos Hatzis, Michael Kiriakakis, George Tsibinos, Constantine Vardavas, Manolis Sbokos, Eva Protoyeraki, and Maria Fasoulaki. From the Institut für Ernährungs- und Lebensmittelwissenschaften–Ernährungphysiologie. Rheinische Friedrich Wilhelms Universität in Germany: Peter Stehle, Klaus Pietrzik, Marcela González-Gross, Christina Breidenassel, Andre Spinneker, Jasmin Al-Tahan, Miriam Segoviano, Anke Berchtold, Christine Bierschbach, Erika Blatzheim, Adelheid Schuch, and Petra Pickert. From the University of Granada in Spain: Manuel J. Castillo, Ángel Gutiérrez, Francisco B Ortega, Jonatan R Ruiz, Enrique G Artero, Vanesa España, David Jiménez-Pavón, Palma Chillón, Cristóbal Sánchez-Muñoz, and Magdalena Cuenca. From the Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione in Italy: Davide Arcella, Elena Azzini, Emma Barrison, Noemi Bevilacqua, Pasquale Buonocore, Giovina Catasta, Laura Censi, Donatella Ciarapica, Paola D'Acapito, Marika Ferrari, Myriam Galfo, Cinzia Le Donne, Catherine Leclercq, Giuseppe Maiani, Beatrice Mauro, Lorenza Mistura, Antonella Pasquali, Raffaela Piccinelli, Angela Polito, Romana Roccaldo, Raffaella Spada, Stefania Sette, and Maria Zaccaria. From the University of Napoli “Federico II” Department of Food Science in Italy: Luca Scalfi, Paola Vitaglione, and Concetta Montagnese. From Ghent University in Belgium: Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere, and Inge Huybrechts. From the Medical University of Vienna in Austria: Kurt Widhalm, Katharina Phillipp, Sabine Dietrich, Birgit Kubelka, and Marion Boriss-Riedl. From Harokopio University in Greece: Yannis Manios, Eva Grammatikaki, Zoi Bouloubasi, Tina Louisa Cook, Sofia Eleutheriou, Orsalia Consta, George Moschonis, Ioanna Katsaroli, George Kraniou, Stalo Papoutsou, Despoina Keke, Ioanna Petraki, Elena Bellou, Sofia Tanagra, Kostalenia Kallianoti, Dionysia Argyropoulou, Stamatoula Tsikrika, and Christos Karaiskos. From the Institut Pasteur de Lille in France: Jean Dallongeville and Aline Meirhaeghe. From the Karolinska Institutet in Sweden: Michael Sjöstrom, Jonatan R Ruiz, Francisco B. Ortega, María Hagströmer, Anita Hurtig Wennlöf, Lena Hallström, Emma Patterson, Lydia Kwak, Julia Wärnberg, and Nico Rizzo. From the Asociación de Investigación de la Industria Agroalimentaria in Spain: Jackie Sánchez-Molero, Sara Castelló, Elena Picó, Maite Navarro, Blanca Viadel, José Enrique Carreres, Gema Merino, Rosa Sanjuán, María Lorente, and María José Sánchez. From Campden BRI in the United Kingdom: Chantal Gilbert, Sarah Thomas, Elaine Allchurch, and Peter Burgess. From SIK, Institutet foer Livsmedel och Bioteknik in Sweden: Gunnar Hall, Annika Astrom, Anna Sverkén, and Agneta Broberg. From Meurice Recherche & Development asbl in Belgium: Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, and Laurence Fontaine. From the Campden & Chorleywood Food Development Institute in Hungary: Andras Sebok, Tunde Kuti, and Adrienn Hegyi. From Productos Aditivos SA in Spain: Cristina Maldonado and Ana Llorente. From Cárnicas Serrano SL in Spain: Emilio García. From Cederroth International AB in Sweden: Holger von Fircks, Marianne Lilja Hallberg, and Maria Messerer. From Lantmännen Food R&D in Sweden: Mats Larsson, Helena Fredriksson, Viola Adamsson, and Ingmar Börjesson. From the European Food Information Council in Belgium: Laura Fernández, Laura Smillie, and Josephine Wills. From the Universidad Politécnica de Madrid in Spain: Marcela González-Gross, Raquel Pedrero-Chamizo, Agustín Meléndez, Jara Valtueña, David Jiménez-Pavón, Ulrike Albers, Pedro J. Benito, Juan José Gómez Lorente, David Cañada, Alejandro Urzanqui, Rosa María Torres, and Paloma Navarro.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nut.2022.111893.

References

[1] Gale C, O'Callaghan F, Godfrey K, Law CM, Martyn CN. Critical periods of brain growth and cognitive function in children. Brain 2004;127:321–9.
[2] Lassi Z, Moin A, Bhutta Z. Nutrition in middle childhood and adolescence. In: Bundy DAP, de Silva N, Horton S, Jamison DT, Patton GC, editors. Child and adolescent health and development, 3rd ed., Washington (DC): The International Bank for Reconstruction and Development/The World Bank; 2017.
[3] World Health Organization. European food and nutrition action plan 2015−2020. Available at: https://www.euro.who.int/en/publications/abstracts/european-food-and-nutrition-action-plan-20152020−2014. Accessed June 2021.
[4] Kearney J. Food consumption trends and drivers. Philos Trans R Soc Lond B Biol Sci 2010;365:2793–807.
[5] Albar SA, Alwan NA, Evans CE, Cade JE. Is there an association between food portion size and BMI among British adolescents? Br J Nutr 2014;112:841–51.
[6] Flieh S, González Gil E, Miguel-Berges M, Moreno Aznar LA. Food portion sizes, obesity, and related metabolic complications in children and adolescents. Nutr Hosp 2021;38:169–76.
[7] Lyons J, Walton J, Flynn A. Food portion sizes and dietary quality in Irish children and adolescents. Public Health Nutr 2015;18:1444–52.
[8] Rippin H, Hutchinson J, Jewell J, Breda JJ, Cade JE. Child and adolescent nutrient intakes from current national dietary surveys of European populations. Nutr Res Rev 2019;32:38–69.
[9] Fernández Fernández E, Martínez Hernández J, Martínez Suárez V, Moreno Villares JM, Collado Yurrita LR, Hernández Cabria M, et al. Consensus document: Nutritional and metabolic importance of cow's milk. Nutr Hosp 2014;31:92–101.
[10] Holick M. Vitamin D deficiency. N Engl J Med 2007;357:266–81.
[11] Geleijnse J, Grobbee D, Hofman A. Sodium and potassium intake and blood pressure change in childhood. BMJ 1990;300:899–902.
[12] Novaković R, Cavelaars AEJM, Bekkering GE, Roman-Viñas B, Ngo J, Gurinović M, et al. Micronutrient intake and status in Central and Eastern Europe compared with other European countries, results from the EURRECA network. Public Health Nutr 2013;16:824–40.
[13] Rippin H, Hutchinson J, Evans C, Jewell J, Breda JJ, Cade JE. National nutrition surveys in Europe: A review on the current status in the 53 countries of the WHO European region. Food Nutr Res 2018;62:1362.
[14] Flieh S, Miguel-Berges M, González-Gil E, Gottrand F, Censi L, Widhalm K, et al. The association between portion sizes from high-energy dense foods and body composition in European adolescents: The HELENA study. Nutrients 2021;13:954.
[15] Moreno L, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L, et al. Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. Public Health Nutr 2008;11:288–99.
[16] de Henauw S, Gottrand F, Bourdeaudhuij ID, González-Gross M, Leclercq C, Kafatos A, et al. Nutritional status and lifestyles of adolescents from a public health perspective. The HELENA Project—Healthy Lifestyle in Europe by Nutrition in Adolescence. J Public Health 2007;15:187–97.
[17] Béghin L, Castera M, Manios Y, Gilbert CC, Kersting M, de Henauw S, et al. Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA cross-sectional study. Int J Obes (Lond) 2008;32:S12–8.
[18] Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 1991;45:569–81.
[19] United Nations Educational, Scientific and Cultural Organization. International standard classification of education. Available at: http://www.uis.unesco.org/Education/Documents/isced-2011-en.pdf. Accessed April 2, 2021.
[20] Vereecken CA, Covents M, Sichert-Hellert W, Alvira JMF, Le Donne C, De Henauw S, et al. Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. Int J Obes (Lond) 2008;32:S26–34.
[21] Julián-Almárcegui C, Bel-Serrat S, Kersting M, Vicente-Rodriguez G, Nicolas G, Vyncke K, et al. Comparison of different approaches to calculate nutrient intakes based upon 24-h recall data derived from a multicenter study in European adolescents. Eur J Nutr 2016;55:537–45.
[22] Haubrock J, Harttig U, Souverein O, Boeing H. An improved statistical tool for estimating usual intake distributions: The multiple source method (MSM). Arch Public Health 2010;68:S15–6.
[23] Harttig U, Haubrock J, Knüppel S, Consortium EFCOVAL. The MSM program: Web-based statistics package for estimating usual dietary intake using the Multiple Source Method. European J Clin Nutr 2011;65:S87–91.
[24] Lioret S, Volatier JL, Lafay L, Touvier M, Maire B. Is food portion size a risk factor of childhood overweight? Eur J Clin Nutr 2009;63:382–91.
[25] Pereira J, Mendes A, Crispim S, Marchioni DM, Fisberg RM. Association of overweight with food portion size among adults of São Paulo−Brazil. PloS One 2016;11:e0164127.
[26] Ireland J, van Erp-Baart A, Charrondière U, Møller A, Smithers G, Trichopoulou A, et al. Selection of a food classification system and a food composition database for future food consumption surveys. Eur J Clin Nutr 2002;56. S33−45.
[27] Diethelm K, Huybrechts I, Moreno L, De Henauw S, Manios Y, Beghin L, et al. Nutrient intake of European adolescents: Results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. Public Health Nutr 2014;17:486–97.
[28] Lyons J, Walton J, Flynn A. Larger food portion sizes are associated with both positive and negative markers of dietary quality in Irish adults. Nutrients 2018;10:1929.
[29] Joyce T, Wallace A, McCarthy S, Gibney MJ. Intakes of total fat, saturated, monounsaturated and polyunsaturated fatty acids in Irish children, teenagers and adults. Public Health Nutr 2009;12:156–65.
[30] Knowledge for Policy. References to food-based dietary guidelines in Europe. Available at: https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/references-food-based-dietary-guidelines-europe_en. Accessed May 22, 2021.

[31] Elmadfa I, Meyer A, Nowak V, Hasenegger V, Putz P, Verstraeten R, et al. European nutrition and health report 2009. Forum Nutr 2009;62:1–405.
[32] World Health Organization. Health diet. Available at: https://www.who.int/news-room/fact-sheets/detail/healthy-diet. Accessed May, 22, 2021.
[33] Pimpin L, Jebb S, Johnson L, Llewellyn C, Ambrosini GL. Sources and pattern of protein intake and risk of overweight or obesity in young UK twins. Br J Nutr 2018;120:820–9.
[34] Mariotti F. Animal and plant protein sources and cardiometabolic health. Adv Nutr 2019;10:S351–66.
[35] Richter C, Skulas-Ray A, Champagne C, Kris-Etherton PM. Plant protein and animal proteins: Do they differentially affect cardiovascular disease risk? Adv Nutr 2015;6:712–28.
[36] Sadler M, McNulty H, Gibson S. Sugar-fat seesaw: A systematic review of the evidence. Crit Rev Food Sci Nutr 2015;55:338–56.
[37] World Health Organization, Regional Office for Europe. Eliminating trans fats in Europe−A policy brief. Available at: https://www.euro.who.int/__data/assets/pdf_file/0010/288442/Eliminating-trans-fats-in-Europe-A-policy-brief.pdf. Accessed May 25, 2021.
[38] Øverby N, Lillegaard I, Johansson L, Andersen LF. High intake of added sugar among Norwegian children and adolescents. Public Health Nutr 2004;7:285–93.
[39] Rugg-Gunn AJ, Hackett AF, Jenkins GN, Appleton DR. Empty calories? Nutrient intake in relation to sugar intake in English adolescents. J Human Nutr Diet 1991;4:101–11.
[40] Cruz JA. Dietary habits and nutritional status in adolescents over Europe−Southern Europe. Eur J Clin Nutr 2000;54:S29–35.
[41] Lin Y, Huybrechts I, Vereecken C, Mouratidou T, Valtueña J, Kersting M, et al. Dietary fiber intake and its association with indicators of adiposity and serum biomarkers in European adolescents: The HELENA study. Eur J Nutr 2015;54:771–82.
[42] Tonstad S, Sivertsen M. Relation between dietary fat and energy and micronutrient intakes. Arch Dis Child 1997;76:416–20.
[43] Herting D, Drury E. Vitamin E content of vegetable oils and fats. J Nutr 1963;81:335–42.
[44] O'Connor L, Walton J, Flynn A. Dietary energy density and its association with the nutritional quality of the diet of children and teenagers. J Nutr Sci 2013;2:e10.
[45] Frary C, Johnson R, Wang M. Children and adolescents' choices of foods and beverages high in added sugars are associated with intakes of key nutrients and food groups. J Adolesc Health 2004;34:56–63.
[46] Fulgoni VL 3rd, Gaine PC, Scott MO, Ricciuto L, DiFrancesco L. Association of added sugars intake with micronutrient adequacy in U.S. children and adolescents: NHANES 2009−2014. Curr Dev Nutr 2019;3:nzz126.
[47] Marinangeli C, Curran J, Barr S, Slavin J, Puri S, Swaminathan S, et al. Enhancing nutrition with pulses: Defining a recommended serving size for adults. Nutr Rev 2017;75:990–1006.
[48] Madeline E, Jaimee H, Sara G. Plant protein and plant-based meat alternatives: Consumer and nutrition professional attitudes and perceptions. Sustainability 2021;13:1478.