Public Health Nutrition: 17(3), 486–497 doi:10.1017/S1368980013000463

Nutrient intake of European adolescents: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

Katharina Diethelm[1,*], Inge Huybrechts[2], Luis Moreno[3], Stefaan De Henauw[2,4], Yannis Manios[5], Laurent Beghin[6,7], Marcela González-Gross[8], Cinzia Le Donne[9], Magdalena Cuenca-García[10], Manuel J Castillo[10], Kurt Widhalm[11], Emma Patterson[12,13] and Mathilde Kersting[1]

[1]Research Institute of Child Nutrition, Rheinische Friedrich-Wilhelms-University Bonn, Heinstueck 11, 44225 Dortmund, Germany: [2]Department of Public Health, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium: [3]Escuela Universitaria de Ciencias de la Salud, Universidad de Zaragoza, Zaragoza, Spain: [4]Department of Health Sciences, Vesalius Hogeschool Gent, Ghent, Belgium: [5]Department of Nutrition and Dietetics, Harokopio University, Athens, Greece: [6]Centre d'Investigation Clinique de Lille, Lille, France: [7]Unité Inserm U995 & Université Lille Nord de France, Lille, France: [8]ImFINE Research Group, Department of Health and Human Performance, Faculty of Physical Activity and Sport Sciences – INEF, Technical University of Madrid, Madrid, Spain: [9]National Research Institute on Food and Nutrition, Rome, Italy: [10]Department of Medical Physiology, School of Medicine, University of Granada, Granada, Spain: [11]Academic Institute for Clinical Nutrition, Vienna, Austria: [12]Unit for Preventive Nutrition, Department of Biosciences and Nutrition, Karolinska Institute, Stockholm, Sweden: [13]Division of Social Medicine, Department of Public Health Sciences, Karolinska Institute, Stockholm, Sweden

Submitted 13 August 2012: Final revision received 9 January 2013: Accepted 22 January 2013: First published online 8 March 2013

Abstract

Objective: An adequate nutritional intake in childhood and adolescence is crucial for growth and the prevention of youth and adult obesity and nutrition-related morbidities. Improving nutrient intake in children and adolescents is of public health importance. The purpose of the present study was to describe and evaluate the nutrient intake in a European sample using the D-A-CH nutrient intake recommendations and the Nutritional Quality Index (NQI).

Design: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study is a cross-sectional study, the main objective of which is to obtain comparable data on a variety of nutritional and health-related parameters in adolescents aged 12·5–17·5 years.

Setting: Eight cities in Europe.

Subjects: The initial sample consisted of 3528 European adolescents. Among these, 1590 adolescents (54 % female) had sufficient and plausible dietary data on energy and nutrient intakes from two 24 h recalls using the HELENA-DIAT software.

Results: The intakes of most macronutrients, vitamins and minerals were in line with the D-A-CH recommendations. While the intakes of SFA and salt were too high, the intake of PUFA was too low. Furthermore, the intakes of vitamin D, folate, iodine and F were less than about 55 % of the recommendations. The median NQI was about 71 (of a maximum of 100).

Conclusions: The intakes of most nutrients were adequate. However, further studies using suitable criteria to assess nutrient status are needed. Public health initiatives should educate children and adolescents regarding balanced food choices.

Keywords
Nutrient intake
Europe
Adolescents
HELENA Study

There is recent evidence that adequate nutritional intake by children and adolescents is associated with a lower risk of youth(1,2) and adult obesity(3) as well as of subsequent nutrition-related morbidities in adulthood such as CVD(4,5), several cancers(6,7) and type 2 diabetes(8,9).

Adolescents experience pubertal hormonal changes regulating appetite, satiety and body fat distribution(10) and increasingly assert independence from their parents, all of which may affect their eating behaviour(11). Thus adolescence is a critical period(12,13) in which poor dietary practices may constitute an increased risk for several adult chronic diseases(8). Furthermore, dietary habits which have been established in childhood or adolescence may track into adult life(14). Improving the nutritional intake of children and adolescents is therefore a goal for global public health(15,16).

*Corresponding author: Email diethelm@fke-do.de

Several surveys have been conducted on the nutritional intake of European adolescents; however, they have mostly been conducted on national, regional or in non-representative samples[17–20]. For instance, compared with nutrient intake recommendations, the average intake of sucrose was higher and the average intakes of fibre, Fe, folate and vitamin D were lower in 14-year-old Finnish adolescents[17]. German adolescents aged 11–19 years had a slightly higher proportion of energy intake from fat, while the intakes of micronutrients were in line with the recommendations, except for folate, Fe and Ca in girls[18]. In 10- to 18-year-old Italian teenagers and 6- to 7-year-old Spanish pupils, the proportion of energy from fat was higher than recommended and the proportion from carbohydrates was lower[20,21]. Both the Italian and the Spanish adolescents met the recommended intakes for micronutrients[20,21].

However, these surveys differ in methodology, population groups and age categories, and thus the available information is insufficient for a comprehensive conclusion about the nutritional status of adolescents at a pan-European level[22]. The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) Cross-Sectional Study (HELENA-CSS) gathered, for the first time, representative data about the health and nutritional status of a large sample of adolescents across European countries assessed with standardized, harmonized and validated instruments and procedures.

The purpose of the present analysis was to describe and evaluate the nutritional intake by means of the recommendations of the nutrition societies of Germany, Austria and Switzerland (D-A-CH)[23], which are based on a public health-oriented concept and set recommended intakes at a level intended to prevent nutrient-specific deficiency symptoms, but also achieve optimal nutrition and avoid oversupply with energy or certain nutrients[24]. In a further step, the nutrient intake data of the European adolescents were condensed to a single parameter, the Nutritional Quality Index (NQI), to assess overall diet quality[25]. The NQI was constructed on the basis of nutritional recommendations as evaluation criteria[26] and was used as a summary measure of the degree to which the adolescents' diet conformed to the D-A-CH recommendations.

Methods

Study design and sample

The HELENA-CSS was conducted between 2006 and 2007 in ten European cities (Athens, Heraklion (Greece), Dortmund (Germany), Ghent (Belgium), Lille (France), Pecs (Hungary), Rome (Italy), Stockholm (Sweden), Vienna (Austria) and Zaragoza (Spain)). Detailed information about the study has been reported elsewhere[27,28]. The main objective of HELENA-CSS was to obtain reliable and comparable data on a variety of nutritional and health-related parameters in a representative sample of 3528 European adolescents (boys and girls aged 12·5–17·5 years)[28,29]. The ethical committee of each centre approved the study and signed informed consent was obtained from the adolescents as well as from the parents[30].

For the present analysis, data on nutritional intake from Heraklion and Pecs (*n* 678) could not be included because of incomplete data. Furthermore, specific inclusion criteria (complete energy and nutrient intake data on two days obtained by the HELENA-DIAT 24 h recall and data on anthropometry) were defined for the present analysis, which were fulfilled by 1804 adolescents. Finally, adolescents with plausible dietary recalls were ascertained by relating their reported total energy intake to their BMR, as described below. Hence, the cohort analysed here included 1590 adolescents (54 % female).

Dietary intake assessment

Dietary intake data were obtained using a self-administered, computerized 24 h recall, named HELENA-DIAT, which was based on the Young Adolescents' Nutrition Assessment on Computer (YANA-C)[31], a tool validated in Flemish adolescents. The basic version was improved and culturally adapted by adding national dishes to reach a European standard[32]. The dietary data collection is organized in six meal occasions, i.e. breakfast, morning snack, lunch, afternoon snack, evening meal and evening snack. The participants can select from about 400 predefined food items and are free to add non-listed foods manually. Special techniques are used to allow a detailed description and quantification of foods, e.g. pictures of portion sizes and dishes. Amounts eaten could be reported as grams or by common household measures. After a short introduction by a trained researcher, the adolescents completed the HELENA-DIAT 24 h recall during school time while a research staff member was present in the classroom to assist the adolescents if necessary. They completed the HELENA-DIAT twice on non-consecutive days within a time span of 2 weeks, to achieve information closer to habitual food intake than assessing food intake on consecutive days. The two 24 h recalls thus comprised weekdays and weekend days, but not necessarily a weekday and weekend day for each individual.

To calculate energy and nutrient intake, data of the HELENA-DIAT were linked to the German Food Code and Nutrient Database (BLS (Bundeslebensmittelschlüssel) version II·3·1, 2005)[33]. For this purpose, culture-specific composite dishes were disaggregated into their basic food components, all of which were available in the German database. In addition to energy, a total of thirty-two nutrients (macronutrients, vitamins and minerals) were assessed. The Multiple Source Method was used to adjust the intake data taking into account both between- and within-individual variability of the dietary intake[34]. However, table salt, fortified foods and supplement consumption were not assessed in HELENA-DIAT.

The daily intakes of each nutrient as well as total daily energy intake were calculated for each participant from the mean of the two 24 h recalls. Total daily energy intake was used to exclude potentially implausible recalls by comparing it with BMR estimated using the equations of Schofield[35]. Using the approach of Goldberg *et al.*[36], fifty-one (47 % male and 53 % female) adolescents were considered as under-reporters (ratio of energy intake to BMR <0·99) and 163 (61 % male and 39 % female) adolescents were considered as over-reporters (ratio of energy intake to BMR rate >2·40) and were therefore excluded from the analysis.

The purpose of the present data analysis was to comprehensively describe the nutritional intake of European adolescents and to evaluate it in the light of recommended intakes. We used the age- and sex-specific reference values for nutrient intake provided by the nutrition societies of Germany, Austria and Switzerland (D-A-CH)[23], since these recommendations provide data for all thirty-two nutrients in HELENA[24] and are used in two of the eight HELENA cities. The individual percentage achievement of the recommendations for the particular nutrients was ascertained, since the D-A-CH values do not include a specific value to compare mean intakes of groups with the recommended value.

In order to assess the overall health-related quality of dietary habits as a summary measure, Gedrich and Karg developed the Nutritional Quality Index (NQI)[26]. For this analysis we calculated two approaches of the NQI, one based on absolute values and one based on nutrient densities. The NQI is based on the proportional intake as compared with the reference values. In order to calculate the NQI, the nutrients are classified into two groups: (i) those which should not exceed the recommended level; and (ii) those which should not fall below the recommended level. Intakes that meet the corresponding reference values are rated with an intake quality score (IQS) of 100. For nutrients of the first group the exceeding portion is subtracted from 100 to form the IQS, e.g. SFA intake of 130 % of the recommendation results in an IQS of 70. For the second group the portion that is below the recommendation is subtracted from 100, e.g. a vitamin C intake of 80 % of the recommendation results in an IQS of 80. In a further step, the NQI is calculated as the harmonic mean of all IQS values for each individual. Thus, the NQI scores range from 0 to 100, with a higher score indicating better diet quality[26].

Anthropometric measurements

Measurements were performed by trained staff in a standardized way[37], with the adolescents barefoot and in underwear. Weight was measured with an electronic scale to the nearest 0·1 kg, and height was measured with a telescopic stadiometer to the nearest 0·1 cm. BMI was calculated from height and weight (kg/m^2). Sex- and age-independent BMI standard deviation scores (SDS) were calculated using *Z*-values for BMI, calculated via the LMS method by Cole *et al.*[38]. Overweight was defined according to age- and sex-standardized BMI cut-off points based on data of Cole *et al.*[38]. Skinfold thicknesses were measured three times on the left side of the body with a Holtain calliper to the nearest 0·2 mm. Body fat percentage (BF%) was calculated from triceps and subscapular skinfold thicknesses using Slaughter *et al.*'s equations[39].

Socio-economic characteristics

Socio-economic characteristics were assessed with a self-reported questionnaire[40]. The adolescents reported whether their parents were overweight (yes/no) and their parents' educational level (lower education/lower secondary or higher secondary/higher education/university degree)[41]. The familial affluence scale (FAS), previously validated[42], was used as an indicator of the adolescents' material affluence. It was based on information about family car ownership, having an own bedroom, Internet availability and computer ownership. Furthermore, migration status (born outside the country in which they lived during the study: yes/no) was assessed.

Health-related characteristics

Physical activity was assessed with the self-administered International Physical Activity Questionnaire for Adolescents (IPAQ-A) covering questions about physical activity during the last 7 d[43]. The IPAQ-A validity was tested by comparing its results with accelerometer data[44]. Total minutes per week (min/week) were computed and assigned to moderate-to-vigorous physical activity according to the guidelines for data processing[45]. Additionally, smoking status (ever smoked: yes/no) was assessed.

Nutritional knowledge characteristics

To assess the nutritional knowledge of the adolescents, a validated nutritional knowledge test was used[46]. For evaluation, the percentage of correct answers to the twenty-three multiple-choice questions was calculated.

Statistical analysis

SAS procedures (SAS statistical software package version 9·13) were used for data analysis. A *P* value <0·05 was considered statistically significant. Sample weights were applied to adjust for exclusion of study participants due to insufficient data. The sampling weight calibrates the sample so that it matches the theoretical sample with regard to sex and age group.

Differences in characteristics between included and excluded participants and NQI values between boys and girls were tested using ANOVA for normally distributed variables, Kruskal–Wallis tests for non-normally distributed variables and χ^2 tests for categorical variables. Values are presented as weighted frequencies, means and standard deviations, or medians with 25th and 75th percentiles.

Weighted intakes of nutrients by the adolescents were calculated as medians (25th and 75th percentiles). The percentage intake of the reference value was calculated and presented as medians (25th and 75th percentiles) of the respective percentages of each individual's achievement compared with the D-A-CH recommendations.

Results

The present data analysis included 731 (46 %) boys and 859 (54 %) girls. Characteristics regarding anthropometry, socio-economic status, health status and nutritional knowledge for the included and excluded participants are presented in Table 1. The included had a lower BMI-SDS, percentage of overweight and BF% (all $P < 0·0001$). Differences between the included and excluded regarding socio-economic characteristics were also statistically significant (P values <0·0001 or <0·0005) except for migration status, although percentages of parental overweight and education status as well as familial affluence were comparable. The included furthermore reported significantly less to have ever smoked ($P < 0·0001$) and significantly less physical activity ($P = 0·02$) compared with the excluded.

The weighted dietary intakes of nutrients and energy of the European boys and girls, stratified by age group, compared with the recommendations are shown in Tables 2 and 3. The fulfilment of the recommendations for both genders is additionally illustrated in Fig. 1. The recommendations for daily nutrient intake were designed to meet the nutrient requirements of nearly all healthy individuals[47], i.e. the recommended values are about 20–30 % above the average requirement[23]. Thus, we considered an intake of 75–125 % of the recommended values as acceptable.

Regarding protein, the intake was about twice as high as the recommendation, i.e. about 200 and 170 % of the nutrient reference value in boys and girls of all age groups, respectively. While cholesterol intake and fat intake in general were approximately in line with the recommendations in both genders, the intake of SFA was about 40 % higher than recommended, whereas the intake of PUFA was about 40 % lower than the nutrient reference value. Intake of carbohydrates was in line with the recommendations in both genders and all age groups and also fibre intake was within the acceptable range of the reference values with a slightly higher intake among girls compared with boys.

The fat-soluble vitamins A and E were found to be within the acceptable range, with the exception of vitamin E in boys of the two younger age groups whose intake was only about 70 % of the recommendation.

Table 1 Characteristics† of the study sample: 1590 included and 1938 excluded European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study

	HELENA participants						
	Included (n 1590)			Excluded (n 1938)			
Variables	Median or Mean	P25, P75 or SD	n	Median or Mean	P25, P75 or SD	n	P for difference‡
Age (years)	14·7	13·7, 15·7	1590	14·7	13·7, 15·8	1938	>0·9
Anthropometric characteristics							
BMI-SDS§	0·3	1·1	1590	0·7	1·1	1938	<0·0001
Overweight (%)‖	16·4		1590	28·7		1938	<0·0001
BF%¶	21·6	16·2, 27·1	1554	23·9	17·0, 30·7	1781	<0·0001
Socio-economic characteristics							
Maternal overweight (%)††	10·6		1590	12·2		1938	<0·0001
Paternal overweight (%)††	15·8		1590	14·0		1938	<0·0001
High maternal education (%)‡‡	68·6		1519	62·0		1796	<0·0001
High paternal education (%)‡‡	65·5		1476	59·4		1726	<0·0005
High familial affluence (%)§§	33·5		1590	26·2		1938	<0·0001
Migrant (%)‖‖	7·8		1568	6·6		1856	0·2
Health-related characteristics							
Ever smoked (%)	34·9		1590	40·5		1938	<0·0001
Physical activity (min/week)¶¶	540	270, 995	1495	600	270, 1115	1546	0·02
Nutritional knowledge†††	60·9	47·8, 69·6	1567	60·9	47·8, 69·6	1858	0·9

P25, 25th percentile; P75, 75th percentile; SDS, standard deviation score; BF%, body fat percentage.
†Values are presented as weighted median with P25 and P75, mean and standard deviation, or frequency.
‡Significant differences between groups tested using the Kruskal–Wallis test for non-normally distributed variables, ANOVA for normally distributed variables and the χ^2 test for categorical variables.
§BMI-SDS calculated using Z-values for BMI, calculated via the LMS method by Cole *et al.*[38].
‖Derived from the sex- and age-specific cut-offs proposed by the International Obesity Taskforce, which correspond to an adult BMI cut-off of 25 kg/m^2[38].
¶Estimated according to the equations of Slaughter *et al.*[39].
††Obtained from questions about adolescents' perception.
‡‡Higher secondary education and higher education or university degree.
§§Based on information about family car ownership, having an own bedroom, Internet availability and computer ownership.
‖‖Participant was born outside the country in which they lived during the study.
¶¶Moderate-to-vigorous physical activity.
†††Percentage of correctly answered questions in the nutritional knowledge test.

https://doi.org/10.1017/S1368980013000463 Published online by Cambridge University Press

Table 2 Weighted dietary nutrient and energy intakes in comparison with the D-A-CH reference values for nutrient intake, stratified by age group, of 731 European boys aged 12·5–17·5 years from the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) Study

	Age (years)†														
	10 to <13 (*n* 48)					13 to <15 (*n* 365)					15 to <19 (*n* 318)				
	Intake			% intake of ref. value§		Intake			% intake of ref. value§		Intake			% intake of ref. value§	
Nutrient	Median	P25, P75	Ref. value‡	Median	P25, P75	Median	P25, P75	Ref. value‡	Median	P25, P75	Median	P25, P75	Ref. value‡	Median	P25, P75
Protein (g/kg)	2·1	1·6, 2·4	0·9	228	177, 264	1·8	1·5, 2·2	0·9	205	166, 248	1·7	1·3, 1·9	0·9	185	149, 217
Fat (%E)	33·4	29·6, 37·0	30	111	99, 123	33·6	30·3, 36·6	30	112	101, 122	34·3	31·3, 37·9	30	114	104, 126
SFA (%E)	14·0	11·3, 15·4	<10	140	113, 154	14·1	12·5, 15·7	<10	141	125, 157	14·4	12·6, 15·9	<10	144	126, 159
MUFA (%E)	12·5	11·0, 13·9	10	125	110, 139	12·2	10·9, 13·7	10	122	109, 137	12·6	11·2, 14·0	10	126	112, 140
PUFA (%E)	4·2	3·8, 5·2	10	61	54, 75	4·2	3·7, 4·9	10	59	52, 70	4·5	3·8, 5·5	10	65	55, 79
Cholesterol (mg)	352	284, 448	300	117	95, 149	380	310, 457	300	127	103, 152	412	337, 490	300	137	112, 163
Carbohydrates (%E)	49·0	44·5, 54·9	>50	98	89, 110	49·8	45·8, 53·5	>50	100	92, 107	48·9	45·5, 53·2	>50	98	91, 106
Fibre (g/4184 kJ (1000 kcal))	7·9	6·7, 9·1	10	80	70, 93	7·9	6·7, 9·0	10	80	68, 91	7·3	6·5, 8·6	10	75	66, 88
Vitamin A (mg)	0·9	0·7, 1·2	0·9	100	80, 132	1·0	0·8, 1·3	1·1	92	74, 116	1·1	0·9, 1·3	1·1	101	78, 120
Vitamin D (μg)	1·8	1·3, 2·3	5	36	27, 46	2·0	1·5, 2·6	5	40	31, 52	2·1	1·6, 2·8	5	42	31, 56
Vitamin E (mg)	9·1	7·7, 11·1	13	70	59, 85	9·5	8·1, 11·4	14	68	58, 82	11·3	9·5, 13·4	15	76	63, 90
Vitamin K (μg)	223	175, 289	40	557	437, 723	226	189, 281	50	453	378, 562	247	203, 306	70	353	290, 437
Thiamin (mg)	1·3	1·2, 1·5	1·2	111	97, 128	1·3	1·1, 1·6	1·4	96	81, 114	1·5	1·2, 1·8	1·3	115	95, 135
Riboflavin (mg)	1·7	1·3, 2·0	1·4	124	94, 142	1·8	1·5, 2·1	1·6	111	92, 132	1·7	1·4, 2·1	1·5	114	96, 140
Niacin (mg)	15·9	13·5, 19·4	15	106	90, 129	15·9	13·0, 19·4	18	88	72, 108	17·0	14·1, 20·0	17	100	83, 118
Vitamin B_6 (mg)	1·7	1·5, 2·1	1·0	173	145, 211	1·8	1·5, 2·2	1·4	130	107, 155	1·9	1·6, 2·3	1·6	118	99, 142
Folate (μg)	202	175, 249	400	50	44, 62	217	178, 258	400	54	45, 64	221	186, 271	400	55	46, 68
Pantothenic acid (mg)	5·2	4·4, 6·2	6	104	87, 124	5·4	4·5, 6·3	6	89	75, 105	5·4	4·5, 6·4	6	90	75, 106
Biotin (μg)	45·4	34·1, 49·8	20	227	170, 249	46·3	38·8, 54·7	25	185	155, 219	47·2	38·8, 54·9	30	158	129, 183
Vitamin B_{12} (μg)	6·6	4·6, 8·1	2·0	328	231, 407	6·3	5·0, 7·6	3·0	211	165, 255	6·2	4·9, 7·6	3·0	207	164, 254
Vitamin C (mg)	90·6	51·3, 127·4	90	101	57, 142	90·4	61·4, 127·7	100	90	61, 128	90·1	64·4, 131·7	100	90	64, 132
Na (mg)‖	2170	1943, 2741	510¶	425	381, 537	2540	2093, 3055	550¶	462	381, 556	2761	2332, 3284	550¶	502	424, 597
Cl (mg)‖	3776	3340, 4426	770¶	490	434, 575	4313	3694, 5008	830¶	520	445, 603	4578	4016, 5216	830¶	551	484, 628
K (mg)‖	2797	2257, 3111	1700¶	165	133, 183	2954	2515, 3501	1900¶	155	132, 184	3008	2532, 3584	2000¶	150	127, 179
Ca (mg)	859	695, 1046	1100	78	63, 95	937	662, 1229	1200	78	55, 102	857	561, 1130	1200	72	47, 94
P (mg)	1427	1219, 1618	1250	114	98, 129	1532	1301, 1784	1250	123	104, 143	1572	1320, 1815	1250	126	106, 145
Mg (mg)	315	279, 368	230	137	121, 160	349	298, 403	310	112	96, 130	361	309, 424	400	90	77, 106
Fe (mg)	12·8	11·7, 14·9	12	107	97, 124	13·9	11·9, 16·1	12	116	99, 134	14·7	13·1, 17·0	10	123	109, 142
Iodine (μg)	97·7	82·8, 119·1	180	54	46, 66	108	89·8, 127·9	200	54	45, 64	109	91·7, 127·7	200	54	46, 64
F (mg)	0·6	0·5, 0·7	2·0	30	27, 36	0·7	0·6, 0·8	3·2	22	19, 25	0·8	0·7, 0·9	3·2	24	20, 28
Zn (mg)	12·1	11·3, 13·9	9·0	135	126, 154	13·1	11·4, 15·1	9·5	138	120, 159	13·9	12·0, 15·7	10·0	139	120, 157
Cu (mg)	1·9	1·7, 2·4	1·0	194	175, 240	2·2	1·9, 2·5	1·0	218	186, 253	2·3	2·0, 2·7	1·0	233	202, 267
Energy (MJ)	9·44	8·70, 10·64	8·45	111	103, 126	10·54	9·41, 1·93	9·96	106	95, 120	11·74	10·32, 13·15	11·42	109	96, 122
Energy (kcal)	2255	2080, 2544	2020	111	103, 126	2518	2249, 2852	2380	106	95, 120	2806	2465, 3144	2730	109	96, 122

P25, 25th percentile; P75, 75th percentile; %E, percentage of energy intake.
†Values are presented as median with P25 and P75.
‡D-A-CH reference values for nutrient intake of the German Nutrition Society, Austrian Nutrition Society, Swiss Society for Nutrition Research and Swiss Nutrition Association[23].
§Median (P25, P75) of the respective percentages of each individual's intake compared with the D-A-CH reference values.
‖Discretionary salt intake was not included.
¶Estimated values for minimum intake.

Table 3 Weighted dietary nutrient and energy intakes in comparison with the D-A-CH reference values for nutrient intake, stratified by age group, of 859 European girls aged 12·5–17·5 years from the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) Study

	Age (years)†														
	10 to <13 (*n* 51)					13 to <15 (*n* 451)					15 to <19 (*n* 357)				
	Intake			% intake of ref. value§		Intake			% intake of ref. value§		Intake			% intake of ref. value§	
Nutrient	Median	P25, P75	Ref. value‡	Median	P25, P75	Median	P25, P75	Ref. value‡	Median	P25, P75	Median	P25, P75	Ref. value‡	Median	P25, P75
Protein (g/kg)	1·5	1·4, 1·8	0·9	169	152, 202	1·5	1·3, 1·8	0·9	166	142, 201	1·4	1·2, 1·6	0·8	178	146, 205
Fat (%E)	34·0	31·1, 38·4	30	113	104, 128	34·0	30·5, 37·6	30	113	102, 125	34·5	31·1, 37·5	30	115	104, 125
SFA (%E)	14·4	12·8, 16·5	<10	144	128, 165	14·0	12·5, 15·7	<10	140	125, 157	14·1	12·5, 15·6	<10	141	125, 156
MUFA (%E)	12·7	10·9, 14·5	10	127	109, 145	12·3	10·9, 13·9	10	123	109, 139	12·7	11·2, 13·8	10	127	112, 138
PUFA (%E)	4·6	4·0, 5·1	10	66	57, 73	4·7	4·0, 5·5	10	66	57, 78	4·8	4·1, 5·6	10	69	59, 80
Cholesterol (mg)	302	252, 371	300	101	84, 124	310	264, 371	300	103	88, 124	309	260, 366	300	103	87, 122
Carbohydrates (%E)	48·7	44·1, 53·4	>50	97	88, 107	49·8	46·0, 53·9	>50	100	92, 108	49·6	45·9, 53·4	>50	99	92, 107
Fibre (g/4184 kJ (1000 kcal))	7·9	7·2, 9·0	10	80	73, 91	8·6	7·6, 10·2	10	87	77, 103	8·8	7·5, 10·1	10	89	76, 102
Vitamin A (mg)	0·9	0·7, 1·1	0·9	95	82, 127	0·9	0·8, 1·1	1·0	92	78, 114	1·0	0·8, 1·2	0·9	106	89, 132
Vitamin D (μg)	1·6	1·3, 2·2	5	33	26, 44	1·8	1·4, 2·2	5	36	28, 44	1·8	1·5, 2·2	5	36	29, 45
Vitamin E (mg)	8·6	7·1, 9·4	13	79	65, 86	8·9	7·5, 10·3	14	74	63, 86	9·5	7·9, 11·1	15	79	66, 93
Vitamin K (μg)	200	167, 232	40	499	417, 580	207	173, 252	50	413	346, 504	208	177, 252	60	347	296, 420
Thiamin (mg)	1·1	0·9, 1·3	1·0	108	88, 126	1·1	0·9, 1·3	1·1	99	86, 115	1·1	1·0, 1·3	1·0	111	95, 128
Riboflavin (mg)	1·4	1·2, 1·6	1·2	115	102, 131	1·4	1·2, 1·6	1·3	105	90, 122	1·3	1·1, 1·6	1·2	112	94, 132
Niacin (mg)	12·3	11·2, 15·4	13	95	86, 119	13·0	11·2, 15·7	15	87	74, 104	13·1	10·9, 15·8	13	101	84, 122
Vitamin B_6 (mg)	1·4	1·3, 1·9	1·0	144	128, 188	1·5	1·3, 1·8	1·4	108	93, 127	1·5	1·2, 1·8	1·2	123	104, 146
Folate (μg)	177	147, 213	400	44	37, 53	187	162, 217	400	47	40, 54	195	160, 225	400	49	40, 56
Pantothenic acid (mg)	4·2	3·7, 4·8	6	84	74, 96	4·3	3·8, 5·0	6	72	63, 83	4·3	3·6, 5·1	6	72	61, 84
Biotin (μg)	38·7	32·3, 44·2	20	193	162, 221	37·8	33·3, 44·7	25	151	133, 179	37·2	31·8, 44·8	30	124	106, 149
Vitamin B_{12} (μg)	4·7	4·1, 6·0	2·0	236	204, 298	4·7	4·0, 5·9	3·0	156	133, 195	4·7	3·8, 5·9	3·0	157	128, 198
Vitamin C (mg)	77·0	54·3, 132·1	90	86	60, 147	91·0	64·0, 132·3	100	91	64, 132	86·8	60·3, 124·7	100	87	60, 125
Na (mg)‖	1965	1563, 2393	510¶	385	307, 469	2012	1681, 2463	550¶	366	306, 448	2072	1791, 2488	550¶	377	326, 452
Cl (mg)‖	3269	2774, 3963	770¶	425	360, 515	3373	2924, 3951	830¶	406	352, 476	3516	3072, 4042	830¶	424	370, 487
K (mg)‖	2451	2014 2921	1700¶	144	118, 172	2491	2146, 2920	1900¶	131	113, 154	2475	2093, 2936	2000¶	124	105, 147
Ca (mg)	809	635, 953	1100	74	58, 87	727	483, 955	1200	61	40, 80	661	459, 880	1200	55	38, 73
P (mg)	1197	1053, 1297	1250	96	84, 104	1220	1063, 1400	1250	98	85, 112	1212	1039, 1440	1250	97	83, 115
Mg (mg)	278	240, 305	250	111	96, 122	291	251, 330	310	94	81, 107	294	249, 346	350	84	71, 99
Fe (mg)	10·9	9·3, 12·6	15	73	62, 84	11·2	10·1, 12·9	15	75	67, 86	11·8	10·2, 13·5	15	79	68, 89
Iodine (μg)	92·1	84·0, 104·4	180	51	47, 58	92·8	79·2, 108·5	200	46	40, 54	90·5	77·2, 107·8	200	45	39, 54
F (mg)	0·6	0·5, 0·7	2·0	28	23, 34	0·6	0·5, 0·7	2·9	20	17, 24	0·6	0·5, 0·7	2·9	22	18, 26
Zn (mg)	10·2	9·1, 11·4	7·0	145	130, 163	10·5	9·2, 11·9	7·0	150	131, 170	10·8	9·2, 12·3	7·0	154	131, 176
Cu (mg)	1·9	1·6, 2·0	1·0	186	162, 203	1·9	1·6, 2·1	1·0	187	164, 211	1·9	1·7, 2·2	1·0	194	168, 224
Energy (MJ)	8·46	7·40, 9·29	7·36	115	101, 126	8·52	7·65, 9·62	8·12	105	94, 119	8·75	7·90, 9·77	9·20	101	91, 113
Energy (kcal)	2021	1769, 2220	1760	115	101, 126	2036	1828, 2300	1940	105	94, 119	2091	1889, 2336	2200	101	91, 113

P25, 25th percentile; P75, 75th percentile; %E, percentage of energy intake.
†Values are presented as median with P25 and P75.
‡D-A-CH reference values for nutrient intake of the German Nutrition Society, Austrian Nutrition Society, Swiss Society for Nutrition Research and Swiss Nutrition Association[23].
§Median (P25, P75) of the respective percentages of each individual's intake compared with the D-A-CH reference values.
‖Discretionary salt intake was not included.
¶Estimated values for minimum intake.

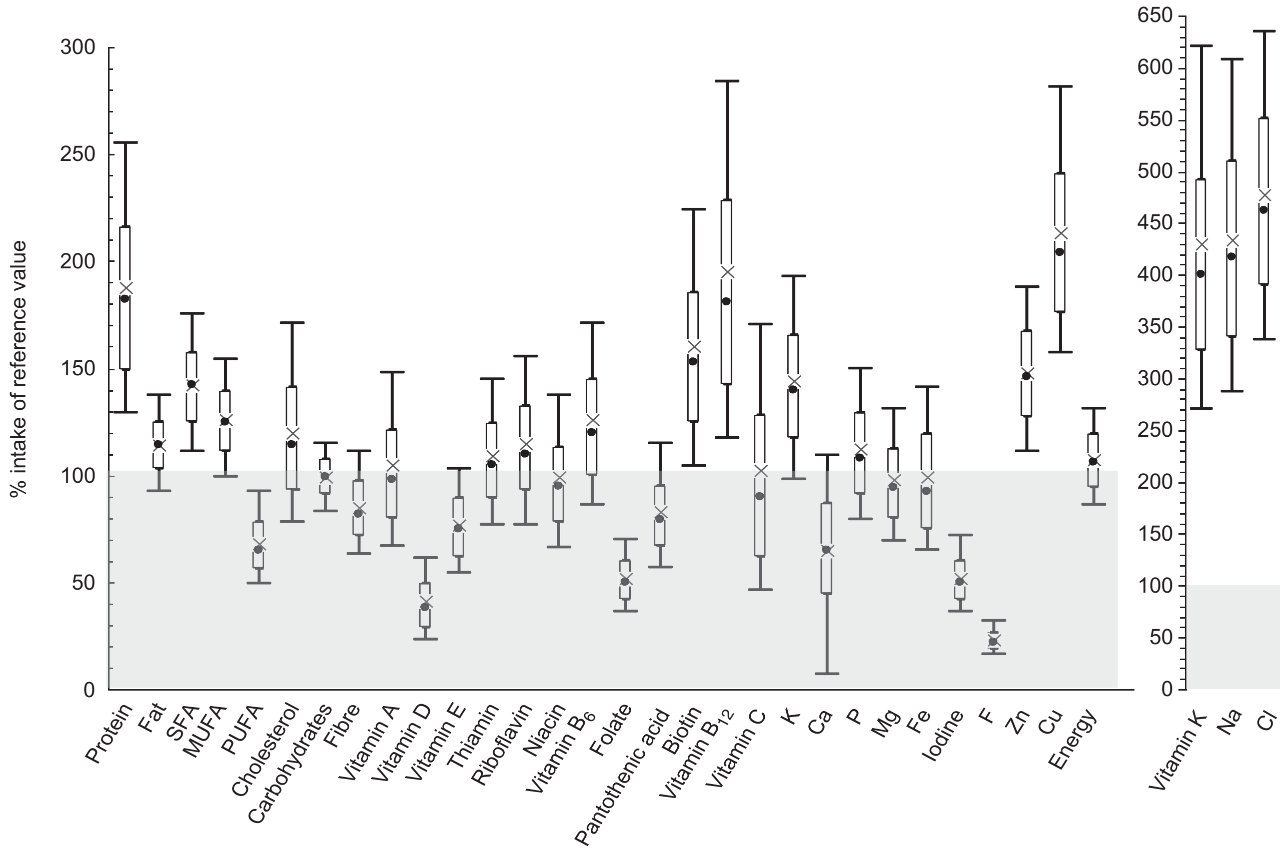

Fig. 1 Dietary nutrient and energy intakes in comparison with the D-A-CH reference values for nutrient intake among 1590 European adolescents aged 12·5–17·5 years from the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) Study. Data are presented as box-and-whisker plots in which the bottom and top of the box represent the 25th and 75th percentile (quartile 1 and quartile 3), respectively; the bottom and top of the whisker represent the 10th and 90th percentile, respectively; × represents the mean; and ● represents the median; ▢ represents intake inadequacy compared with the reference value

However, the intake of vitamin D was far below the acceptable range with only about 40 % and 35 % of the recommended intake in boys and girls, respectively. In contrast, vitamin K intake was about three to five times higher than the nutrient reference value.

Intakes of the water-soluble vitamins thiamin, riboflavin, niacin, vitamin B_6, pantothenic acid, biotin, vitamin B_{12} and vitamin C met or exceeded the recommendations among the European adolescents. Only folate failed to reach approximately 50 % of the recommended intake.

Regarding minerals, the intakes of Na and Cl were about three to five times higher than the recommended values in boys and girls among all age groups. Furthermore, the intakes of K, P, Mg, Zn and Cu were sufficient. With respect to Ca, boys aged 10–15 years had an acceptable intake of about 80 % of the recommended minimum value, whereas the intake of the older boys was lower (about 70 %). For girls, Ca intake reached the lower acceptable level of about 75 % of the recommendation in the youngest group, but only 55 % of the recommended intake for the oldest age group. The intake of Fe was within the acceptable range among both genders, with only slightly lower values among girls of the youngest age groups. In contrast, iodine and F intakes were insufficient, as intakes did not reach more than about 55 % of the recommendation for iodine and no more than 30 % for F.

Energy intakes of both genders were in line with the recommendations.

Finally, the weighted NQI derived from both absolute values and densities of the European adolescents, stratified by age group, are presented in Table 4. The median NQI was approximately 72 in absolute value and 71 in terms of nutritional density (of a maximum value of 100). The NQI values were highest in 10- to 13-year-old boys (about 77 and 75 for absolute and density values, respectively) and lowest for 13- to 15-year-old girls (about 70 and 69 for absolute values and density values, respectively). Significant differences between boys and girls existed regarding the NQI density in the youngest age group (10–<13 years) and regarding both NQI absolute and NQI density in the middle age group (13–<15 years), with consistently higher values for boys. Since there is no specific cut-off for the NQI indicating an 'adequate' diet, the same cut-off as for evaluating single nutrient intake was used, i.e. 75 %. Thus, the overall nutritional quality was rather low among the European adolescents.

Table 4 Weighted nutritional quality index derived both from absolute values and from densities, stratified by age group, of 1590 European adolescents aged 12·5–17·5 years from the Healthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) Study

	Age (years)†											
	10 to <13 (*n* 99)				13 to <15 (*n* 816)				15 to <19 (*n* 675)			
	Boys (*n* 48)		Girls (*n* 51)		Boys (*n* 365)		Girls (*n* 451)		Boys (*n* 318)		Girls (*n* 357)	
	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75
NQI absolute	77·0	73·5, 79·2	74·7	70·4, 78·1	72·3	63·7, 77·1	70·2*	64·5, 75·0	72·1	60·2, 76·9	71·4	64·9, 77·1
NQI density	74·4	71·1, 76·8	71·4*	67·0, 74·5	72·1	66·8, 75·3	69·1*	63·5, 74·0	71·0	62·6, 75·4	71·8	66·2, 75·4

P25, 25th percentile; P75, 75th percentile; NQI, Nutritional Quality Index.
Median values were significantly different from those of boys (tested using the Kruskal–Wallis test): $*P < 0.05$.
†Values are presented as median with P25 and P75.

Discussion

The present analysis provides for the first time detailed and comprehensive data from a standardized dietary assessment of the energy and nutrient intakes of adolescents across Europe. Compared with widely used nutrient reference intakes, the energy intake and the proportions of energy intake from carbohydrates, fat and protein are sufficient. However, the quality of fat intake needs to be improved in the European adolescents. For the micronutrients as well as for dietary fibre, the intake levels are mostly within an acceptable range, with the exceptions of vitamin D, folate, iodine and F across the study population and Ca in older girls. However, regarding the nutritional quality as a whole, the European boys and girls have a rather low overall diet quality with a median NQI of about 72 and 71 for absolute and density values, respectively.

These results from the HELENA Study are generally concordant with earlier regional studies in several European countries. In comparison with the D-A-CH reference values (or with the similar US recommended daily allowance[48]), the protein intake of the HELENA adolescents was about twice as high. These findings are in line with the results of other European studies[22,49,50]. Although an increase in protein intake may have negative effects on bone health[51], no long-term studies have revealed adverse effects of protein intake above the recommended amount[52], i.e. at levels such as those in our sample. Moreover, in 6- to 18-year-old German[53] and 17-year-old Danish[54] children and adolescents, protein intake was positively associated with bone strength and mineralization. Thus, the described protein intake of the European adolescents might not be of concern.

The total intakes of fat and cholesterol in the HELENA sample are well in line with the guidelines. However, the proportions of energy from SFA and PUFA among the European adolescents are in need of improvement, since the intake of SFA exceeded the recommendations by about 40 % and the intake of PUFA was found to be 40 % lower. This pattern – which has also been described in other studies among European adolescents[49,55–58] – may not only negatively influence present health but may also increase the risk for diabetes, dyslipidaemia or CVD later in life[15,59]. Associations between fat intake during childhood and the quality of the adult diet two decades later have been reported[60], and so it is of importance in the prevention of diet-related diseases to improve the dietary fat quality already in adolescence[61].

Regarding micronutrients, most vitamins and minerals were consumed in accordance with the D-A-CH reference values used here. Some smaller deviations, e.g. a lower intake of vitamin E intake in younger boys, of Ca among older boys or of Fe in younger girls, might be attributed to the specific recommendations used here or to the skewed distribution of recommendations. Since the deviations do not exceed 30 % and the recommended intakes are designed to be 20–30 % higher than the average requirement, this might not be an indication of deficiencies[23]. Unfortunately, at the moment a diversity of nutrient reference values is used across Europe with considerable differences in the stated nutritional requirements. The nutritional quality of the diet of European adolescents based on nutrient intake would thus be estimated differently depending on what recommendations are used[62]. While some of the disparities can be attributed to physiological and environmental differences between populations, most are due to methodological differences[24].

However, compared with the D-A-CH reference values, and also in comparison with the recommendations of most other European countries[24], the intakes of vitamin D, folate, iodine and F were insufficient among European adolescents, as was the intake of Ca in 13- to 19-year-old girls. As shown in various publications[22,49,56], vitamin D intake often reaches only about 40 % of the recommended level. This is due to the fact that vitamin D is found naturally in only a few foods and even fortification – which is a widely used technique to increase vitamin D intake in many industrialized countries – has only modest effects on vitamin D status[63] and could not be considered in the HELENA Study. Of greater importance is the endogenous synthesis of vitamin D when the skin is exposed to sunlight. However, skin synthesis may not fully compensate for the low nutritional intake among all adolescents throughout Europe, because Europe is located over many degrees of latitude and skin production of vitamin D varies considerably at different latitudes[64].

The intake of folate reached only about 50 % of the recommendation in this sample. Other nutritional surveys describe intakes at a similar level[22,55], with slightly higher values in Southern Europe[57]. Folate intake is difficult to assess because neither cooking losses nor food fortification were accounted for in HELENA-DIAT. Since folate deficiency is not only important for the prevention of neural tube defects in pregnancy but also of CVD and some malignancies[65], the low folate intake among the European adolescents is of concern.

The intakes of iodine and F were also very low, reaching only about 50 % and 20 % of the recommendations, respectively. While the intake of F is not reported in other European surveys among adolescents, iodine intake has repeatedly been found to be below the recommended intakes[22]. Again these minerals are difficult to assess with HELENA-DIAT, since a major part of the iodine and F intake stems from fortification of e.g. table salt[66,67] and – in the case of F – swallowed toothpaste[68]. However, deficiencies of these minerals can result in thyroid diseases[67] and dental caries and should thus be prevented by comprehensive fortifications.

On the other hand, there are some micronutrients that were ingested in much higher amounts among the HELENA adolescents than recommended, i.e. vitamin K, Na and Cl. However, the toxicity of vitamin K is extremely low and no upper level has been established[47]. The Na and Cl intakes equate to about 6 g of salt and thus around the accepted amount of daily salt intake[23]. However, this value is certainly highly underestimated since table salt is not considered in HELENA-DIAT and might be not completely assessed in processed or convenience food. Therefore, the actual salt intake – which includes table salt – might be critically high.

Furthermore, the median energy intake of adolescents participating in the HELENA study was about 11 046 kJ/d (2640 kcal/d) for boys and about 8619 kJ/d (2060 kcal/d) for girls and is therefore in the range presented in the European Nutrition and Health Report (9498–14 518 kJ/d (2270–3470 kcal/d) for boys, 6820–9707 kJ/d (1630–2320 kcal/d) for girls)[49].

Nutritional indices are a way to assess overall diet quality with a single parameter[25]. However, most indices are calculated based on the arithmetical mean, which is known to balance data, i.e. deficiencies of a few nutrients are compensated for by adequate intakes of other nutrients[69–71]. Such a mathematical compensation is not, however, physiologically possible. The NQI is therefore based on the harmonic mean. In this, a low intake of one nutrient is weighted more heavily and decreases the overall nutritional quality disproportionately[26]. Compensation is thus reduced, corresponding more to metabolic pathways. The HELENA adolescents had a median absolute and density NQI of about 72 and 71, respectively. Unfortunately, the interpretation of these values is not straightforward, since specific cut-offs indicating an 'adequate' diet are not determined for most indices and are difficult to justify in the absence of an overall biomarker. Some studies have used the assumption that values below 67 % of the optimum might indicate a suboptimal state of nutrition[69], while others used the indices only to compare subsamples[25,70,71]. We used the same cut-off as for single nutrients, i.e. 75 %, and found a rather low overall nutritional quality. Since the harmonic mean was used in this data analysis, the noticeable low intakes of folate, vitamin D, iodine and F might have affected the NQI of the adolescents excessively. Under these considerations, the overall nutritional quality seems to be close to adequate among the HELENA sample.

Before giving any recommendation for supplementation of specific nutrients, the nutrient status of the European adolescents should be established[72] and potential country- or population-specific situations should be taken into account. Some biomarker evaluations of nutritional status have already been executed or are in process in a HELENA sub-sample[73].

Since the 24 h recall used in HELENA was identified to have substantial under-reporting bias[31,74], 214 (12 %) under- and over-reporters were excluded from the analysis. The groups differed significantly in their adherence to the D-A-CH recommendations in nearly all nutrients (except for carbohydrates and fat) and in their NQI (data not shown). Furthermore, the included adolescents differed

https://doi.org/10.1017/S1368980013000463 Published online by Cambridge University Press

significantly from the rest of the whole HELENA sample regarding their anthropometric, socio-economic and health related characteristics (Table 1). These results point to the fact that data of the excluded adolescents were biased. Therefore, it can be assumed that the data obtained in the present analysis from the included participants only are more reliable and allow meaningful information about nutrient intake among European adolescents.

Some limitations of the study need to be mentioned. To begin with, the HELENA-CSS cohort is not a fully representative European sample, since due to the selection procedure of classes from all schools in the chosen cities representativeness can be at best achieved on the city level. However, this procedure was anticipated to give a fair approximation of the average situation, if the objective was to only describe the adolescents' characteristics, as was the case in the present study[27]. Furthermore, the 24 h recall used in the HELENA Study has been shown to be prone to under-reporting in a validation study[32,74]. Nevertheless, due to the exclusion of over- and under-reporters in the present sample, systematic bias due to inadequate reporting should have been reduced. On the other hand, the exclusion might have induced selection bias since the misreporters might have a special food choice or eating behaviour. Furthermore, large within-person variation might be of concern, given that dietary data were assessed only by two 24 h recalls. However, the large size of the sample (nearly 1600 adolescents) should have alleviated large within-person variations[75]. Additionally, sample weights that were constructed for the sample after over- and under-reporters were excluded calibrated the sample so that it matched the European population with regard to sex and age group. Another limitation is the fact that the 24 h recalls were all completed during school days (about the dietary intake of the previous day) and thus did not include information about the adolescents' diet on Fridays and Saturdays or on holidays. Moreover, a 24 h recall like HELENA-DIAT might not be an adequate tool to estimate some minerals like Na, Cl, iodine and F stemming mostly from (fortified) table salt, as well as the amount and quality of additional fat for meal preparation.

One of the major strengths of the present study, besides the large sample size, is the geographical spread over eight European cities. The sample consists of adolescents assessed using highly standardized and validated procedures; for example, all countries used the same 24 h recall (HELENA-DIAT) and the same food composition database (BLS). Another strength is the use of the Multiple Source Method taking into account both between- and within-individual variability of the dietary intake data. Moreover, the current study is one of the first examining the overall nutrient intake and not just specific nutrients among adolescents at a pan-European level. We evaluated the overall nutritional quality of the adolescents with the NQI. Nutritional indices can be used to some extent to evaluate a diet's adequacy[71]. However, they are not appropriate to derive specific recommendations to improve nutritional quality, since the intake of single nutrients has to be considered. This has been conducted here extensively by the use of public health-oriented reference values[24].

Conclusion

The present analysis of the HELENA Study provides new, reliable and comprehensive insight into the intake of a large number of nutrients among European adolescents. Compared with the D-A-CH reference values the intakes of most nutrients can be assumed to be adequate. However, further studies using suitable criteria to assess nutrient status are needed and further research should also investigate the high protein and salt intakes found in the HELENA adolescents.

Overall, public health initiatives should educate children and adolescents regarding balanced food choices (possibly with the addition of fortified foods or supplements for some critical nutrients, if evidence dictates), since health behaviour adopted in childhood and adolescence might be carried over into adulthood and may thus play an important role in the prevention of nutrition-related diseases.

Acknowledgements

Sources of funding: The HELENA Study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD CT-2005-007034). The contents of this paper reflect only the authors' views and the rest of HELENA Study Members and the European Community are not liable for any use that may be made of the information contained herein. *Ethics:* The ethical committee of each city approved the study. *Conflicts of interest:* The authors have no conflicts of interest. *Authors' contributions:* L.M. coordinated the project. L.M., M.G.-G. and M.K. designed and carried out the HELENA project. K.D. carried out the data analyses and drafted the manuscript. M.K. provided critical input on the data analyses and on earlier versions of the manuscript and supervised the study. I.H., S.D.H., Y.M., L.B., M.G.-G., C.L.D., M.C.-G., M.J.C., K.W. and E.P. contributed to interpretation of the data of the submitted manuscript. Each author has seen and approved the contents of the submitted manuscript. *Acknowledgements:* The participation of all adolescents in the HELENA Study is gratefully acknowledged.

References

1. Villa I, Yngve A, Poortvliet E *et al.* (2007) Dietary intake among under-, normal- and overweight 9- and 15-year-old Estonian and Swedish schoolchildren. *Public Health Nutr* **10**, 311–322.

2. Tucker LA, Seljaas GT & Hager RL (1997) Body fat percentage of children varies according to their diet composition. *J Am Diet Assoc* **97**, 981–986.
3. Guo SS, Wu W, Chumlea WC *et al.* (2002) Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *Am J Clin Nutr* **76**, 653–658.
4. Amati L, Chiloiro M, Jirillo E *et al.* (2007) Early pathogenesis of atherosclerosis: the childhood obesity. *Curr Pharm Des* **13**, 3696–3700.
5. Baker JL, Olsen LW & Sorensen TI (2007) Childhood body-mass index and the risk of coronary heart disease in adulthood. *N Engl J Med* **357**, 2329–2337.
6. Must A, Spadano J, Coakley EH *et al.* (1999) The disease burden associated with overweight and obesity. *JAMA* **282**, 1523–1529.
7. Law M (2000) Dietary fat and adult diseases and the implications for childhood nutrition: an epidemiologic approach. *Am J Clin Nutr* **72**, 5 Suppl., 1291S–1296S.
8. Biro FM & Wien M (2010) Childhood obesity and adult morbidities. *Am J Clin Nutr* **91**, issue 5, 1499S–1505S.
9. Morrison JA, Glueck CJ, Daniels S *et al.* (2010) Determinants of persistent obesity and hyperinsulinemia in a biracial cohort: a 15-year prospective study of schoolgirls. *J Pediatr* **157**, 559–565.
10. Lustig RH (2006) Childhood obesity: behavioral aberration or biochemical drive? Reinterpreting the First Law of Thermodynamics. *Nat Clin Pract Endocrinol Metab* **2**, 447–458.
11. Lytle LA & Kubik MY (2003) Nutritional issues for adolescents. *Best Pract Res Clin Endocrinol Metab* **17**, 177–189.
12. van Lenthe FJ, Kemper CG & van Mechelen W (1996) Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam Growth and Health Study. *Am J Clin Nutr* **64**, 18–24.
13. Dietz WH (1994) Critical periods in childhood for the development of obesity. *Am J Clin Nutr* **59**, 955–959.
14. Mikkila V, Rasanen L, Raitakari OT *et al.* (2005) Consistent dietary patterns identified from childhood to adulthood: the Cardiovascular Risk in Young Finns Study. *Br J Nutr* **93**, 923–931.
15. World Health Organization (2003) *Diet, Nutrition, and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation*. *WHO Technical Report Series* no. 916. Geneva: WHO.
16. Moreno LA (2008) Adolescence. In *Nutrition in Practice*, pp. 114–117 [B Koletzko, editor]. Basel: Karger.
17. Hoppu U, Lehtisalo J, Tapanainen H *et al.* (2010) Dietary habits and nutrient intake of Finnish adolescents. *Public Health Nutr* **13**, 965–972.
18. Libuda L, Alexy U, Buyken AE *et al.* (2009) Consumption of sugar-sweetened beverages and its association with nutrient intakes and diet quality in German children and adolescents. *Br J Nutr* **101**, 1549–1557.
19. Toselli S, Argnani L, Canducci E *et al.* (2010) Food habits and nutritional status of adolescents in Emilia-Romagna, Italy. *Nutr Hosp* **25**, 613–621.
20. Royo-Bordonada MA, Gorgojo L, Martin-Moreno JM *et al.* (2003) Spanish children's diet: compliance with nutrient and food intake guidelines. *Eur J Clin Nutr* **57**, 930–939.
21. Sette S, Le Donne C, Piccinelli R *et al.* (2011) The third Italian National Food Consumption Survey, INRAN-SCAI 2005–06 – part 1: nutrient intakes in Italy. *Nutr Metab Cardiovasc Dis* **21**, 922–932.
22. Lambert J, Agostoni C, Elmadfa I *et al.* (2004) Dietary intake and nutritional status of children and adolescents in Europe. *Br J Nutr* **92**, Suppl. 2, S147–S211.
23. German Nutrition Society, Austrian Nutrition Society, Swiss Society for Nutrition Research *et al.* (editors) (2000) *Reference Values for Nutrient Intake (D-A-CH)*, 1st ed. Frankfurt am Main: Umschau/Braus.
24. Prentice A, Branca F, Decsi T *et al.* (2004) Energy and nutrient dietary reference values for children in Europe: methodological approaches and current nutritional recommendations. *Br J Nutr* **92**, Suppl. 2, S83–S146.
25. Thiele S, Mensink GB & Beitz R (2004) Determinants of diet quality. *Public Health Nutr* **7**, 29–37.
26. Gedrich K & Karg G (2001) Dietary habits of German vs. Non-German residents in Germany. In *Culinary Arts and Sciences III – Global and National Perspectives*, pp. 419–428 [JSA Edwards, editor]. Al-Fayoum: Al-Karma Press.
27. Moreno LA, De Henauw S, Gonzalez-Gross M *et al.* (2008) Design and implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int J Obes (Lond)* **32**, Suppl. 5, S4–S11.
28. Moreno LA, Gonzalez-Gross M, Kersting M *et al.* (2008) 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* **11**, 288–299.
29. Beghin L, Huybrechts I, Vicente-Rodriguez G *et al.* (2012) Main characteristics and participation rate of European adolescents included in the HELENA study. *Arch Public Health* **70**, 14.
30. Beghin L, Castera M, Manios Y *et al.* (2008) Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. *Int J Obes (Lond)* **32**, Suppl. 5, S12–S18.
31. Vereecken CA, Covents M, Matthys C *et al.* (2005) Young adolescents' nutrition assessment on computer (YANA-C). *Eur J Clin Nutr* **59**, 658–667.
32. Vereecken CA, Covents M, Sichert-Hellert W *et al.* (2008) Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. *Int J Obes (Lond)* **32**, Suppl. 5, S26–S34.
33. Dehne LI, Klemm C, Henseler G *et al.* (1999) The German Food Code and Nutrient Data Base (BLS II.2). *Eur J Epidemiol* **15**, 355–359.
34. Haubrock J, Nothlings U, Volatier JL *et al.* (2011) Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study. *J Nutr* **141**, 914–920.
35. Schofield WN (1985) Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* **39**, Suppl. 1, 5–41.
36. Goldberg GR, Black AE, Jebb SA *et al.* (1991) 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* **45**, 569–581.
37. Nagy E, Vicente-Rodriguez G, Manios Y *et al.* (2008) Harmonization process and reliability assessment of anthropometric measurements in a multicenter study in adolescents. *Int J Obes (Lond)* **32**, Suppl. 5, S58–S65.
38. Cole TJ, Bellizzi MC, Flegal KM *et al.* (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* **320**, 1240–1243.
39. Slaughter MH, Lohman TG, Boileau RA *et al.* (1988) Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* **60**, 709–723.
40. Iliescu C, Beghin L, Maes L *et al.* (2008) Socioeconomic questionnaire and clinical assessment in the HELENA Cross-Sectional Study: methodology. *Int J Obes (Lond)* **32**, Suppl. 5, S19–S25.
41. United Nations Educational, Scientific and Cultural Organization (2006) International Standard Classification of Education ISCED 1997 (May 2006, Re-edition). http://www.uis.unesco.org/Library/Documents/isced97-en.pdf
42. Currie C, Molcho M, Boyce W *et al.* (2008) Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. *Soc Sci Med* **66**, 1429–1436.

43. Hagstromer M, Bergman P, De Bourdeaudhuij I *et al.* (2008) Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELENA Study. *Int J Obes (Lond)* **32**, Suppl. 5, S42–S48.
44. Ottevaere C, Huybrechts I, De Bourdeaudhuij I *et al.* (2011) Comparison of the IPAQ-A and Actigraph in relation to VO2max among European adolescents: the HELENA study. *J Sci Med Sport* **14**, 317–324.
45. IPAQ Group (2005) Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) – Short and Long Forms. http://www.ipaq.ki.se/scoring.pdf
46. Kersting M, Sichert-Hellert W, Vereecken CA *et al.* (2008) Food and nutrient intake, nutritional knowledge and diet-related attitudes in European adolescents. *Int J Obes (Lond)* **32**, Suppl. 5, S35–S41.
47. Institute of Medicine (2001) *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc*. Washington, DC: National Academy Press.
48. National Academy of Sciences, Institute of Medicine, Food and Nutrition Board (2005) *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids*. Washington, DC: National Academy Press.
49. Elmadfa I, Meyer A, Nowak V *et al.* (2009) European nutrition and health report 2009. *Forum Nutr* **62**, 1–405.
50. Parizkova J (2000) Dietary habits and nutritional status in adolescents in Central and Eastern Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S36–S40.
51. Barzel US & Massey LK (1998) Excess dietary protein can adversely affect bone. *J Nutr* **128**, 1051–1053.
52. Ginty F (2003) Dietary protein and bone health. *Proc Nutr Soc* **62**, 867–876.
53. Alexy U, Remer T, Manz F *et al.* (2005) Long-term protein intake and dietary potential renal acid load are associated with bone modeling and remodeling at the proximal radius in healthy children. *Am J Clin Nutr* **82**, 1107–1114.
54. Budek AZ, Hoppe C, Ingstrup H *et al.* (2007) Dietary protein intake and bone mineral content in adolescents – The Copenhagen Cohort Study. *Osteoporos Int* **18**, 1661–1667.
55. Elmadfa I & Freisling H (2009) Nutritional status in Europe: methods and results. *Nutr Rev* **67**, Suppl. 1, S130–S134.
56. Samuelson G (2000) Dietary habits and nutritional status in adolescents over Europe. An overview of current studies in the Nordic countries. *Eur J Clin Nutr* **54**, Suppl. 1, S21–S28.
57. Cruz JA (2000) Dietary habits and nutritional status in adolescents over Europe – Southern Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S29–S35.
58. Rolland-Cachera MF, Bellisle F & Deheeger M (2000) Nutritional status and food intake in adolescents living in Western Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S41–S46.
59. German Nutrition Society (2006) *Evidence Based Guidelines: Fat Consumption and Certain Nutrition-Related Diseases*. Bonn: German Nutrition Society.
60. Mikkila V, Rasanen L, Raitakari OT *et al.* (2004) Longitudinal changes in diet from childhood into adulthood with respect to risk of cardiovascular diseases: the Cardiovascular Risk in Young Finns Study. *Eur J Clin Nutr* **58**, 1038–1045.
61. Spinneker A, Egert S, Gonzalez-Gross M *et al.* (2012) Lipid, lipoprotein and apolipoprotein profiles in European adolescents and its associations with gender, biological maturity and body fat – The HELENA Study. *Eur J Clin Nutr* **66**, 727–735.
62. Tabacchi G, Wijnhoven TM, Branca F *et al.* (2009) How is the adequacy of micronutrient intake assessed across Europe? A systematic literature review. *Br J Nutr* **101**, Suppl. 2, S29–S36.
63. Ovesen L, Andersen R & Jakobsen J (2003) Geographical differences in vitamin D status, with particular reference to European countries. *Proc Nutr Soc* **62**, 813–821.
64. Kimlin MG, Downs NJ & Parisi AV (2003) Comparison of human facial UV exposure at high and low latitudes and the potential impact on dermal vitamin D production. *Photochem Photobiol Sci* **2**, 370–375.
65. Molloy AM (2002) Folate bioavailability and health. *Int J Vitam Nutr Res* **72**, 46–52.
66. World Health Organization (1995) Fluorides and oral health. *Bull World Health Organ* **73**, 124–125.
67. Delange F (2002) Iodine deficiency in Europe and its consequences: an update. *Eur J Nucl Med Mol Imaging* **29**, Suppl. 2, S404–S416.
68. Oganessian E, Ivancakova R, Lencova E *et al.* (2011) Alimentary fluoride intake in preschool children. *BMC Public Health* **11**, 768.
69. Madden J & Yoder MD (1972) Program evaluation: food stamps and commodity distribution in rural areas of central Pennsylvania. *Pennsylvania Agricultural Experiment Station Bulletin* **78**, 1–119.
70. Basiotis P, Guthrie J, Bowman S *et al.* (1995) Construction and evaluation of a diet status index. *Fam Econ Nutr Rev* **8**, 2–13.
71. Waijers PM, Feskens EJ & Ocke MC (2007) A critical review of predefined diet quality scores. *Br J Nutr* **97**, 219–231.
72. Al-Tahan J, Gonzalez-Gross M & Pietrzik K (2006) B-vitamin status and intake in European adolescents. *A review of the literature. Nutr Hosp* **21**, 452–465.
73. Gonzalez-Gross M, Valtuena J, Breidenassel C *et al.* (2012) Vitamin D status among adolescents in Europe: the Healthy Lifestyle in Europe by Nutrition in Adolescence study. *Br J Nutr* **107**, 755–764.
74. Vereecken C, Dohogne S, Covents M *et al.* (2010) How accurate are adolescents in portion-size estimation using the computer tool Young Adolescents' Nutrition Assessment on Computer (YANA-C)? *Br J Nutr* **103**, 1844–1850.
75. van 't Veer P (1994) Measuring nutritional exposures including biomarkers. *Proc Nutr Soc* **53**, 27–35.

https://doi.org/10.1017/S1368980013000463 Published online by Cambridge University Press