Food intake of European adolescents in the light of different food based dietary guidelines – results of the HELENA Study

ABSTRACT

Objective: Since inadequate food consumption patterns during adolescence are not only linked with the occurrence of obesity in youth, but also with the subsequent risk of developing diseases in adulthood, the establishment and maintenance of a healthy diet already early in life is of great public health importance. Therefore, the aim of this study was to describe and evaluate for the first time food consumption of European adolescents in a well-characterized sample.

Design: The HEalthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study is a cross-sectional study, whose main objective was to obtain comparable data on a variety of nutritional and health-related parameters in adolescents aged 12.5-17.5 years.

Setting: 10 cities in Europe.

Subjects: The initial sample consisted of more than 3000 European adolescents. Among these, 1593 adolescents (54% female) had sufficient and plausible energy- and dietary food intake-data of two 24h recalls using the HELENA-DIAT software.

Results: Food intake of adolescents in Europe is not optimal compared to the two food based dietary guidelines Optimized Mixed Diet and Food Guide Pyramid, examined in this study. Adolescents eat half of the recommended amount of fruit and vegetables and less than two thirds of the recommended amount of milk (-products), but do consume much more meat (-products), fats, and sweets than recommended. However, median total energy intake may be estimated to be nearly in line with the recommendations.

Conclusion: The results urge the need to improve the dietary habits of adolescents in order to maintain health in later life.

INTRODUCTION

Inadequate food consumption patterns during childhood and adolescence are not only linked with the occurrence of obesity in youth[1], but also with the subsequent risk of developing diseases such as cancer[2], obesity[3] and cardiovascular diseases[4] in adulthood. Adolescence is a potentially critical period for body composition in later life and the development of obesity in adulthood[5]. This may be due to the hormonal changes regulating appetite, satiety, and fat distribution that occur during puberty[6]. In addition, adolescence is a time of dramatic behavioural changes in which children test their autonomy and assert independence from their parents, which may affect both eating behaviours[7] and changes in physical activity[8]. Since poor dietary habits in this critical period of adolescence[9] might continue into adulthood and then become extremely resistant to modification[10], the establishment and maintenance of a healthy diet already early in life is of great public health importance.

Up to now, investigations of the adolescents' dietary intake and eating habits have been carried out in several European countries only on a national or regional level. For example, in Germany[11] and Spain[12], it was found that adolescents eat less vegetables, fruit, bread and potatoes than recommended, and too much meat (-products). In Greece[13] and Belgium[14], the intakes of energy-dense and low-nutritious foods were high. Moreover in England[15] the foods consumed mostly were white bread, fried chips and confectionery.

However, differences in methodology, population groups and age categories make it difficult to use these data for a detailed evaluation of dietary intake among adolescents in a European perspective[16]. The HEalthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CCS) provided for the first time the opportunity to examine food consumption of a large sample of adolescents across several European countries using standardized, harmonized and validated instruments and procedures for the dietary intake assessment.

Therefore, the purpose of this analysis was to describe and evaluate food consumption among anthropometric- and socioeconomic-well characterized European adolescents. Although assessment of food consumption is – especially for children and adolescents - an adequate and moreover practical approach to evaluate and improve dietary habits, there are no generally accepted reference values for the food intake of adolescents. Hence, for the evaluation we used two sets of food-based dietary recommendations for children and adolescents that are designed to translate nutrient-based recommendations into practical, total diet concepts[17], namely the Optimized Mixed Diet (OMD)[18] and the Food Guide Pyramid (FGP)[19].

METHODS

Study design and population

The HELENA-CCS is a multi-centre investigation that was conducted between 2006 and 2007 in 10 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[20,21]. The main objective of HELENA-CSS was to obtain reliable and comparable data on a variety of nutritional and health-related parameters in a sample of more than 3000 European adolescents (boys and girls aged 12.5-17.5 years)[20]. Therefore, a random cluster sampling among all classes from all schools in the 10 cities was carried out[21]. The ethical committee of each city approved the study and signed informed consent was obtained from the adolescents as well as from the parents[22].

For this analysis, data on food intake from Heraklion and Pecs were not available. Further, specific inclusion criteria (complete energy- and food intake data of two days obtained by the HELENA-DIAT 24h recall and data on anthropometry) were defined for this analysis and fulfilled by 2330 adolescents. Among these, adolescents with plausible dietary recalls were ascertained by relating their reported total energy intake to their basal metabolic rate, as described below. Hence, the sample analyzed here included 1593 adolescents (54% female).

Dietary intake assessment

Dietary intake data was obtained using a self administered, computerized 24h recall, named HELENA-DIAT, which was based on Young Adolescents' Nutrition Assessment on computer (YANA-C)[23] and validated in Flemish adolescents and then improved and culturally adapted by adding national dishes to reach a European standard[24]. The program is organized in 6 meal occasions and 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 24h recall by themselves during school time while research staff was available in the classroom to assist the adolescents if necessary. They completed the HELENA-DIAT twice on non-consecutive days within a time span of two weeks, to achieve information closer to habitual food intake than assessing food intake on consecutive days.

Since the purpose of this data analysis was to describe food consumption of European adolescents in a detailed and practice-oriented way, we used the 45 predefined food groups, whom each consumed single food item had been assigned to in HELENA-DIAT (e.g. mozzarella is assigned to the HELENA group "cheese"). The intake (g/day) of each food group as well as total daily energy intake (kcal/day) were calculated for each participant from the mean of the two

respective 24h recalls. Total daily energy intake was used to exclude potentially implausible recalls by comparing it to the basal metabolic rate estimated with the equations of Schofield et al.[25]. Using the well-acknowledged approaches of Goldberg et al.[26] and Johannson[27], overall, 574 (43% male and 57% female) adolescents were assigned as underreporters and 163 (61% male and 39% female) adolescents were assigned as overreporters. Both under- and overreporters were hence excluded from the analysis.

To compare the adolescents' food intake with age-specific food-based dietary guidelines we used the total diet concepts of the OMD for children and adolescents living in a European country, developed by the German Research Institute of Child Nutrition[18], and the dietary guidelines for Americans, the FGP, developed by the U.S. Department of Agriculture[19].

The OMD recommendations are categorized into 11 food groups to which the 45 HELENA food groups were assigned to, e.g. the HELENA group "cheese" was assigned to the OMD group "milk and milk products". If a HELENA food group could not be assigned to any OMD group, it was allocated as "others", e.g. meat substitutes and vegetarian products (Table 1). Recommended food group intakes were given in gram per day and are sex- and age-group-specific based on the respective recommended energy intake. For this analysis we used the OMD recommendations for boys and girls in the age groups 13-14 and 15-18 years[18].

The FGP is structured into 6 food groups to which the HELENA food groups were assigned to or were respectively allocated as "others" (Table 1). The FGP recommendations are stated as numbers of servings per day from each food group[19]. What counts as a serving is specified separately and exemplary for several foods in each group by means of ounces or household measures such as cups or teaspoons, e.g. 1 serving of milk products is equal to 1 cup of yoghurt[28-33]. To derive food-specific weights for the respective serving sizes (e.g. cups)[34], we used data on the number of grams per household measure in the "MyPyramid Equivalents Database, 2.0 for USDA Survey Foods"[35], e.g. 1 cup of yoghurt equates 245g. Mean weights of the exemplary foods[28-33] of each food group were then assumed as the food-group specific weight of one serving. These weights were multiplied with the recommended sex- and age-group-specific number of servings for each food group within the FGP. For this analysis we used the FGP recommendations for boys and girls in the predefined age groups 9-13 and 14-18 years of the FGP.

Anthropometric measurements

Measurements were performed by trained staff in a standardized way[36] with the adolescents barefoot and in underwear. Weight was measured with an electronic scale to the nearest 0.1kg, and height was measured with a telescopic stadiometer to the nearest 0.1cm. Body mass index (BMI) was calculated from height and weight (kg/m²). Sex- and age-independent BMI standard deviation

scores (BMI-SDS) were calculated using z-values for BMI, calculated via the LMS method by Cole et al.[37] and overweight was defined according to age- and sex-standardized BMI cut off points based on data of Cole et al.[37]. Skinfold thicknesses were measured three times on the left side of the body with a Holtain calliper to the nearest 0.2mm. Body fat percentage (%BF) was calculated from triceps and subscapular skinfold thicknesses using Slaughter's equations[38].

Socioeconomic characteristics

Socioeconomic characteristics were assessed with a self-reported questionnaire[39]. 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). The familial affluence scale, which was previously validated[40], 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 they lived during the study: yes/no) and smoking status (ever smoked: yes/no) was assessed.

Health-related characteristics

Physical activity was assessed with the self-administered Physical Activity Questionnaire for Adolescents covering questions about physical activity during the last seven days[41]. Total minutes per week (min/week) were computed and assigned to moderate to vigorous physical activity.

To assess the nutritional knowledge of the adolescents, the validated Nutritional Knowledge Test was used[42]. For evaluation, correct answers of the 23 multiple choice questions were summed up and used as percentages of total number of questions.

Diet-related preferences and determinants of healthy eating were examined using the Food Choices and Preferences Questionnaire and the Determinants of Healthy Eating Questionnaire[21]. For this analysis we used questions about frequencies of breakfast skipping, bringing fruit to school and fruit availability at home.

Statistical analysis

SAS procedures (SAS, version 9.13; SAS Institute, Cary, NC, USA) were used for data analysis. A *P*-value <0.01 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 in that way, that it matches the European population with regard to sex and age-group.

Differences in characteristics between boys and girls were tested using analyses of variance for normally distributed variables, Kruskal-Wallis tests for non-normally distributed variables, and chi-square tests for categorical variables.

Weighted intakes of food groups by the adolescents were calculated as medians (25^{th} and 75^{th} percentiles). Wilcoxon's rank sum tests, applicable for non-normally distributions and paired observations, were used to test if the median of the individual differences between dietary intake and recommendations of each individual was zero[43].

RESULTS

The present data analysis included 732 (46%) boys and 861 (54%) girls. Characteristics regarding anthropometry, socioeconomic status and health are presented in table 2 stratified by sex. In comparison with boys, girls had a lower BMI-SDS (0.2 vs. 0.4), but had a higher percentage of body fat (24.6% vs. 16.3%), which was to be expected. Gender differences regarding socioeconomic characteristics could only be observed for the percentage of overweight mothers (about 13% in girls and 8% in boys). With respect to the health-related characteristics, boys reported significantly more physical activity than girls (about 640min/week vs. 430 min/week) and less frequent breakfast skipping (about 11% vs. 16%), whereas girls reported a higher availability of fruit at home (about 47% vs. 41%) and at school (about 14% vs. 6%).

The weighted dietary intake of food groups of the European adolescents, stratified by sex and age-group, and compared with the OMD, is shown in Tables 3 and 4. Boys and girls of both age groups significantly exceeded the OMD recommendations for energy intake (105%, $P<0.01$), except for the 15-17.5 years old boys.

For both age groups of the adolescent boys and girls, the average daily intakes and the OMD recommendations were significantly different for all food groups. For drinks, the HELENA boys and girls fulfilled the recommendations by about 60%. Boys of the two age-groups reached the recommendations for vegetables and fruit by only about 30% and 40%, respectively, whereas girls had slightly higher values (about 35% and 50%, respectively). OMD recommendations for potatoes as well as bread and cereals were reached by about 70% and 50%, respectively, for both genders. The milk and milk products OMD recommendations as well as recommendations for eggs were achieved to higher degrees by boys (70% for milk products and 80% for eggs) compared to girls (60% of the recommendations for both food groups). For the meat and fish food groups, the European adolescents – especially the boys - exceeded the OMD recommendations. Boys had an average meat intake of about 230% of the recommendations, girls of about 190%. The average fish intake was about 160% of the recommendations for boys and 150% for girls. Oils and fats OMD

recommendation were fulfilled up to 40% (girls) to 50% (boys). Finally, the average intake of sweets (including sweetened beverages) was between 400g and 700g. The OMD tolerates a sweet intake of 10% of the recommended energy intake, i.e. 200-270kcal/day. For comparison, 200-270 kcal would be about 40-50g chocolate or potato crisps or about 60-80g wine gum or 450-650 ml soft drinks. Therefore, the adolescents highly exceeded the OMD recommendations.

Similar results were found when comparing weighted dietary intake of food groups of the HELENA participants with the FGP, as shown in Table 5 and 6, stratified by sex and age-group. As for the OMD, the adolescents' average energy intake significantly exceeded the FGP recommendation for energy (about 120%) in both boys and girls ($p<0.01$). Furthermore, all food groups (except the meat, fish, eggs and pulses group for 13 year-old boys) showed significant differences between average daily intakes and recommendations.

Similar as in the case of evaluating by use of OMD, the fruit and vegetable intake of the European boys was on average about 35% of the FGP recommendations, while girls reached slightly higher values of about 40% for vegetables and about 50% for fruit recommendations. The intake of bread, cereals, rice and pasta equalled on average about 130% of the FGP recommendations for both genders. In the group of milk and milk products, boys fulfilled the FGP recommendations by 65% and girls by about 50%. In the group of meat, fish, eggs and pulses, boys also reached the recommendations to a higher degree of about 90% compared to girls with about 75%. The highest exceeding of the recommendations occurred in the oils, fats and sweets groups, with more than 250% in both genders.

DISCUSSION

The present analysis provides for the first time evidence from a comprehensive and standardized dietary assessment that food intake in adolescents on a European level is not optimal in the light of European and US food based dietary concepts. In particular, adolescents eat less than half of the recommended amount of fruit and vegetables and less than two thirds of the recommended amount of milk (-products), but consume much more meat (-products) and oils, fats and sweets than recommended. Median total energy intake may be estimated to be nearly in line with the recommendations, although statistical significant differences emerge.

Although both food based dietary guidelines are based on low physical activity levels[19,44], the recommended energy intake in the OMD is about 300-600kcal higher than in the FGP. Therefore, the recommended intake of the food groups potatoes (with rice and pasta), bread and cereals as well as oils and fats in the OMD is more than twice as high (about 450-650g and 35-45g,

respectively) as in the FGP (about 200-300g and 20-30g, respectively), which explains the different achievement levels for the OMD and FGP in this study sample.

Unsatisfactory consumption of fruit, fruit juice and vegetables as well as milk and other dairy products has been reported for adolescents living in Central and Eastern Europe[45] and in Northern Europe[46]. However, in southern European countries intake of fruit and vegetables is higher than in nordic regions[47]. A remarkable low fruit and even lower vegetable intake has been shown in the Pro Children Project, a cross-European survey focussing on fruit and vegetable intake, in 11 years old children in 9 European countries[48], similar to the youngest age groups of HELENA. A large proportion of the participants of the Pro Children Project stated a frequency of fruit and vegetable intake which was less than once a day. Similarly, one quarter of our HELENA adolescents have not consumed any fruit during the 2 recalled days. Also a meta-analysis of Pomerlau et al.[49] in 14 subregions, showed that the mean intake in adolescents across Europe was well below European public health recommendations for this food groups which are set to 400g/d[50.]

On the other hand adolescents consumed about 200% of the OMD meat and meat products recommendation and also the consumption of sweets was far too high. Meat and meat products were previously also reported to be consumed frequently in Central, Eastern[45] and Northern Europe[46]. Furthermore, snacking - for which food items like sweets and savoury snacks are most popular[46,47] - is reported to be common in Northern Europe[46]. In Western Europe, sucrose and fat intake are high and most amounts of protein are from animal sources, whereas fibre intake is low[51], pointing to similar food consumption patterns as those found in the HELENA sample.

Bread and bread products were consumed in large quantities in Central, Eastern[45] and Northern Europe[46], whereas in HELENA for this food group an opposite picture resulted from comparison with the two recommendations due to different definitions of food groups. For instance, the FGP includes cakes, pies, biscuits and savoury snacks in the bread and cereals group, whereas they are characterized as sweets in the OMD. Since snacks may have an adverse effect on body weight[52], the conclusion that bread and cereal consumption is regarded as sufficient according to the FGP may be questionable. The same applies for meat, fish, eggs and pulses, which are considered as one group in the FGP and as separate groups in the OMD. A distinction between these food groups might be of importance, since fish and pulses consumption have been found to benefit health[53,54], contrary to meat[55]. Another important difference is, that drinks are included in the OMD concept, but not in the FGP. Alcoholic beverages in particular are allocated as tolerated foods like sweets in the OMD, since they are characterized by low nutrient density, but high hedonic rating among adolescents. Regarding the FGP, beverages are no single food group and thus all beverages are allocated as “others”. However, although alcohol consumption is common among

European adolescents[46,47], only about 6% of the HELENA adolescents reported to have consumed alcoholic beverages during the two recalling days and thus alcohol intake seems to be of minor importance in this sample. Hence, food intake quality can be estimated considerably different depending on what recommendations are used. In this analysis, it appears, that the OMD - and to a greater extend the FGP - might overestimate the real dietary quality of adolescents with regard to special food groups, in particular the diverse group of sweets and snack foods. Furthermore, the oils and fats group in both the OMD and FGP did not include hidden fat from convenience foods, sauces or milk products. Therefore, oil and fat consumption may have been underestimated in the dietary survey.

In contrast, fruit intake may be slightly underestimated in this analysis, since fruit juice has not been included in the fruit group, as it has been shown that children and adolescents have problems distinguishing fruit juice from sweetened fruit drinks or lemonades[56]. In the OMD[18] and FGP recommendations[19] one glass of 100% fruit juice (200ml) can be counted as one portion of fruit. Median intake of fruit and vegetable juice was 100ml/day in girls and boys of both age groups (data not shown). Therefore, if fruit and vegetable juice would be added to the fruit group (assuming that children and adolescents are commonly drinking fruit but not vegetable juice[56]), boys would on average fulfil the OMD and FGP fruit recommendations and girls would even exceed them. Therefore, our results may potentially be rather pessimistic with regard to fruit intake. However, it is not clear whether the reported half glass of juice is really 100% juice and moreover, one quarter of the sample has not reported any juice consumption during the two recalled days at all (data not shown).

There are some gender differences regarding the compliance with the dietary recommendations that were to be expected. Whereas girls fulfilled more of the recommendations concerning fruit and vegetables, boys in their turn were better for milk and milk products as well as meat and meat products (i.e. more overconsumption when the OMD recommendations are considered). This gender difference is in line with the already often described observation that girls have an overall healthier choice of foods than boys[14,46,57].

Furthermore, it has been shown that females are more likely to underreport their dietary intake than boys[58], which is also a considerable problem in HELENA. Self-reported dietary intake tends to be particularly problematic in adolescents[59] and the 24h recall used in HELENA was identified to have substantial underreporting bias[23,60]. Therefore, under- and overreporters were excluded for analysis. The excluded adolescents differed significantly from those eligible for analysis regarding their anthropometric and most socioeconomic characteristics, but only for few health-related characteristics (data not shown) and thus could be assumed to have similar health consciousness. However, the included adolescents might have been more willing to participate in a

dietary study. In a further analysis we examined the difference between the included and excluded adolescents regarding the fulfilment of the OMD and FGP recommendations and observed that the groups differed indeed significantly in the adherence to the dietary concepts in nearly all food groups (except for drinks, fruits, eggs and fish for OMD and fruits for FGP, data not shown). This results point to the fact that data of the excluded was seriously biased. Therefore, it can be assumed that the data obtained in this analysis from the included participants is reliable and allows meaningful information about food intake in European adolescents. Future evaluation of the HELENA dietary data should examine the reporting bias in more detail.

Since it is important to improve dietary habits early in life, the consumption of fruit and vegetable, the most neglected food group among adolescents in this and other surveys, should be promoted in children and adolescents in line with the strive for reducing the burden of diet-related diseases in later life. Evidence confirms that multi-component, multi-media approaches at the school setting, including behavioural and situational prevention have been more successful[57,61] than educational campaigns[49]. In line with this, the HELENA project comprises a computer-tailored intervention, which provides adolescents with individualised feedback about their dietary behaviour[20,62,63]. Moreover, in the HELENA Study, information of adolescents' food preferences will be used to guide the development of healthy new food products by the food industry[4].

Some limitations of this study need to be mentioned. To begin with, the HELENA-CSS cohort is not a fully European representative sample, since due to the selection procedure of classes from all schools in the cities representativeness can be at least achieved on the city-level. However, this procedure is anticipated to give a fair approximation of the average picture of the situation, if the objective was to only describe the adolescents characteristics, as was the case in our study[21]. Furthermore, the 24h recall used in HELENA has been shown to be prone for underreporting in a validation study[23,60]. However, due to the exclusion of over- and underreporters in our sample, systematic bias should have been reduced. Large within-person variation might be of concern, given that dietary data was only assessed by two 24h recalls (and not on Fridays and Saturdays and holidays, since the 24h recalls were all completed during school days). Anyway, the still large sample size (nearly 1600 adolescents) should have alleviated large within-person variations[64]. Additionally, sample weights that were constructed for the sample after over- and underreporters were excluded calibrated the sample in that way, that it matched the European population with regard to sex and age-group.

One of the major strengths of the present study, besides the large sample size, is the geographical spread over 10 European cities. Another strength is the use of the Multiple Source Method taking into account both, between and within individual variability of the dietary intake data. Nevertheless, wide distributions of the achievement of the guidelines occurred, as can be seen

in the standard deviations. Moreover, this study is one of the first examining the total daily food consumption and not only specific food groups of well-characterized adolescents across Europe with highly standardized and validated procedures. We used for the first time two existing food based dietary concepts fulfilling public health approaches to translate nutrient-based recommendations into practical food-based recommendations. Such concepts are useful to evaluate food intake particularly in adolescents, especially since they were adapted for adolescents' energy requirements. Since both concepts revealed broadly the same main conclusions, it can be proposed that food consumption has been truly evaluated in this large sample of European adolescents. Nevertheless, the HELENA food and nutrient intake data together with the biomarkers of nutritional status may allow to develop tailored food based dietary guidelines for European adolescents that are still missing. In this it may be a specific challenge to consider particular national or regional food habits, e.g. pasta, potatoes, type of bread.

To conclude, this study provides new, reliable evidence about food consumption patterns of European adolescents. In the light of actual food based dietary concepts from Europe and the USA, European adolescents consume far too little fruit, vegetables and milk products, but far too much meat and meat-products and sweets. A key message from this analysis might be, that adolescents do not need to eat more or less (regarding calories), but need to re-arrange their food patterns. The results do urge the need to improve the dietary habits of adolescents in order to maintain health in later life.

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Table 1: Categorization of the HELENA food groups in the foods groups of the Optimized Mixed Diet[a] and the Food Guide Pyramid[b]

HELENA food groups	**Optimized Mixed Diet**
Water, coffee, tea	Drinks
Vegetables without potatoes	Vegetables
Fruit, olives, avocados	Fruit
Starchroot including potatoes, pulses, pasta, rice	Potatoes
Flour, bread, cereals	Bread and cereals
Milk, yoghurt beverages, white milk, buttermilk, yogurt, quark, cheese, creams, other milk products	Milk and milk products
Meat	Meat and meat products
Eggs	Eggs
Fish, fish products	Fish and fish products
Vegetable oils, margarine, lipids of mixed origin, butter, animal fats, nuts, seeds, olives	Oils and fats
Chocolate, other sugar products, desserts/pudding milk based, desserts/puddings soy based, nuts and seeds (spreads), cakes, pies, biscuits, savoury snacks, sugar/honey/jam/syrup, confectionary non chocolate, fruit and vegetable juices, carbonated/soft/isotonic drinks, beer, wine, cider, other alcoholic beverages	Sweets
Sauces, other miscellaneous, products for special nutritional use, meat substitutes, vegetarian products, soy beverages, soups, bouillon	Others
HELENA food groups	**Food Guide Pyramid**

Vegetables without potatoes, starchroot including potatoes	Vegetables
Fruit, olives, avocados	Fruit
Flour, bread, cereals, pasta, rice, cakes, pies, biscuits, savoury snacks	Bread and cereals
Milk, yoghurt beverages, white milk, buttermilk, yogurt, quark, cheese, creams, other milk products, milk based desserts, puddings	Milk and milk products
Meat, fish, eggs, meat substitutes, vegetarian products, pulses	Meat, fish, eggs, pulses
Vegetable oils, margarine, lipids of mixed origin, butter, animal fats, nuts, seeds, olives, nuts and seeds (spreads), chocolate, other sugar products, desserts/puddings soy based, sugar/honey/jam/syrup, confectionary non chocolate	Oils, fats, sweets
Sauces, other miscellaneous, products for special nutritional use, soups, bouillon, water, coffee, tea, soy beverages, fruit and vegetable juices, carbonated/soft/isotonic drinks, beer, wine, cider, other alcoholic beverages	Others

[a] See: Kersting M, Alexy U & Clausen K (2005) Using the concept of Food Based Dietary Guidelines to Develop an Optimized Mixed Diet (OMD) for German children and adolescents. J Pediatr Gastroenterol Nutr 40, 301-308

[b] See: U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans, 2005. Vol. 6th Edition. Washington, DC: U.S. Government Printing Office; 2005

Table 2: Characteristics [a] of the study sample: 1593 European adolescents from the HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study stratified by sex

Variables	1.1.1 **HELENA participants**				
	Boys (n=732)	**n**	**Girls (n=861)**	**n**	**p for difference [b]**
Age (years)	15 (14, 16)	732	15 (14, 16)	861	0.5
Anthropometric characteristics					
BMI-SDS	0.4 (1.1)	732	0.2 (1.0)	861	0.002
Overweight (%) [c]	18.5	732	14.7	861	0.07
Percentage body fat [d]	16.3 (12.4, 22.1)	703	24.6 (20.8, 29.3)	854	<0.001
Socioeconomic characteristics					
Maternal overweight (%) [e]	7.9	724	13.3	844	0.002
Paternal overweight (%) [e]	14.5	722	17.7	838	0.05
High maternal education (%) [f]	67.1	704	69.4	817	0.3
High paternal education (%) [f]	66.6	685	64.0	793	0.3
High familial affluence (%) [g]	35.0	729	33.2	857	0.3
Migrant (%) [h]	8.1	726	8.0	845	0.9
Health related characteristics					
Ever smoked (%)	37.0	726	37.3	847	0.3
Physical activity (min/week) [i]	639 (340, 1140)	688	425 (210, 840)	810	<0.001
Nutritional knowledge [j]	60.9 (47.8, 69.6)	717	60.9 (52.2, 73.9)	853	0.001
Often breakfast skipping (%) [k]	11.3	629	16.1	769	0.003
Fruit always available at home (%) [k]	41.1	707	46.7	830	0.01
Always bring fruit to school (%) [k]	5.8	707	13.5	830	<0.001

[a] Values are presented as weighted frequencies, means (SD) or medians (25^{th} and 75^{th} percentiles).

[b] Significant differences between groups tested using ANOVA for normally-distributed variables, Kruskal-Wallis test for non-normally distributed variables, and Chi-square-test for categorical variables.

[c] Derived from the sex- and age-specific cut-offs proposed by the International Obesity Task Force, which correspond to an adult BMI cut-off of 25[37].

[d] Estimated according to the equations of Slaughter et al.[38].

[e] Obtained from questions about adolescents' perception.

[f] Higher secondary education and higher education or university degree.

[g] Based on information about family car ownership, having an own bedroom, internet availability, and computer ownership.

[h] Participant is born outside the country they lived during the study.

[i] Moderate to vigorous physical activity.

[j] % right answered questions of nutritional knowledge test.

[k] Strongly agree with this statement from the Food Choices and Preferences Questionnaire.

Table 3: Dietary intake of food groups compared with the Optimized Mixed Diet (OMD) stratified by age group of 732 European boys, aged 12.5-17.5 years from the HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study

Energy intake and Food Groups	**Age group 12.5-14.9 years (n=414)**		**Age group 15.0-17.5 years (n=318)**		**% intake of recommendation [b]**
	Daily intake [a]	**OMD daily recommendation**	**Daily intake [a]**	**OMD daily recommendation**	
Total energy intake (kcal)	2468 (2042, 2941)	2400 *	2721 (2244 , 3309)	2700	104.6 (24.8)
Drinks (g)	611 (275, 1000)	1300 *	793 (314, 1271)	1500 *	56.7 (46.4)
Vegetables (g)	61.9 (18.0, 120)	300 *	70.0 (26.3, 138)	350 *	28.5 (31.4)
Fruit (g)	93.8 (0.00, 195)	300 *	92.5 (0.00, 170)	350 *	40.7 (48.7)
Potatoes (g)	183 (110,284)	280 *	180 (101, 284)	330 *	68.2 (47.5)
Bread and cereals (g)	120 (72.5, 184)	280 *	150 (90.3, 222)	330 *	49.5 (31.9)
Milk and milk products (g)	319 (172, 500)	450 *	245 (113, 406)	500 *	71.9 (61.6)
Meat and meat products (g)	155 (79.5, 232)	75 *	164 (95.3, 248)	85 *	229.0 (172.8)
Eggs (g)	0.00 (0.00, 14.3)	18 *	0.00 (0.00, 18.5)	18 *	82.9 (183.6)
Fish and fish products (g)	0.00 (0.00, 17.5)	14 *	0.00 (0.00, 8:5)	14 *	163.2 (449.3)
Oils and fats (g)	12.4 (0.00, 28.3)	40 *	12.9 (0.00, 34.2)	45 *	48.5 (57.3)
Sweets (g)	506 (281, 854)	max 240 kcal/d	711 (405, 1115)	max 270 kcal/d	
Other (g)	60.0 (12.0, 155)		61.0 (15.0, 157)		

[a] Values are presented as medians (25^{th} and 75^{th} percentiles).

[b] Values are presented as mean (SD) of the respective percentages of each individual's intake compared to the recommendation.

* Wilcoxon-rank-sum test shows that the median of differences between dietary intake and recommendations of each individual is significantly different from zero with $P<0.01$.

Table 4: Dietary intake of food groups compared with the Optimized Mixed Diet (OMD) stratified by age group of 861 European girls, aged 12.5-17.5 years from the HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study

Energy intake and Food Groups	**Age group 12.5-14.9 years (n=503)**		**Age group 15.0-17.5 years (n=358)**		**% intake of recommendation [b]**
	Daily intake [a]	**OMD daily recommendation**	**Daily intake [a]**	**OMD daily recommendation**	
Total energy intake (kcal)	1983 (1686, 2415)	1950 *	2031 (1722, 2372)	2200 *	101.0 (23.7)
Drinks (g)	625 (346, 1024)	1200 *	718 (410, 1131)	1400 *	60.7 (44.5)
Vegetables (g)	70.0 (31.9, 128)	260 *	82.5 (34.3, 144)	300 *	35.1 (35.7)
Fruit (g)	100 (33.8, 200)	260 *	96.0 (17.5, 210)	300 *	49.3 (50.2)
Potatoes (g)	160 (91.3, 240)	220 *	150 (82.5, 219)	270 *	70.2 (47.4)
Bread and cereals (g)	95.0 (54.0, 144)	220 *	124 (75.0, 181)	270 *	50.9 (36.5)
Milk and milk products (g)	213 (106, 353)	425 *	166 (70.0, 345)	450 *	56.5 (51.0)
Meat and meat products (g)	110 (57.5, 166)	65 *	110 (55.0, 184)	75 *	181.2 (141.5)
Eggs (g)	0.00 (0.00, 14.7)	18 *	0.00 (0.00, 10.5)	18 *	60.2 (128.2)
Fish and fish products (g)	0.00 (0.00, 15.0)	14 *	0.00 (0.00, 22.5)	14 *	151.0 (339.7)
Oils and fats (g)	11.1 (0.00, 24.0)	35 *	12.0 (3.00, 25.5)	40 *	42.7 (31-1)
Sweets (g)	414 (226, 674)	195 max kcal/d	440 (241, 735)	220 max Kcal/d	
Other (g)	57.5 (10.0, 151)		50.0 (11.3, 135)		

[a] Values are presented as medians (25^{th} and 75^{th} percentiles).

[b] Values are presented as mean (SD) of the respective percentages of each individual's intake compared to the recommendation.

* Wilcoxon-rank-sum test shows that the median of differences between dietary intake and recommendations of each individual is significantly different from zero with $P<0.01$.

Table 5: Dietary intake of food groups compared with the Food Guide Pyramid (FGP) stratified by age group of 732 European boys, aged 12.5-17.5 years from the HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study

Energy intake and Food Groups	**Age group 12.5-13.9 years (n=61)**		**Age group 14.0-17.5 years (n=671)**		**% intake of recommendation [b]**
	Daily intake [a]	**FGP daily recommendation**	**Daily intake [a]**	**FGP daily recommendation**	
Energy (kcal)	2192 (1914, 2698)	1800 *	2608 (2170, 3140)	2200 *	122.8 (29.7)
Vegetables (g)	104 (30.0, 192)	388 *	134 (63.0, 226)	465 *	35.2 (29.7)
Fruit (g)	87.5 (0.00, 195)	269 *	93.8 (0.00, 185)	358 *	37.4 (44.3)
Bread, cereals, rice, pasta (g)	274 (191, 354)	228 *	334 (243, 447)	266 *	133.5 (61.6)
Milk and milk products (g)	282 (151, 433)	540 *	285 (141, 488)	540 *	65.0 (53.3)
Meat, fish, eggs, pulses (g)	200 (125, 345)	225	197 (125, 295)	270 *	87.2 (61.9)
Oils, fats, sweets (g)	42.2 (21.0, 82.5)	24 *	55.0 (24.0, 100)	29 *	256.3 (248.4)
Others (g)	1130 (825, 1500)		1426 (1027, 1903)		

[a] Values are presented as medians (25^{th} and 75^{th} percentiles).

[b] Values are presented as mean (SD) of the respective percentages of each individual's intake compared to the recommendation.

* Wilcoxon-rank-sum test shows that the median of differences between dietary intake and recommendations of each individual is significantly different from zero with $P<0.01$.

Table 6: Dietary intake of food groups compared with the Food Guide Pyramid (FGP) stratified by age group of 861 European girls, aged 12.5-17.5 years from the HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study

Energy intake and Food Groups	**Age group 12.5-13.9 years (n=70)**		**Age group 14.0-17.5 years (n=791)**		
	Daily intake [a]	**FGP daily recommendation**	**Daily intake [a]**	**FGP daily recommendation**	**% intake of recommendation [b]**
Energy (kcal)	1976 (1708, 2371)	1600 *	2018 (1707, 2382)	1800 *	116.9 (26.8)
Vegetables (g)	131 (60.0, 197)	310 *	141 (76.0, 223)	388 *	41.6 (31.1)
Fruit (g)	94.4 (27.5, 148)	269 *	100 (30.0, 210)	269 *	51.0 (51.6)
Bread, cereals, rice, pasta (g)	276 (181, 346)	190 *	268 (192, 358)	228 *	127.2 (60.2)
Milk and milk products (g)	252 (120, 392)	540 *	205 (104, 358)	540 *	48.5 (42.0)
Meat, fish, eggs, pulses (g)	160 (106, 227)	225 *	148 (88.3, 224)	225 *	74.9 (51.0)
Oils, fats, sweets (g)	37.9 (21.3, 67.1)	22 *	49.7 (24.8, 83.6)	24 *	257.2 (213.6)
Others (g)	1197 (906, 1535)		1184 (868, 1602)		

[a] Values are presented as medians (25^{th} and 75^{th} percentiles).

[b] Values are presented as mean (SD) of the respective percentages of each individual's intake compared to the recommendation.

* Wilcoxon-rank-sum test shows that the median of differences between dietary intake and recommendations of each individual is significantly different from zero with $P<0.01$.