Nutrition, Metabolism and Cardiovascular Diseases

Ultra-processed foods consumption and diet quality of European children, adolescents and adults: results from the I.Family study

--Manuscript Draft--

Manuscript Number:	NMCD-D-21-00523R2
Article Type:	Research Paper
Keywords:	Nova classification; Ultra-processed foods; Diet quality; Children; adolescents; adults
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Abstract:	Background and Aims : The objectives of the present study were to provide a description of the consumption of ultra-processed foods (UPFs) in the large population of children, adolescents and adults from eight European countries participating to the I.Family study, and to investigate the association between UPFs intake and nutritional quality of the diet. Methods and Results: Dietary intake was assessed using a 24-h dietary recall. The quality of the diet was evaluated by the Healthy Dietary Adherence Score (HDAS) using an FFQ. UPFs were classified according to NOVA classification. Almost half of the daily energy intake of the 7073 participants came from UPFs, and this trend decreased progressively with age. UPFs contributed more than 50% of the daily intake of total and saturated fat, carbohydrates and about 70% of sugars intake in children and adolescents. No differences in UPFs consumption were found according to the educational and socio-economic status of the population. Energy intake increased across the quintiles of UPFs intake, while HDAS decreased. The frequency of consumption of fruit and vegetable, fish, and fibre rich-foods was low in the fifth quintile of UPFs intake, both in adolescents and in adults. The consumption of foods rich in calories and low in nutritional content, operationally defined as “junk food”, was significantly higher in the fifth quintile. Conclusions : in our study population, UPFs contributed a large proportion of the daily energy intake, especially in children and adolescents. Higher consumption of UPFs

	was associated with a lower quality of the diet.

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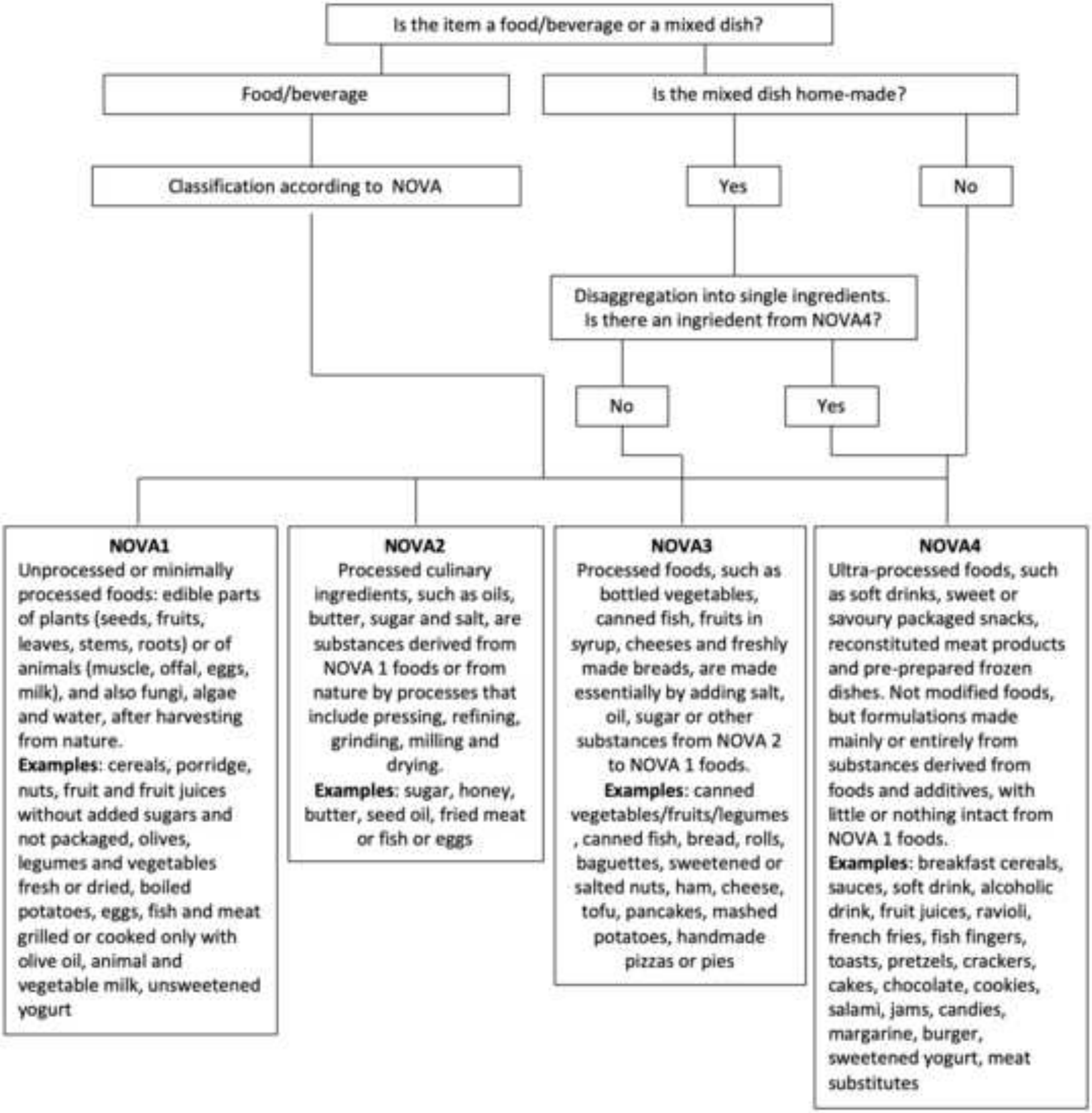
Highlights:

- Energy intake from Ultra Processed Foods (UPFs) represents almost half of the daily energy intake within our study population, and this trend decrease progressively with age with no differences by cultural and socio-economic status;
- Considering the quintiles of the dietary share of UPFs, energy intake increases across the quintiles, and diet quality is significantly lower in the fifth quintile than in the first;
- The consumption of foods rich in calories and low in nutritional content, operationally defined as "junk food", is significantly higher in the fifth quintile of the dietary share of UPFs;
- A North/South Europe divide is observed in processed food consumption in that North European consumes more UPFs.

Figure 1 Click here to access/download;Figure(s);figure_1.tiff

Figure 2 Click here to access/download;Figure(s);figure_2.tiff



Supplemental Figure

Online Supporting Material

Consiglio Nazionale delle Ricerche

Istituto di Scienze dell'Alimentazione

Avellino, June 30th, 2021

To:
Prof. Pasquale Strazzullo
Editor, Nutrition, Metabolism and Cardiovascular Diseases
Re: MANUSCRIPT NMCD-D-21-00523R1 **"Ultra-processed foods consumption and diet quality of European children, adolescents and adults: results from the I.Family study "** by F. Lauria et al.

Dear Editor,

We would like to submit the revision of the paper in reference. We wish to thank the reviewers for their suggestions and comments that allowed us to improve the paper. A detailed point-by-point reply is attached to the re-submission, while all the changes are highlighted in the revised manuscript. We hope that now the paper could be suitable for publication on Nutrition, Metabolism and Cardiovascular Diseases.
All authors have read and approved the new version of the manuscript. The manuscript has not been published and is not being considered for publication elsewhere. We declare that no conflict of interest exists with this paper.

Best regards

Fabio Lauria, on behalf of the authors

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Editor's comment: This Editor believes that in their revised version the authors effectively met the reviewers' criticisms and suggestions. However, I recommend a careful further reading of the manuscript in order to amend a few gramatical errors and typos throughout the paper.

Moreover, I suggest to reconsider the following sentences which are quite long and/or hard to understand: pg 8 (lines 90-95), pg 11 (lines 156-9), pg 16 (lines 287-92).

The authors wish to thank the Editor for the suggestions. The text was checked for errors and typos.

pg 8 (lines 90-95): the sentence was clarified.

pg 11 (lines 156-9): the sentence is part of the description of the statistical methods. It could look quite difficult to understand for non-statisticians, but the authors are in favour to keep it as it is, because it could be of help for other statistical experts for analyses in which when daily variance in diet needs to be accounted for. Of course, the authors are ready to delete the sentence in the case the editor would prefer so.

pg 16 (lines 287-92): the long sentence was divided into two sentences.

Ultra-processed foods consumption and diet quality of European children, adolescents and adults: results from the I.Family study

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Competing Interests

Authors Paola Russo and Alfonso Siani have editorial roles in Nutrition, Metabolism and Cardiovascular Diseases.

Registration

The Pan-European IDEFICS/I.Family children cohort is registered under ISRCTN62310987 (https://www.isrctn.com/ISRCTN62310987). Date assigned: 23/02/2018.

Keywords

Nova classification, Ultra-processed foods, diet quality, children, adolescents, adults

Abbreviations list

%TEI = Percentage of the Total Energy Intake

24-HDR = 24-h dietary recall

ANOVA = One-way analysis of variance

BLS = Bundeslebensmittelschlüssel

BMI = Body Mass Index

CEHQ = Children's Eating Habits Questionnaire

CI = Confidence Intervals

FFQ = Food Frequency Questionnaire

HDAS = Healthy Dietary Adherence Score

MPFs = Unprocessed or Minimally Processed Foods

NCDs = Non-Communicable Diseases

NCI-method = U.S. National Cancer Institute -method

PCIs = Processed Culinary Ingredients

PFs = Processed Foods

SACANA = Self-Administered Children, Adolescents, and Adult Nutrition Assessment

SACINA = Self-Administered Children and Infant Nutrition Assessment

SD = Standard Deviation

UPFs = Ultra-Processed Foods

Word count of the abstract = 277

Word count of the text = 4847

Number of references = 66

Number of tables = 4

Number of figures = 2

Abstract

Background and Aims: Food processing has been indicated as a factor capable of negatively affecting the global food system, including the profile of consumers' diets. The objectives of the present study were to provide a description of the consumption of ultra-processed foods (UPFs) in the large population of children, adolescents and adults from eight European countries participating to the I.Family study, and to investigate the association between UPFs intake and nutritional quality of the diet. **Methods and Results:** Dietary intake was assessed using a 24-h dietary recall. The quality of the diet was evaluated by the Healthy Dietary Adherence Score (HDAS) using an FFQ. UPFs were classified according to the NOVA classification. Almost half of the daily energy intake of the 7 073 participants came from UPFs, and this trend decreased progressively with age. UPFs contributed more than 50% of the daily intake of total and saturated fat, carbohydrates and about 70% of sugars intake in children and adolescents. No differences in UPFs consumption were found according to the educational and socio-economic status of the population. Energy intake increased across the quintiles of UPFs intake, while HDAS decreased. The frequency of consumption of fruit and vegetable, fish, and fibre rich foods was low in the fifth quintile of UPFs intake, both in adolescents and in adults. The consumption of foods rich in calories and low in nutritional content, operationally defined as "junk food", was significantly higher in the fifth quintile. **Conclusions**: in the population of the European I.Family study, UPFs contributed a large proportion of the daily energy intake, especially in children and adolescents. Higher consumption of UPFs was associated with a lower quality of the diet.

Registration number for clinical trials: ISRCTN62310987

Introduction

Food processing has played a leading role in human evolution making foods more edible, palatable, safe and easy to use, offering more variety in foods, and preserving them for long periods by controlling all the parameters necessary to maintain or minimize the loss of the nutritional quality [1]. However, in the recent years, the type, intensity and purpose of food processing has been perceived as a factor negatively affecting the global food system, including the profile of diets and consumers' health [2]. Until a few decades ago, dietary recommendations for healthy eating, in the form of guidelines, emphasized the role of specific nutrients and their vegetable or animal origin. More recently, guidelines have shifted attention to the overall diet by making recommendations concerning the amounts of foods, food groups, dietary patterns [3], and, increasingly, food processing [4–6].

There is no consensus among researchers regarding the classification of foods in terms of their degree of processing [7]. However, one widely used method in the scientific literature to comprehend the relationship between food processing and health is the NOVA classification system [8]. This classification divides all foods into four groups according to their degree of processing as follow: unprocessed or minimally processed foods (MPFs), processed culinary ingredients (PCIs), processed foods (PFs), and ultra-processed foods (UPFs) [8].

UPFs consumption and availability are rapidly increasing globally in both high- and lower- income countries, with estimate contribution of UPF to the total energy intake ranging from 10% to 60% in different countries [9–15].

UPFs consumption has been shown to be associated with sociodemographic characteristics. Studies in high income countries have found that UPFs consumption was high among younger aged [11–13,15–17], less educated and low-income individuals [11,16].

In addition, recent literature has supported the association of UPFs consumption with a high risk to develop obesity [18,19] and other diet-related chronic non-communicable diseases (NCDs) [20], such as type 2 diabetes, hypertension [21], cardiovascular and all cause mortality [22] and some common cancers [23]. Several studies have found an inverse association between consumption of specific MPFs and weight gain [24,25]. However, no clear and strong conclusions can be drawn due to very limited direct research on the relationship between processed foods as a group and NCDs, specifically obesity[18].

Nevertheless, it has been recognized that UPFs have lower nutritional quality compared to less processed foods [10,26] and several studies have shown the negative impact of elevated consumption of UPFs on the nutritional profile of diets [13,27–29]. A positive linear trend was found between UPFs consumption and sugar intake [13,14,16,20,30], and total, saturated and fatty acids intake [13,14,20,30]. The opposite trend was found for proteins [13,20,30] and fibre [13,16,20]. Replacing UPFs with a higher consumption of MPFs improved the quality of the diet [13].

Though considerable evidence indicates that the degree of food processing effectively predicts nutritional quality, in-depth studies are still needed to better understand all aspects related to the impact of the different NOVA foods groups on dietary nutritional profile of European countries. The large population of children, adolescents and adults from eight European countries participating in the I.Family study provided us the opportunity to fill these research gaps. The aim of the present analysis was twofold: first, we provided for the first time a description of the contribution of UPF to energy intake in eight European countries, using comparable data. Second, we investigated the association between UPF intake and nutritional quality of the diet assessed through rigorous and standardized approaches.

Methods

Study Population

Building on the earlier IDEFICS study, the population-based I.Family project (www.ifamilystudy.eu), was conducted from 2013 to 2018 to investigate the aetiology of diet- and lifestyle-related diseases in children, adolescents and their families in eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden). The follow-up examination took place in 2013/2014, including 7 228 of the 16 229 children participating in the IDEFICS study (www.ideficsstudy.eu), their parents (n=7 788) and siblings (n=2 364) [31]. All measures used in the present investigation were obtained using standardized procedures in all eight countries. Questionnaires were developed in English, translated into local languages and then back-translated to check for translation errors. Details of the general design, instruments, and survey characteristics can be found elsewhere [32].

For the present cross-sectional analysis, a total of 7 073 participants (males 41.6%, normal weight 64.7%, high ISCED 55.8%, high INCOME 28.2%), with sociodemographic and anthropometric information available, and at least one 24h dietary recall completed, were eligible, after the exclusion of 10 307 participants (males 45,2%, normal weight 54.7%, high ISCED 48.0%, high INCOME 18.7%) with missing data on key variables. Compared to the original full cohort, this means that our sample is somewhat biased toward better educated and higher income families. The flow chart of the selection process is shown in **Figure 1**.

Ethics

In each country, the participating centres obtained ethical approval from the local ethics committees. Parents and children from the age of 12 provided written informed consent for all examinations. Younger children were consented by their parent. In all cases, each child was informed orally about all procedures by field workers and asked for his/her consent immediately before the examination. This study was conducted according to the standards of the Declaration of Helsinki.

Dietary Data

Dietary intake was assessed using the web-assisted 24-HDR, called SACANA ("Self-Administered Children, Adolescents, and Adult Nutrition Assessment"). This 24-HDR has been validated as a self-reporting instrument for assessing dietary intakes in children, adolescents and adults [33,34]. A full description of the SACANA software can be found elsewhere [35].

The first 24-HDR was completed at the examination centre and it was recommended to complete another two 24-HDRs on non-consecutive days including one weekend day during the next 2 weeks. Most participants from our study population reported more than one 24HDR (only one 39.6 %, exactly two 19.1%, and three or more 41.4%). Parents were asked to assist smaller children (<11 years) in completing their 24-HDR.

Participants reported information on the amount and type of foods and drinks consumed during the previous day, starting from the first intake after waking up in the morning. Estimation of portion size was facilitated using standardized photographs [36]. The German Food Collection Tables Bundeslebensmittelschlüssel (BLS) were linked to each food or recipe in order to calculate energy and nutrients intake [37]. The choice to use German BLS database was a pragmatic approach, aiming to improve comparability between countries. This approach was based on a previous analysis on the adolescents' cohort of the HELENA study that compared 24-h recall data linked to the local/national food composition databases with 24-h recall data linked to the German BLS database, which includes a larger food list. Strong correlations (0.70–0.95) were found between both methods for all nutrients [38]. To evaluate the diet quality, the Healthy Dietary Adherence Score (HDAS) was calculated using a food frequency questionnaire (FFQ), which was part of the Children's Eating Habits Questionnaire (CEHQ) [39].

The self-administered CEHQ-FFQ was designed as a screening tool to assess eating behaviours associated with risk of overweight, obesity and general health. It was completed at home by reporting the number of times participants consumed the food groups included in the questionnaire during a typical week over the previous month. The FFQ was found to provide reproducible and valid data [40,41]. It included 43 Pan-European food items clustered into 14 food groups according to their nutritional profiles [42], and also to make them comparable to the food categories of the 24-HDR.

HDAS is a measure of the degree of adherence to the dietary guidelines developed according to the principles reviewed by Waijers et al.[43]. Healthy dietary recommendations suggest to: limit the intake of refined sugars, reduce fat intake, especially of saturated fat, choose whole meal when possible, consume 400–500 g of fruits and vegetables per day and fish 2–3 times per week. Hence, the HDAS considers five components: 1. sugar, 2. fat, 3. whole meal, 4. fruits and vegetables, and 5. fish. Each component has a minimum score of 0 and a maximum score of 10, the final HDAS added up to a maximum score of 50, where the highest score indicates the highest possible adherence to the dietary guidelines [39]. The analysis of diet quality also considered the frequency of consumption, in time per day, of the following food groups: fruit and vegetables (including: potatoes, vegetables, legumes, fresh fruit), "junk food" (including: sugar sweetened drinks, chocolate/nut-based spread, salty and sweet snacks, ice cream, milk or fruit based bars that are foods rich sugar, in fat, and/or salt but low in nutritional content), fish (including: not fried, fried, coated and canned fish), milk and yogurt, fatty foods (including: fried potatoes/potato croquettes, fried and/or coated fish, fried meat and poultry, fried and/or coated fish), simple sugar foods (including: fruit juices, not carbonated sugar sweetened drinks, sweetened breakfast cereals, sweetened milk and yogurt, sweet snacks, biscuits, packaged cakes or pastries and puddings, ice cream, milk or fruit based bars, jam, honey), fibres rich foods (including: potatoes, vegetables, legumes, fresh fruit, whole meal bread/dark roll/dark crispbread, whole meal pasta/noodles/brown rice/other cereals, nuts and seeds, dried fruits, unsweetened cereals/porridge), dairy products (including: milk, yogurt, cheese, butter/margarine on bread), red meat (including: cold cuts and preserved meat products, fried and not fried meat). Since no public health organizations have given a common definition of junk food, for the purpose of the present analysis we operationally defined the food group "junk food", according to the available evidence [44].

NOVA classification

Monteiro et al. described MPFs as parts of plants or animals which have not undergone industrial processes or that were not altered by methods and processes chosen to preserve their nature [8,45]. PCIs comprise oils, lard, butter, salt and sugar. They may be obtained from the MPFs group or from nature via industrial processes and can be used at home and in restaurants in combination with other foods to prepare tasty meals and dishes [8,45]. PFs such as canned fish and vegetables, fruit in syrup, smoked meats and cheese are essentially prepared by adding oil, salt, sugar and other substances from MPFs and PCIs groups [8,45]. Finally, UPFs are defined as multi-ingredient formulations made at an industrial level by processes that cannot be realised in households, aimed at creating standardised foods ready to consume, eat or heat up [8,45]. Generally, they contain different additives (e.g. flavours, emulsifiers, colours, artificial sweeteners) used to improve the sensory characteristics of the final product or to hide unwanted organoleptic characteristics [8,45,46]. Into this category fall soft drinks, fruit drinks, fruit juices made from concentrates, sweet or savoury packaged snacks, chocolate, candies, instant soups, packaged pre-prepared meals, breakfast 'cereals', potato crisps and fast-food-meals [45,47]. Strong advertising and marketing of these products encourage preferences and consumption as compared to MPFs[48].

Each food and beverage reported in the 24-HDR interview was classified according to the NOVA classification [45] on the basis of the extent and purpose of industrial food processing. In the case of home-made recipes, to ensure a more accurate classification, the ingredients were considered. Three co-authors independently reviewed the classification of each item. Discrepant classifications were resolved by discussion. **Figure 2** describes the classification process.

To estimate the corresponding individual usual daily intakes of energy, protein, fat, saturated fatty acids, carbohydrates, sugar and fibres in the 4 NOVA groups separately for the three different age groups the so-called U.S. National Cancer Institute -method (NCI-method) was applied [49]. The method assumes a non-linear mixed effect measurement error model to estimate the association between covariates and reported intake. Furthermore, the model includes a random effect term for interindividual variation and a random variable for daily or intraindividual variation. Since intake distributions are often skew, the Box-Cox transformation is used in this model. Following the regression calibration approach, the individual usual intakes are then estimated as conditional mean intakes given the recalls and the individual covariates, using the estimated non-linear mixed effect measurement error model. Thus, the method corrects for variance inflation caused by daily variation in diet and does not require repeated measurements for every participant. In our analysis we used age, body mass index (BMI), sex and the sequence of recall days as covariates. If intake distribution was zero-inflated, i.e., if a NOVA group was not consumed daily, the NCI-method additionally considers the consumption probability. For this part of the analysis the statistical software SAS 9.3 was used.

For each NOVA group, the relative contribution of foods in that category to the total energy intake for each participant was computed. Finally, the UPFs group was divided into age- and sex-specific quintiles according to relative energy contribution of that category.

Socio-economic data

Socio-demographic data were collected using a questionnaire filled in at home by parents. The parental education level was assessed by asking parents for their highest educational attainment and categorized according to the International Standard Classification of Education (ISCED) into low (ISCED levels 1 and 2), medium (ISCED levels 3 and 4), and high (ISCED level 5) educational attainment [50].

Household income was assessed using country-specific categories based on the median equivalent income. The total amount was then equalized to the number of household members using the Organization for Economic Co-operation and Development’s square root scale [51].

Anthropometric Measurements

A detailed description of the anthropometric measurements in the I.Family study, including intra- and inter-observer reliability, has been published elsewhere [52].

Weight was determined to the nearest 0.1 kg using a body composition analyzer (Tanita BC 420 SMA, Tanita Europe GmbH, Sindelfingen, Germany) with participants in fasting status, without shoes and with light clothing. Height was measured with a calibrated stadiometer (Seca 225, Seca GmbH & Co., KG., Hamburg, Germany) and recorded to the nearest 0.1 cm. BMI was calculated by dividing body weight (in kg) by height squared (in m^2). Children and adolescents were classified as normal weight, overweight, or obese according to the cut-offs released by the International Obesity Task Force [53]. For adults, a BMI less than 25 kg/m^2 was considered normal weight, a BMI greater than or equal to 25 to 29.9 kg/m^2 was considered overweight and a BMI greater than or equal to 30 kg/m^2 was considered obese [54].

Statistical analysis

All of the analyses were performed by age groups (6<10 years, 10<20 years, >20 years) [55]. Data were expressed as mean and standard deviation (SD) or 95% confidence intervals (95% CI), as indicated in the tables.

For the analysis, the usual daily energy intake in kilo calories (kcal) and the total intake of principal macronutrients (protein, fat, saturated fatty acids, carbohydrates, sugars, fibre) expressed in grams, the percentage contributions to total energy intake (%TEI) of protein, fat, saturated fatty acids, carbohydrates, sugars, and for the fibre, the total daily amount in grams per 1 000 kcal were calculated.

In order to evaluate the nutritional content of the diet by age, country of origin, and NOVA food groups we used one-way analysis of variance (ANOVA) and the multiple comparison with the Bonferroni correction. Analysis of variance (general linear model) was performed to compare the nutritional profile and the diet quality across the quintiles of UPF %TEI. The model was adjusted for sex, age, country of origin, family income, family ISCED and total daily energy. The model was adjusted for total daily energy following Willett et al. (1997) to prevent for confounding if the energy intake itself is associated with the outcome [56].IBM SPSS Statistics (Version 23.0. IBM Corp., Armonk, NY, USA) was used for the statistical analyses, and statistical significance was accepted at *p*-value less than 0.05.

Results

A total of 7 073 subjects (female = 58%) were included in the analysis (**Figure 1**). The proportion of foods consumed by the extent of processing (NOVA classification) and by study population characteristic are displayed in **Table 1**. Almost half of the usual daily energy intake in both sexes came from UPFs, although in males the average percentage of daily energy intake (%TEI) was slightly higher than in females. Females consumed a higher proportion of their usual daily energy intake from MPFs and PFs compared to males. PCIs represented a negligible percentage of usual total daily energy intake in the whole samples, though higher in males.
Usual energy intake from UPFs tended to decrease progressively with age, and was lower in adults.
Conversely, MPFs and PFs consumption increased with age and was higher in adults.
No differences in consumption of UPFs by educational or socio-economic status were found.
Considering MPFs, we observed a reduction of the %TEI as the levels of ISCED increased and an increase in the participants with lower income levels. For PCIs and PFs we noted a reverse trend, with higher consumption of %TEI in the higher levels of ISCED and income.

Differences in NOVA food group consumption were found by country. Participants from Spain consumed the highest proportion of MPFs, followed by Italy (both 34%);

in Estonia and Germany we found the highest consumption of PCIs (6% and 5% respectively); participant from Sweden, Belgium and Cyprus consumed the highest proportion of PFs; in Belgium and Germany about half of the %TEI came from UPFs (respectively 49% and 48%). The consumption of UPFs % TEI was reduced with increasing BMI in all age groups, the opposite trend was observed for the contribution in %TEI from the consumption of MPFs, PCIs, and PFs which increased from normal weight to obese subjects.

The nutritional content of consumed foods, weighted by relative intake in grams, by age groups is shown in **Table 2**. UPFs were highest in caloric intake in each group. Almost half of the usual daily energy intake came from UPFs, the average contribution decreased in adults (49.0%, 48.8%, and 40.2%, in 6-10, 10-20, and > 20 years group, respectively). UPFs contributed more than 50% of the usual daily intake of total fat, saturated fat, carbohydrates and about 70% of usual sugar intake in children and adolescents. The MPFs contributed to the highest usual intake of protein and fiber, in all the age groups. Usual fiber intake was on average higher in adults (10.4 g / 1 000kcal) than in the other age groups. PCIs were lowest in energy and nutrients intake, in all age groups.

As shown in **Table 3**, the usual energy intake from UPFs increased across the quintiles, and values in the fifth quintile were statistically significantly higher than in the first 3 quintiles, both in the 10-20 years age group and in adults. Usual protein intake, both in grams per day and in percentage of the total energy intake, showed a negative and statistically significant trend across the quintiles in all age groups. No differences were found in usual total and saturated fat intake, both in grams per day and percentage of the total energy intake, across the quintiles in all age groups. Usual carbohydrate intake increased across the quintiles in the 6-10 years group, while no statistically significant differences were observed in other age groups. Usual sugar intake increased across the quintiles, with the highest intake in the fifth quintile in the 6-10 years group, and higher in the fifth quintile compared to the first 3 quintiles in the 10-20 years group. Usual fiber intake decreased across the quintiles, in all age groups, with the fifth quintile statistically significantly lower than all other quintiles. Differences in usual energy and nutrients intake were found among countries in the different age groups (**Supplemental Figure 1**). For children and adolescents, the contribution of UPFs to usual total energy intake was highest in Belgium, Germany and Sweden. MPFs contributed to a greater percentage of usual protein intake in Italy and Spain. UPFs contributed to the highest consumption of total fat and saturated fatty acids in all age groups, with a lower consumption of total fat and saturated fatty acids observed in Italy compared to the other countries, in all age groups. The highest contribution in usual carbohydrates and sugar intake was given by UPFs, in the 6-10 years group in all countries. After Italy, where all age groups obtained the most energy from carbohydrates, we saw that children and adolescents from Germany, and adults from Belgium consumed the most energy from carbohydrates compared to other countries. The consumption of sugars was greater in German children, and in Estonian adolescents and adults, in Italy we observed the lowest usual intake of sugars in the 6-10 and 10-20 age groups. The greatest contribution of carbohydrates and sugars for Germany came from UPFs in all age groups. MPFs and UPFs highly contributed to fiber consumption in all age groups (**Supplemental Figure 1**).

Table 4 shows the HDAS according to quintiles of the UPFs dietary share by age group, as well as the consumption frequency of specific food groups considered in our analysis. The HDAS was significantly lower in the fifth quintile than in the first in all age groups, and overall tended to decrease across quintiles. The frequency of consumption of fruit and vegetables, fish, and fiber rich foods was the lowest in the fifth quintile for the 10-20 years and adult age groups. Junk food consumption was significantly higher in the fifth quintile in each group. In addition, in adults we observed the highest frequency of consumption of simple sugar foods in the fifth quintile.

Discussion

The present study assessed the share of the NOVA foods group in the diets of European children, adolescents and adults, using individual-level data from a large multinational sample belonging to the I.Family study, also considering participants' sociodemographic characteristics.

In the last decades, we have seen a widespread increase in diffusion and consumption of UPFs in both developed and developing countries [45], including Europe [10]. In Spain the percentage of UPFs in all food purchases almost tripled between 1990 and 2010 (from 11.0 to 31.7%) [57]. In 2015 data from the U.K. found that a mean of 53% of energy was derived from UPFs [58]. In

France UPFs play an important role in the diet with about 36% of energy intake coming from this NOVA group [16]. In our study population, which consisted of 7 073 individuals from eight European countries, we found that the percentage of daily energy contribution from UPFs ranged from 43% in Spain and Cyprus to 49% in Belgium. Interestingly, our data provide a quite different scenario as compared to that reported by Monteiro et al in their analysis of the household availability of NOVA food groups in nineteen European countries [10] . The average household availability of ultra-processed foods ranged from 10.2 % in Portugal and 13.4 % in Italy to 46.2 % in Germany and 50.4 % in the UK in the paper by Monteiro et al. In our population, a more homogenous pattern was observed, with children and adolescents obtaining about 50% of the usual daily calories from UPFs, and adults about 40%. Different hypotheses can be raised to explain the differences. First, the data analysed by Monteiro and colleagues were collected on average twenty years ago, and may no longer reflects the dietary changes that occurred recently in some countries particularly those of Southern Europe. Second, data collected from household surveys are by definition different from individual-level data as those analysed in the present study.

Another interesting finding of the present paper is that UPFs consumption decreased with age and did not vary with education and income levels. Lack of differences among socio-economic strata indicate how UPFs consumption has reached all classes of population. This marks an important shift in dietary patterns of the entire European population, traditionally characterized by the consumption of healthy, and home-made foods, and bringing them ever closer to dietary patterns associated with the United States. There are some variations, however. Participants from Belgium, Germany and Sweden showed the highest energy intake from consumption of UPFs and the lowest from MPFs, as opposed to Italy, Spain and Cyprus. The same stratification was also detectable for the percentage of protein, fat and sugars obtained from UPFs consumption, in all age groups. This data suggests, then, a North/South divide in Europe relating to processed food consumption. These differences may be attributed to the cultural and dietary traditions that distinguish North European and Mediterranean populations, despite the evident increase in fruit and vegetable consumption in the North and increase in animal-based product consumption in the South [59].

Increased consumption of UPFs is accompanied by a reduction in diet quality [45,60]. Results showed that UPFs consumption is characterized by a high usual daily intake of total fats, saturated fats, and carbohydrates [61]. Fiber intake did not reach the adequate intake [62] in all age groups in the different countries. We also evaluated diet quality with reference to the quintiles of UPFs dietary share. In the fifth quintile, the HDAS was generally low and this was confirmed by a diet characterized by a high consumption of junk foods and a low consumption of fruit and vegetables, fish and fiber rich foods, in all age groups. These findings correspond to our further finding (data not shown) that children and adolescents had worse diet quality than adults, as also reported by other researchers [63].

The negative influence of UPFs consumption on dietary quality that we observed is in line with results previously reported [16,20,30]. However, we should note that our data did not show two patterns that other authors have reported. In adults, we did not see an association between dietary share of UPFs and increased usual intake of carbohydrates and sugar. In the whole population, we did not see an association between dietary share of UPFs and total saturated fat intake. This may be due to the specific characteristics of the diet of the different age groups and the different countries being investigated.

Our results lend further support to the finding that, while processes of industrialization, economic development and market globalization have improved standards of living in many countries, they also correspond to negative consequences in terms of unhealthy diets [64]. These changes seem to be responsible for the increase of diet-related chronic diseases and some forms of cancer in developed countries [64]. Specifically, previous studies have confirmed a positive association between the consumption of UPFs and obesity [10]. However, although higher intakes of UPFs were associated with unhealthier dietary profiles in our sample, and the usual energy intake from this food group increased across the quintiles, UPFs consumption was low in subjects with higher values of BMI. This finding could be interpreted in line with previous studies showing that children and adolescents with overweight or obesity report energy intakes similar or even lower than normal weight peers (64). Social desirability reporting bias cannot be excluded, even when appropriate instruments for dietary assessment are used.

Our study has limitations as well as strengths. The cross-sectional nature of the study limits our results. Moreover, the studied sample is not representative of the whole European population, although our findings mostly correspond with studies on other populations in Europe. An important strength is the large study sample with comprehensive data on diet, socio-economic levels and anthropometry. The use of two different methods to evaluate diet, a 24-HDR and a validated FFQ, is another strength. 24-HDR is likely to give a more accurate assessment of total dietary intake, and the availability of more than one dietary interview resulted in a reduction both in error and bias. Moreover, the recoding of all interviews using the German Food Collection Tables Bundeslebensmittelschlüssel, thanks to its regular updates, improves the quality of the dataset. Finally, since measurement error is a common issue in dietary data [65], we applied the NCI-method to estimate usual intakes of food groups and to reduce bias in effect estimates due to variance inflation. In doing so, we also took into account the influence of covariates and consumption probability. Furthermore, we used categorized dietary exposures which might additionally reduce bias in effect estimates [66], allowing us to take a more realistic view of the cohort's consumption habits.

In conclusion, the present study showed that most of the daily energy intake of European consumers comes from UPFs, and that an increase in the consumption of UPFs is associated with unhealthy dietary patterns characterized by high consumption of sugars and low consumption of protein and fiber. Given the pervasiveness of ultra-processed foods among the different socio-economic strata, this data confirms the need for policies to improve food quality and to make it easier for consumers, especially children and adolescents, to access healthier foods and drinks.

Acknowledgement

This research was done in the framework of the I.Family study (http://www.ifamilystudy.eu/). We are grateful for the participation of European children and their parents in this examination. We acknowledge the support received from school boards, headmasters, and communities.

Funding

This work was supported by the European Commission within the Seventh RTD Framework Program Contract No. 266044; The study was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 391977161.

Competing Interests

Authors Paola Russo and Alfonso Siani have editorial roles in Nutrition, Metabolism and Cardiovascular Diseases. According to the Journal's rules, every effort is made to minimise any bias in the review process by having another Editor independently handling the peer review procedure of the manuscript.

References

[1] Allende A, Tomás-Barberán FA, Gil MI. Minimal processing for healthy traditional foods. Trends in Food Science and Technology 2006;17:513–9. https://doi.org/10.1016/j.tifs.2006.04.005.

[2] Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. Public Health Nutrition 2009;12. https://doi.org/10.1017/S1368980009005291.

[3] Reedy J, Subar AF, George SM, Krebs-Smith SM. Extending methods in dietary patterns research. Nutrients 2018;10. https://doi.org/10.3390/nu10050571.

[4] PNNS. Superior Health Council. Pnns 2015;Edidtion c.

[5] Superior Health Council [Internet]. Available from: www.shc-belgium.be.

[6] Ministry of Health of Brazil Secretariat of Health Care Primary Health Care Department B. Dietary GuiDelines for the Brazilian PoPulation. Available from: http://189.28.128.100/dab/docs/portaldab/publicacoes/guia_alimentar_

[7] Gibney MJ, Ciar´ C, Forde CG, Mullally D, Gibney ER. Ultra-processed foods in human health: a critical appraisal n.d. https://doi.org/10.3945/ajcn.

[8] Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada MLC, Jaime PC. The un Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. Public Health Nutrition 2018;21:5–17. https://doi.org/10.1017/S1368980017000234.

[9] Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. Obesity Reviews 2013;14. https://doi.org/10.1111/obr.12107.

[10] Monteiro CA, Moubarac JC, Levy RB, Canella DS, da Costa Louzada ML, Cannon G. Household availability of ultra-processed foods and obesity in nineteen European countries. Public Health Nutrition 2018;21:18–26. https://doi.org/10.1017/S1368980017001379.

[11] Baraldi LG, Martinez Steele E, Canella DS, Monteiro CA. Consumption of ultra-processed foods and associated sociodemographic factors in the USA between 2007 and 2012: Evidence from a nationally representative cross-sectional study. BMJ Open 2018;8. https://doi.org/10.1136/bmjopen-2017-020574.

[12] Marrón-Ponce JA, Sánchez-Pimienta TG, da Costa Louzada ML, Batis C. Energy contribution of NOVA food groups and sociodemographic determinants of ultra-processed food consumption in the Mexican population. Public Health Nutrition 2018;21:87–93. https://doi.org/10.1017/S1368980017002129.

[13] Moubarac JC, Batal M, Louzada ML, Martinez Steele E, Monteiro CA. Consumption of ultra-processed foods predicts diet quality in Canada. Appetite 2017;108. https://doi.org/10.1016/j.appet.2016.11.006.

[14] MacHado PP, Steele EM, Levy RB, Sui Z, Rangan A, Woods J, et al. Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: Evidence

from a nationally representative cross-sectional study. BMJ Open 2019;9. https://doi.org/10.1136/bmjopen-2019-029544.

[15] Cediel G, Reyes M, da Costa Louzada ML, Martinez Steele E, Monteiro CA, Corvalán C, et al. Ultra-processed foods and added sugars in the Chilean diet (2010). Public Health Nutrition 2018;21:125–33. https://doi.org/10.1017/S1368980017001161.

[16] Julia C, Martinez L, Allès B, Touvier M, Hercberg S, Méjean C, et al. Contribution of ultra-processed foods in the diet of adults from the French NutriNet-Santé study. Public Health Nutrition 2018;21:27–37. https://doi.org/10.1017/S1368980017001367.

[17] Vandevijvere S, de Ridder K, Fiolet T, Bel S, Tafforeau J. Consumption of ultra-processed food products and diet quality among children, adolescents and adults in Belgium. European Journal of Nutrition 2019;58:3267–78. https://doi.org/10.1007/s00394-018-1870-3.

[18] Poti JM, Braga B, Qin B. Ultra-processed Food Intake and Obesity: What Really Matters for Health-Processing or Nutrient Content? Current Obesity Reports 2017;6:420–31. https://doi.org/10.1007/s13679-017-0285-4.

[19] Costa CS, Del-Ponte B, Assunção MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: A systematic review. Public Health Nutrition 2018;21:148–59. https://doi.org/10.1017/S1368980017001331.

[20] Rauber F, Louzada ML da C, Steele EM, Millett C, Monteiro CA, Levy RB. Ultra-processed food consumption and chronic non-communicable diseases-related dietary nutrient profile in the UK (2008–2014). Nutrients 2018;10. https://doi.org/10.3390/nu10050587.

[21] de Deus Mendonça R, Souza Lopes AC, Pimenta AM, Gea A, Martinez-Gonzalez MA, Bes-Rastrollo M. Ultra-processed food consumption and the incidence of hypertension in a mediterranean cohort: The seguimiento universidad de navarra project. American Journal of Hypertension 2017;30:358–66. https://doi.org/10.1093/ajh/hpw137.

[22] Bonaccio M, di Castelnuovo A, Costanzo S, de Curtis A, Persichillo M, Sofi F, et al. Ultra-processed food consumption is associated with increased risk of all-cause and cardiovascular mortality in the Moli-sani Study. The American Journal of Clinical Nutrition 2021;113. https://doi.org/10.1093/ajcn/nqaa299.

[23] Fiolet T, Srour B, Sellem L, Kesse-Guyot E, Allès B, Méjean C, et al. Consumption of ultra-processed foods and cancer risk: Results from NutriNet-Santé prospective cohort. BMJ (Online) 2018;360. https://doi.org/10.1136/bmj.k322.

[24] Bertoia ML, Mukamal KJ, Cahill LE, Hou T, Ludwig DS, Mozaffarian D, et al. Changes in Intake of Fruits and Vegetables and Weight Change in United States Men and Women Followed for Up to 24 Years: Analysis from Three Prospective Cohort Studies. PLoS Medicine 2015;12. https://doi.org/10.1371/journal.pmed.1001878.

[25] Alinia S, Hels O, Tetens I. The potential association between fruit intake and body weight - A review. Obesity Reviews 2009;10. https://doi.org/10.1111/j.1467-789X.2009.00582.x.

[26] Monteiro CA, Levy RB, Claro RM, de Castro IRR, Cannon G. Increasing consumption of ultra-processed foods and likely impact on human health: Evidence from Brazil. Public Health Nutrition 2011;14:5–13. https://doi.org/10.1017/S1368980010003241.

[27] da Costa Louzada ML, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. Public Health Nutrition 2018;21. https://doi.org/10.1017/S1368980017001434.

[28] Cornwell B, Villamor E, Mora-Plazas M, Marin C, Monteiro CA, Baylin A. Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. Public Health Nutrition 2018;21. https://doi.org/10.1017/S1368980017000891.

[29] Martínez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: Evidence from a nationally representative cross-sectional study. Population Health Metrics 2017;15. https://doi.org/10.1186/s12963-017-0119-3.

[30] de Miranda RC, Rauber F, de Moraes MM, Afonso C, Santos C, Rodrigues S, et al. Consumption of ultra-processed foods and non-communicable diseases-related nutrient profile in Portuguese adults and elderly (2015-2016): The Upper project. British Journal of Nutrition 2020. https://doi.org/10.1017/S000711452000344X.

[31] Ahrens W, Bammann K, Siani A, Buchecker K, de Henauw S, Iacoviello L, et al. The IDEFICS cohort: Design, characteristics and participation in the baseline survey. International Journal of Obesity 2011;35. https://doi.org/10.1038/ijo.2011.30.

[32] Ahrens W, Siani A, Adan R, de Henauw S, Eiben G, Gwozdz W, et al. Cohort Profile: The transition from childhood to adolescence in European children-how I.Family extends the IDEFICS cohort. International Journal of Epidemiology 2017;46. https://doi.org/10.1093/ije/dyw317.

[33] Intemann T, Pigeot I, de Henauw S, Eiben G, Lissner L, Krogh V, et al. Urinary sucrose and fructose to validate self-reported sugar intake in children and adolescents: results from the I.Family study. European Journal of Nutrition 2019;58. https://doi.org/10.1007/s00394-018-1649-6.

[34] Murtas R, Krogh V, Intemann T, Lissner L, Eiben G, Molnár D, et al. Does Providing Assistance to Children and Adolescents Increase Repeatability and Plausibility of Self-Reporting Using a Web-Based Dietary Recall Instrument? Journal of the Academy of Nutrition and Dietetics 2018;118. https://doi.org/10.1016/j.jand.2018.07.017.

[35] Hebestreit A, Wolters M, Jilani H, Eiben G, Pala V. Web-Based 24-h Dietary Recall: The SACANA Program, 2019. https://doi.org/10.1007/978-3-319-98857-3_5.

[36] Livingstone MBE, Robson PJ. Measurement of dietary intake in children. Proceedings of the Nutrition Society, vol. 59, 2000. https://doi.org/10.1017/S0029665100000318.

[37] Hebestreit A, Barba G, de Henauw S, Eiben G, Hadjigeorgiou C, Kovács É, et al. Cross-sectional and longitudinal associations between energy intake and BMI z-score in European children. International Journal of Behavioral Nutrition and Physical Activity 2016;13. https://doi.org/10.1186/s12966-016-0344-3.

[38] Julián-Almárcegui C, Bel-Serrat S, Kersting M, Vicente-Rodriguez G, Nicolas G, Vyncke K, et al. Comparison of different approaches to calculate nutrient intakes based upon 24-h recall data derived from a multicenter study in European adolescents. European Journal of Nutrition 2016;55. https://doi.org/10.1007/s00394-015-0870-9.

[39] Arvidsson L, Eiben G, Hunsberger M, de Bourdeaudhuij I, Molnar D, Jilani H, et al. Bidirectional associations between psychosocial well-being and adherence to healthy dietary guidelines in European children: Prospective findings from the IDEFICS study. BMC Public Health 2017;17. https://doi.org/10.1186/s12889-017-4920-5.

[40] Lanfer A, Hebestreit A, Ahrens W, Krogh V, Sieri S, Lissner L, et al. Reproducibility of food consumption frequencies derived from the children's eating habits questionnaire used in the IDEFICS study. International Journal of Obesity 2011;35. https://doi.org/10.1038/ijo.2011.36.

[41] Bel-Serrat S, Mouratidou T, Pala V, Huybrechts I, Börnhorst C, Fernández-Alvira JM, et al. Relative validity of the Children's Eating Habits Questionnaire-food frequency section among young European children: The IDEFICS Study. Public Health Nutrition 2014;17. https://doi.org/10.1017/S1368980012005368.

[42] Pala V, Reisch LA, Lissner L. Dietary Behaviour in Children, Adolescents and Families: The Eating Habits Questionnaire (EHQ), 2019. https://doi.org/10.1007/978-3-319-98857-3_6.

[43] Waijers PMCM, Feskens EJM, Ocké MC. A critical review of predefined diet quality scores. British Journal of Nutrition 2007;97. https://doi.org/10.1017/S0007114507250421.

[44] Milani GP, Silano M, Pietrobelli A, Agostoni C. Junk food concept: Seconds out. International Journal of Obesity 2017;41. https://doi.org/10.1038/ijo.2017.18.

[45] Monteiro CA, Cannon G, Lawrence M, Laura Da Costa Louzada M, Machado PP. Ultra-processed foods, diet quality, and health using the NOVA classification system Prepared by. Available from: http://www.wipo.int/amc/en/mediation/rules.

[46] Monteiro CA, Cannon G, Levy R, Moubarac J-C, Jaime P, Martins AP, et al. NOVA. The star shines bright. World Nutrition 2016;7.

[47] Monteiro CA, Cannon G, Levy RB, Moubarac JC, Louzada MLC, Rauber F, et al. Ultra-processed foods: What they are and how to identify them. Public Health Nutrition 2019;22. https://doi.org/10.1017/S1368980018003762.

[48] Monteiro CA, Cannon G. The impact of transnational "big food" companies on the south: A view from brazil. PLoS Medicine 2012;9. https://doi.org/10.1371/journal.pmed.1001252.

[49] Kipnis V, Midthune D, Buckman DW, Dodd KW, Guenther PM, Krebs-Smith SM, et al. Modeling data with excess zeros and measurement error: Application to evaluating relationships between episodically consumed foods and health outcomes. Biometrics 2009;65. https://doi.org/10.1111/j.1541-0420.2009.01223.x.

[50] Schneider SL. The international standard classification of education 2011. Comparative Social Research 2013;30. https://doi.org/10.1108/S0195-6310(2013)0000030017.

[51] Growing Unequal? OECD; 2008. https://doi.org/10.1787/9789264044197-en.

[52] Stomfai S, Ahrens W, Bammann K, Kovács, Mårild S, Michels N, et al. Intra- And inter-observer reliability in anthropometric measurements in children. International Journal of Obesity 2011;35. https://doi.org/10.1038/ijo.2011.34.

[53] Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatric Obesity 2012;7. https://doi.org/10.1111/j.2047-6310.2012.00064.x.

[54] Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization - Technical Report Series 2000;894.

[55] The health of youth. WHO. Geneva, 1989 (document A42/Technical Discussions/2).

[56] Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. American Journal of Clinical Nutrition, vol. 65, 1997. https://doi.org/10.1093/ajcn/65.4.1220S.

[57] Latasa P, Louzada MLDC, Martinez Steele E, Monteiro CA. Added sugars and ultra-processed foods in Spanish households (1990–2010). European Journal of Clinical Nutrition 2018;72. https://doi.org/10.1038/s41430-017-0039-0.

[58] Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: Cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). International Journal of Behavioral Nutrition and Physical Activity 2015;12. https://doi.org/10.1186/s12966-015-0317-y.

[59] Balanza R, García-Lorda P, Pérez-Rodrigo C, Aranceta J, Bonet MB, Salas-Salvadó J. Trends in food availability determined by the Food and Agriculture Organization's food balance sheets in Mediterranean Europe in comparison with other European areas. Public Health Nutrition 2007;10. https://doi.org/10.1017/S1368980007246592.

[60] Bleiweiss-Sande R, Sacheck JM, Chui K, Goldberg JP, Bailey C, Evans EW. Processed food consumption is associated with diet quality, but not weight status, in a sample of low-income and ethnically diverse elementary school children. Appetite 2020;151. https://doi.org/10.1016/j.appet.2020.104696.

[61] Mertens E, Kuijsten A, Dofková M, Mistura L, D'Addezio L, Turrini A, et al. Geographic and socioeconomic diversity of food and nutrient intakes: a comparison of four European countries. European Journal of Nutrition 2019;58:1475–93. https://doi.org/10.1007/s00394-018-1673-6.

[62] Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. EFSA Journal 2010;8. https://doi.org/10.2903/j.efsa.2010.1462.

[63] de Andrade SC, Previdelli ÁN, Cesar CLG, Marchioni DML, Fisberg RM. Trends in diet quality among adolescents, adults and older adults: A population-based study. Preventive Medicine Reports 2016;4:391–6. https://doi.org/10.1016/j.pmedr.2016.07.010.

[64] World Health Organization. Globalization, diets and noncommunicable diseases. World Health Organization; 2002.

[65] Shaw PA, Deffner V, Keogh RH, Tooze JA, Dodd KW, Küchenhoff H, et al. Epidemiologic analyses with error-prone exposures: review of current practice and recommendations. Annals of Epidemiology 2018;28. https://doi.org/10.1016/j.annepidem.2018.09.001.

[66] Gustafson P, Le ND. Comparing the effects of continuous and discrete covariate mismeasurement, with emphasis on the dichotomization of mismeasured predictors. Biometrics 2002;58. https://doi.org/10.1111/j.0006-341X.2002.00878.x.

Table 1. *Distribution of sociodemographic characteristics for the whole population across NOVA food groups.*

Values are expressed as mean±SD. ISCED, International Standard Classification of Education;

	N	MPFs (%TEI)	PCIs (%TEI)	PFs (%TEI)	UPFs (%TEI)
GENDER					
All	7 073	29.3±7.4	4.4±2.8	20.8±5.2	45.4±8.2
Male	2 949	28.2±7.1	4.6±2.8	20.6±5.4	46.6±7.8
Female	4 124	30.1±7.5	4.3±2.8	21.0±5.0	44.6±8.3
AGE-GROUP					
6-10 ys	1 184	28.5±7.2	4.0±1.9	18.4±3.8	49.0±6.4
10-20 ys	3 061	28.0±6.9	3.9±2.0	19.3±4.2	48.8±6.5
>20 ys	2 828	31.1±7.7	5.2±3.5	23.5±5.4	40.2±7.6
ISCED					
low	255	31.6±7.6	3.9±2.0	19.2±5.6	45.4±7.1
medium	2 819	29.5±7.5	4.4±2.7	20.5±5.3	45.6±8.2
high	3 999	29.1±7.3	4.5±2.9	21.2±5.1	45.3±8.2
INCOME					
low	1 186	31.0±7.5	4.3±2.6	19.7±5.4	45.0±8.0
low-medium	578	30.3±7.6	4.1±2.3	20.3±5.3	45.3±8.1
medium	2 392	28.8±7.4	4.4±2.8	21.1±5.1	45.7±8.1
medium-high	934	28.7±7.5	4.3±2.8	21.4±5.0	45.6±8.1
high	1 983	29.0±7.1	4.8±3.0	21.1±5.1	45.2±8.3
COUNTRIES					
BEL	336	24.2±6.5	3.1±1.6	23.8±5.2	48.9±8.2
CYP	612	30.3±7.1	3.5±1.7	22.8±5.3	43.3±8.4
ESP	499	34.4±6.7	3.6±2.1	18.7±4.3	43.3±7.3
EST	1 833	29.0±7.0	6.0±3.6	20.5±4.8	44.5±8.8
GER	1 088	24.9±6.6	4.9±3.0	22.2±5.2	48.0±8.7
HUNG	536	29.5±6.5	3.8±1.9	20.9±4.7	45.8±7.8
ITA	1 155	34.1±6.4	3.6±1.7	17.8±4.7	44.4±6.3
SWE	1 014	28.0±6.4	3.6±1.8	22.3±4.8	46.1±7.4
BMI CATEGORIES					
normal weight	4 539	28.4±7.2	4.3±2.7	20.4±4.8	46.9±7.9
overweight	1 710	30.5±7.3	4.6±3.0	21.4±5.6	43.5±7.9
obese	823	32.0±7.7	4.9±3.1	22.1±6.1	41.1±7.8

Countries: BEL, Belgium; CYP, Cyprus; ESP, Spain; EST, Estonia; GER, Germany; HUNG, Hungary; ITA, Italy; SWE = Sweden; MPFs (%TEI), contribution in percentage of total energy intake from unprocessed or minimally processed foods; PCIs (%TEI), contribution in percentage of total daily energy intake from processed culinary ingredients; PFs (%TEI), contribution in percentage of total daily energy intake from processed foods; UPFs (%TEI), contribution in percentage of total daily energy intake from ultra-processed foods;

Table 2. *Mean nutritional content of the diet by age and NOVA food groups.*

6-10ys					
	Overall diet	**MPFs (%TEI)**	**PCIs (%TEI)**	**PFs (%TEI)**	**UPFs (%TEI)**
Energy (kcal/day)	1 575±202	452±140[a]	53±29[a]	289±61[a]	781±150[a]
Protein (g/day)	66.0±10.6	27.4±10.2[a]	3.2±1.3[a]	14.3±3.3[a]	21.2±4.2[a]
Total fat (g/day)	61.1±8.8	13.9±4.7[a]	4.1±2.8[a]	9.8±2.2[a]	33.2±6.9[a]
SFA (g/day)	25.3±3.8	5.4±1.9[a]	2.2±1.7[a]	4.4±1.2[a]	13.3±2.7[a]
Total carb (g/day)	190.0±26.6	53.5±16.3[a]	3.4±3.2[a]	35.7±9.4[a]	97.4±20.7[a]
Sugars (g/day)	83.0±19.9	22.4±8.5[a.b]	2.0±2.6a	2.3±0.6[c]	56.3±17.8[ab]
Fibre (g/day)	14.1±2.1	6.0±1.7[a]	0.1±0.1[a]	3.1±1.0[a]	5.0±1.1[a]
Kcal (%TEI)	100	28.5±7.2[a]	4.0±1.9[a]	18.4±3.8[a]	49.0±6.4[a]
Protein (%TEI)	17.0±1.8	7.0±2.4[a]	0.8±0.3[a]	3.7±0.8[a]	5.4±0.9[a]
Total fat (%TEI)	34.2±2.7	7.8±2.3[a]	2.3±1.5[a]	5.5±1.2[a]	18.5±3.0[a]
SFA (%TEI)	14.2±1.4	3.0±1.0[a]	1.2±0.9[a]	2.5±0.6[a]	7.4±1.2[a]
Total carb (%TEI)	48.8±3.1	13.7±3.7[a]	0.9±0.8[a]	9.2±2.3[a]	25.0±4.1[a]
Sugars (%TEI)	21.2±3.9	5.7±2.0[a.b.c]	0.5±0.6[b]	0.6±0.2[c]	14.4±3.9[a.b.c]
Fibre (g/1000kcal)	9.0±1.0	3.8±1.0[a]	0.1±0.1[a]	2.0±0.6[a]	3.2±0.5[a]
10-20ys					
	Overall diet	**MPFs (%TEI)**	**PCIs (%TEI)**	**PFs (%TEI)**	**UPFs (%TEI)**
Energy (kcal/day)	1 590±245	450±138[a]	50±32[a]	303±71[a]	787±170[a]
Protein (g/day)	68.3±11.9	28.3±10.2[a]	3.1±1.4[a]	15.2±3.8[a]	21.7±4.7[a]
Total fat (g/day)	60.3±10.5	13.6±4.2[a]	4.0±3.1[a]	10.7±2.7[a]	32.0±7.8[a]
SFA (g/day)	24.9±4.6	5.1±1.6[a]	2.2±2.0[a]	4.8±1.4[a]	12.8±3.1[a]
Total carb (g/day)	192.0±31.1	52.0±17.6[a]	3.3±3.1[a]	36.4±10.8[a]	100.3±23.0[a]
Sugars (g/day)	79.1±21.3	19.4±8.5[a.b.c]	1.9±2.5[b]	2.3±0.8[c]	55.4±18.8[a.b.c]
Fibre (g/day)	14.4±2.5	5.9±2.0[a]	0.1±0.1[a]	3.2±1.1[a]	5.3±1.2[a]
Kcal (%TEI)	100	28.0±6.9[a]	3.9±2.0[a]	19.3±4.2[a]	48.8±6.5[a]
Protein (%TEI)	17.5±1.8	7.2±2.3[a]	0.8±0.4[a]	3.9±0.9[a]	5.5±0.9[a]
Total fat (%TEI)	33.5±2.8	7.6±2.1[a]	2.2±1.7[a]	6.0±1.4[a]	17.7±3.1[a]
SFA (%TEI)	13.8±1.5	2.9±0.8[a]	1.2±1.1[a]	2.7±0.8[a]	7.1±1.3[a]
Total carb (%TEI)	49.0±3.1	13.3±3.9[a]	0.8±0.8[a]	9.4±2.6[a]	25.6±4.2[a]
Sugars (%TEI)	20.1±3.9	5.0±2.0[a]	0.5±0.6[b]	0.6±0.2[c]	14.0±3.9[a]
Fibre (g/1000kcal)	9.1±1.1	3.7±1.1[a]	0.1±0.1[a]	2.0±0.7[a]	3.3±0.6[a]
>20ys					
	Overall diet	**MPFs (%TEI)**	**PCIs (%TEI)**	**PFs (%TEI)**	**UPFs (%TEI)**
Energy (kcal/day)	1 619±311	491±140[a]	78±64[a]	374±105[a]	677±204[a]
Protein (g/day)	70.7±12.5	28.4±7.6[a]	3.7±2.8[a]	20.2±6.0[a]	18.3±5.5[a]
Total fat (g/day)	64.8±14.2	17.6±5.9[a]	5.7±6.1[a]	13.0±3.6[a]	28.4±9.6[a]
SFA (g/day)	26.3±6.6	6.0±1.9[a]	3.1±3.8 a[,b]	6.0±1.9[b]	11.1±3.6[a.b]
Total carb (g/day)	177.7±38.7	52.8±18.0[a]	4.7±6.0[a]	42.8±15.8[a]	77.4±25.9[a]
Sugars (g/day)	76.7±25.1	29.0±14.7[a.b]	4.2±6.4[a]	3.4±1.6[b]	40.2±18.0[a.b]
Fibre (g/day)	16.3±3.6	7.7±2.7	0.1±0.1	4.4±1.9	4.1±1.3
Kcal (%TEI)	100	31.1±7.7[a]	5.2±3.5[a]	23.5±5.4[a]	40.2±7.6[a]
Protein (%TEI)	18.3±2.0	7.4±2.0[a]	1.0±0.7[a]	5.2±1.3[a]	4.7±1.0[a]
Total fat (%TEI)	36.2±3.4	10.0±3.1[a]	3.1±2.8[a]	7.3±1.8[a]	15.8±3.9[a]
SFA (%TEI)	14.6±1.9	3.4±1.0[a]	1.7±1.8[a.b]	3.4±1.0[b]	6.2±1.5[a.b]
Total carb (%TEI)	45.5±3.9	13.7±4.2[a]	1.2±1.4[a]	11.0±3.4[a]	19.7±4.7[a]
Sugars (%TEI)	19.5±4.6	7.5±3.6[a.b]	1.0±1.5[a]	0.9±0.4[b]	10.1±3.6[a.b]
Fibre (g/1000kcal)	10.4±1.7	5.0±1.8[a]	0.1±0.0[a]	2.8±1.1[a]	2.6±0.7[a]

Values are expressed as mean±SD. MPFs (%TEI), contribution in percentage of total energy intake from unprocessed or minimally processed foods; PCIs (%TEI), contribution in percentage of total daily energy intake from processed culinary ingredients; PFs (%TEI), contribution in percentage of total daily energy intake from processed foods; SFA, Saturated fatty acids; Total carb, total carbohydrates; UPFs (%TEI), contribution in percentage of total daily energy intake from ultra-processed foods. For each nutrient, superscript different lowercase letters in the same row indicate significant differences among categories.

Table 3. *Energy intake and nutrient content according to quintiles of the dietary share of ultra-processed foods*

6-10ys	UPFs (%TEI) quintiles				
	I (29.2-43.8)	**II (43.2-47.3)**	**III (47.3-50.7)**	**IV (50.5-54.5)**	**V (54.1-69.4)**
Energy (kcal/day)	1 562 (1 533-1 592)	1 578 (1 549-1 607)	1 591 (1 562-1 620)	1 566 (1 536-1 595)	1 580 (1 551-1 610)
Protein (g/day)	70.6 (69.8-71.4)$^{a.b.c.d}$	67.8 (67.1-68.6)$^{a.b.c.d}$	65.8 (65.0-66.5)$^{a.b.c.d}$	64.0 (63.2-64.8)$^{a.b.c.d}$	60.9 (60.1-61.6)$^{a.b.c.d}$
Total fat (g/day)	60.2 (59.4-60.9)^{a}	61.2 (60.5-61.9)	60.8 (60.1-61.5)	62.0 (61.2-62.7)^{a}	61.6 (60.8-62.3)
SFA (g/day)	25.0 (24.6-25.4)	25.4 (25.0-25.8)	25.5 (25.1-25.9)	25.6 (25.2-26.0)	25.3 (24.9-25.7)
Total carb (g/day)	185.3 (183.4-187.2)$^{a.c.d}$	188.3 (186.4-190.2)^{b}	191.1 (189.2-193.0)^{c}	190.6 (188.7-192.5)^{d}	192.9 (191.0-194.8)$^{a.b}$
Sugars (g/day)	75.8 (73.7-77.9)$^{a.c.d}$	79.5 (77.5-81.5)$^{b.c.d}$	84.0 (82.0-86.0)$^{a.b.c}$	84.7 (82.6-86.7)$^{a.b.d}$	89.1 (87.1-91.2)$^{a.b.c.d}$
Fibre (g/day)	14.5 (14.2-14.7)$^{a.d}$	14.3 (14.0-14.5)^{b}	14.2 (13.9-14.4)^{c}	13.9 (13.7-14.2)^{d}	13.5 (13.3-13.7)$^{a.b.c}$
Protein (%TEI)	18.2 (18.1-18.5)$^{a.b.c.d}$	17.4 (17.2-17.6)$^{a.b.c.d}$	16.9 (16.7-17.1)$^{a.b.c.d}$	16.4 (16.2-16.6)$^{a.b.c.d}$	15.7 (15.5-15.9)$^{a.b.c.d}$
Total fat (%TEI)	33.8 (33.4-34.2)^{a}	34.2 (33.8-34.6)	34.1 (33.7-34.5)	34.7 (34.3-35.1)^{a}	34.5 (34.1-35.0)
SFA (%TEI)	14.1 (13.8-14.3)	14.2 (14.0-14.4)	14.3 (14.1-14.5)	14.3 (14.1-14.5)	14.2 (14.0-14.4)
Total carb (%TEI)	47.9 (47.5-48.4)^{a}	48.4 (47.9-48.8)^{b}	49.0 (48.6-49.5)a	48.9 (48.4-49.4)^{a}	49.8 (49.3-50.2)$^{a.b}$
Sugars (%TEI)	19.4 (18.9-20.0)$^{a.c.d}$	20.4 (19.8-20.9)$^{b.c.d}$	21.6 (21.0-22.1)$^{a.b.c}$	21.6 (21.1-22.1)$^{a.b.d}$	22.9 (22.4-23.4)$^{a.b.c.d}$
Fibre (g/1000kcal)	9.2 (9.1-9.4)$^{a.d}$	9.1 (8.9-9.2)^{b}	9.0 (8.8-9.1)c	8.8 (8.7-9.0)^{d}	8.6 (8.5-8.8)$^{a.b.c}$
10-20ys	**I (24.6-44.0)**	**II (43.2-47.1)**	**III (46.9-50.5)**	**IV (50.3-54.4)**	**V (54.1-75.2)**
Energy (kcal/day)	1 566 (1 542-1 590)^{a}	1 582 (1 559-1 605)^{b}	1 586 (1 563-1 608)^{c}	1 614 (1 590-1 637)	1 636 (1 612-1 660)$^{a.b.c}$
Protein (g/day)	72.8 (72.2-73.4)$^{a.b.c.d}$	69.7 (69.1-70.3)$^{a.c.d}$	68.6 (68.0-69.1)$^{a.c.d}$	66.7 (66.1-67.3)$^{a.b.c.d}$	63.8 (63.2-64.4)$^{a.b.c.d}$
Total fat (g/day)	59.2 (58.6-59.8)$^{a.c.d}$	60.1 (59.6-60.7)^{b}	60.7 (60.2-61.3)^{c}	61.2 (60.7-61.8)^{d}	61.4 (60.9-62.0)$^{a.b}$
SFA (g/day)	24.5 (24.2-24.8)^{a}	25.0 (24.7-25.3)	25.1 (24.8-25.4)	25.2 (24.9-25.5)^{a}	25.0 (24.7-25.3)
Total carb (g/day)	189.6 (188.1-191.1)	190.2 (188.7-191.6)	191.0 (190.0-192.4)	191.4 (190.0-192.9)	192.4 (190.9-193.8)
Sugars (g/day)	72.7 (71.2-74.3)$^{a.b.c.d}$	76.1 (74.6-77.6)$^{a.b.d}$	78.5 (77.1-78.0)$^{a.c.d}$	81.8 (80.3-83.3)$^{b.c.d}$	84.3 (82.8-85.9)$^{a.b.c}$
Fibre (g/day)	15.1 (14.9-15.3)$^{a.b.c.d}$	14.6 (14.4-14.8)$^{a.b.d}$	14.5 (14.3-14.7)$^{a.c}$	14.1 (13.9-14.3)$^{a.b.d}$	13.5 (13.3-13.7)$^{a.b.c.d}$
Protein (%TEI)	18.7 (18.5-18.9)$^{a.b.c.d}$	17.9 (17.7-18.0)$^{a.b.c.d}$	17.5 (17.4-17.7)$^{a.b.c.d}$	17.0 (16.9-17.2)$^{a.b.c.d}$	16.4 (16.2-16.5)$^{a.b.c.d}$
Total fat (%TEI)	32.9 (32.6-33.2)^{a}	33.5 (33.2-33.8)^{b}	33.7 (33.4-34.0)^{a}	34.0 (33.7-34.3)^{a}	34.3 (34.0-34.6)$^{a.b}$
SFA (%TEI)	13.6 (13.5-13.8)^{a}	13.9 (13.7-14.1)	13.9 (13.8-14.1)	14.0 (13.8-14.2)^{a}	14.0 (13.8-14.1)
Total carb (%TEI)	48.4 (48.0-48.7)^{a}	48.7 (48.3-49.0)^{b}	48.8 (48.4-49.1)	49.0 (48.6-49.3)	49.4 (49.0-49.7)$^{a.b}$
Sugars (%TEI)	18.3 (17.9-18.7)$^{a.b.c.d}$	19.3 (18.9-19.7)$^{a.b.d}$	19.9 (19.5-20.2)$^{a.c.d}$	20.8 (20.4-21.2)$^{a.b.c.d}$	21.6 (21.2-22.0)$^{a.b.c.d}$
Fibre (g/1000kcal)	9.6 (9.4-9.7)$^{a.b.c.d}$	9.2 (9.1-9.3)$^{a.b.d}$	9.1 (9.0-9.2)$^{a.c.d}$	8.9 (8.8-9.0)$^{a.b.c.d}$	8.6 (8.4-8.7)$^{a.b.c.d}$
>20ys	**I (14.7-34.4)**	**II (33.9-39.1)**	**III (38.0-42.9)**	**IV (41.5-47.0)**	**V (46.0-73.4)**
Energy (kcal/day)	1 540 (1 510-1 571)$^{a.b.c}$	1 609 (1 580-1 638)$^{a.b}$	1 632 (1 603-1 662)$^{a.c}$	1 683 (1 653-1 712)$^{a.b}$	1 719 (1 688-1 750)$^{a.b.c}$
Protein (g/day)	73.8 (73.1-74.5)$^{a.c.d}$	72.8 (72.1-73.4)$^{b.d}$	71.8 (71.1-72.5)$^{a.c.d}$	70.3 (69.6-71.0)$^{a.b.c.d}$	68.1 (67.4-68.8)$^{a.b.c.d}$
Total fat (g/day)	63.6 (62.8-64.4)	63.8 (63.0-64.6)	64.7 (63.9-65.5)	65.0 (64.2-65.8)	64.8 (64.0-65.7)
SFA (g/day)	25.6 (25.2-26.1)	25.7 (25.2-26.1)	26.0 (25.5-26.4)	26.0 (25.6-26.5)	25.6 (25.2-26.1)
Total carb (g/day)	174.1 (172.0-176.3)	177.0 (175.0-179.0)	176.0 (173.9-178.0)	177.5 (175.5-179.6)	178.3 (176.1-180.4)
Sugars (g/day)	71.3 (69.1-73.4)	73.3 (71.2-75.3)	73.7 (71.6-75.8)	72.7 (70.6-74.8)	74.7 (72.5-76.9)
Fibre (g/day)	16.7 (16.4-17.0)$^{a.c.d}$	16.5 (16.2-16.8)$^{b.d}$	16.1 (15.8-16.4)$^{a.c}$	15.7 (15.3-16.0)$^{a.b.d}$	14.6 (14.3-15.0)$^{a.b.c.d}$
Protein (%TEI)	19.6 (19.4-19.8)$^{a.b.c.d}$	18.9 (18.7-19.1)$^{a.b.d}$	18.6 (18.4-18.8)$^{a.b.d}$	17.9 (17.7-18.2)$^{a.b.c.d}$	17.4 (17.1-17.6)$^{a.b.c.d}$
Total fat (%TEI)	35.6 (35.1-36.0)^{a}	35.7 (35.3-36.1)^{b}	36.2 (35.8-36.6)	36.5 (36.1-36.9)^{a}	36.6 (36.1-37.0)$^{a.b}$
SFA (%TEI)	14.2 (14.0-14.5)	14.3 (14.1-14.6)	14.5 (14.3-14.7)	14.7 (14.4-14.9)	14.6 (14.3-14.8)
Total carb (%TEI)	44.9 (44.4-45.4)^{a}	45.4 (45.0-45.9)	45.2 (44.8-45.7)	45.6 (45.1-46.0)	46.1 (45.6-46.5)^{a}
Sugars (%TEI)	17.9 (17.3-18.4)$^{a.b}$	18.7 (18.2-19.2)	18.9 (18.4-19.5)^{b}	18.9 (18.3-19.4)	19.6 (19.0-20.1)^{a}
Fibre (g/1000kcal)	10.8 (10.6-11.0)$^{a.c.d}$	10.5 (10.3-10.7)$^{b.d}$	10.2 (10.0-10.4)$^{a.c}$	9.9 (9.7-10.1)$^{a.b.d}$	9.4 (9.2-9.6)$^{a.b.c.d}$

Values are expressed as mean (95% CI). SFA, Saturated fatty acids; Total carb, total carbohydrates; UPFs (%TEI), contribution in percentage of total daily energy intake from ultra-processed foods. For each nutrient, superscript lowercase letters in the same row indicate significant differences among quintiles. Analysis adjusted for sex, age, country, family income, family ISCED (International Standard Classification of Education) and total daily energy intake.

Table 4 Diet quality according to quintiles of the dietary share of ultra-processed foods

	UPFs (%TEI) quintiles				
6-10ys	**I (29.2-43.8)**	**II (43.2-47.3)**	**III (47.3-50.7)**	**IV (50.5-54.5)**	**V (54.1-69.4)**
HDAS	18.2 (17.0-19.4)[a]	16.6 (15.4-17.7)	16.6 (15.5-17.7)	17.3 (16.2-18.5)	15.5 (14.4-16.7)[a]
FV (time/day)	2.93 (2.66-3.20)	2.85 (2.58-3.11)	2.92 (2.65-3.18)	2.92 (2.64-3.19)	2.52 (2.25-2.79)
Junk food (time/day)	1.23 (1.04-1.41)[a.b]	1.42 (1.24-1.60)	1.57 (1.39-1.75)	1.62 (1.44-1.80)[b]	1.76 (1.58-1.94)[a]
Fish (time/day)	0.39 (0.33-0.45)	0.35 (0.29-0.41)	0.31 (0.25-0.37)	0.38 (0.32-0.44)	0.29 (0.23-0.35)
Milk/yogurt (time/day)	1.97 (1.76-2.18)	1.87 (1.67-2.08)	1.93 (1.73-2.13)	2.07 (1.87-2.28)	1.78 (1.57-1.98)
Fatty foods (time/day)	0.93 (0.83-1.03)	0.90 (0.80-1.00)	0.79 (0.69-0.89)	0.87 (0.77-0.97)	0.82 (0.72-0.92)
Simple sugar foods (time/day)	3.19 (2.86-3.53)	3.14 (2.82-3.46)	3.23 (2.92-3.55)	3.44 (3.11-3.76)	3.42 (3.10-3.74)
Fiber rich foods (time/day)	3.89 (3.55-4.23)	3.76 (3.44-4.09)	3.79 (3.46-4.11)	3.68 (3.34 -4.01)	3.27 (2.93-3.60)
Dairy products (time/day)	3.41 (3.10-3.72)	3.32 (3.02-3.62)	3.32 (3.02-3.61)	3.46 (3.16-3.76)	3.08 (2.78-3.38)
Red meat (time/day)	1.15 (1.03-1.26)	1.03 (0.92-1.14)	1.04 (0.93-1.15)	1.02 (0.91-1.14)	1.09 (0.98-1.20)
10-20 ys	**I (24.6-44.0)**	**II (43.2-47.1)**	**III (46.9-50.5)**	**IV (50.3-54.4)**	**V (54.1-75.2)**
HDAS	20.3 (19.4-21.1)[a.c.d]	19.7 (18.9-20.5)[b]	18.6 (17.8-19.4)[a.c]	18.2 (17.4-19.0)[a.d]	16.0 (15.1-16.8)[a.b.c.d]
FV (time/day)	3.39 (3.09-3.69)[a]	3.01 (2.72-3.31)	2.86 (2.57-3.14)	2.88 (2.60-3.17)	2.63 (2.32-2.93)[a]
Junk food (time/day)	1.58 (1.36-1.79)[a.b]	1.83 (1.62-2.04)	1.85 (1.65-2.06)	1.98 (1.78-2.19)[b]	2.21 (1.99-2.43)[a]
Fish (time/day)	0.51 (0.44-0.58)[a]	0.46 (0.40-0.53)[b]	0.47 (0.41-0.54)[c]	0.49 (0.42-0.55)[d]	0.30 (0.23-0.37)[a.b.c.d]
Milk/yogurt (time/day)	1.85 (1.65-2.04)	1.74 (1.56-1.92)	1.86 (1.68-2.04)	2.01 (1.83-2.20)	1.79 (1.60-1.98)
Fatty foods (time/day)	1.21 (1.09-1.33)	1.12 (1.00-1.24)	1.14 (1.02-1.26)	1.20 (1.08-1.32)	1.06 (0.93-1.18)
Simple sugar foods (time/day)	3.23 (2.92-3.54)[a]	3.34 (3.04-3.64)	3.71 (3.41-4.00)	3.87 (3.57-4.16)[a]	3.71 (3.40-4.02)
Fiber rich foods (time/day)	4.50 (4.12-4.88)[a]	4.17 (3.81-4.53)	3.86 (3.51-4.22)	3.94 (3.59-4.30)	3.56 (3.18-3.94)[a]
Dairy products (time/day)	3.46 (3.17-3.76)	3.27 (3.00-3.55)	3.43 (3.16-3.71)	3.69 (3.41-3.96)[a]	3.09 (2.80-3.38)[a]
Red meat (time/day)	1.35 (1.23-1.46)	1.15 (1.04-1.26)	1.26 (1.15-1.37)	1.28 (1.16-1.39)	1.28 (1.17-1.40)
>20ys	**I (14.7-34.4)**	**II (33.9-39.1)**	**III (38.0-42.9)**	**IV (41.5-47.0)**	**V (46.0-73.4)**
HDAS	27.5 (26.5-28.6)[a.d]	26.6 (25.5-27.6)[b]	25.9 (24.9-26.9)[c]	24.9 (23.8-25.9)[d]	23.3 (22.2-24.4)[a.b.c]
FV (time/day)	3.24 (3.02-3.47)[a]	3.30 (3.08-3.52)[b]	2.83 (2.61-3.05)	2.96 (2.74-3.18)	2.69 (2.46-2.92)[a.b]
Junk food (time/day)	0.77 (0.64-0.90)[a]	0.88 (0.75-1.00)[b]	0.98 (0.85-1.11)[c]	1.03 (0.90-1.16)[a]	1.32 (1.19-1.45)[a.b.c]
Fish (time/day)	0.45 (0.41-0.49)[a.c]	0.45 (0.41-0.49)[b.d.e]	0.37 (0.33-0.41)[e]	0.37 (0.33-0.41)[c.d]	0.34 (0.30-0.38)[a.b]
Milk/yogurt (time/day)	1.84 (1.64-2.05)	1.81 (1.62-2.00)	1.63 (1.43-1.82)	1.78 (1.59-1.97)	1.61 (1.40-1.81)
Fatty foods (time/day)	0.84 (0.76-0.92)	0.79 (0.71-0.87)	0.74 (0.67-0.82)	0.82 (0.74-0.90)	0.86 (0.78-0.94)
Simple sugar foods (time/day)	1.76 (1.55-1.97)[a]	2.00 (1.80-2.20)	1.96 (1.75-2.16)	1.89 (1.68-2.09)	2.22 (2.00-2.43)[a]
Fiber rich foods (time/day)	4.50 (4.2-4.8)[a]	4.49 (4.20-4.78)[b]	4.18 (3.89-4.48)[c]	4.07 (3.78-4.37)[d]	3.41 (3.09-3.72)[a.b.c.d]
Dairy products (time/day)	3.32 (3.03-3.61)	3.40 (3.12-3.68)	3.25 (2.97-3.54)	3.33 (3.05-3.61)	2.90 (2.61-3.20)
Red meat (time/day)	1.04 (0.95-1.13)	1.04 (0.96-1.13)	1.09 (1.00-1.18)	1.02 (0.93-1.11)	1.06 (0.97-1.16)

Values are expressed as mean (95% CI). FV, Fruit and vegetables; HDAS, Healthy Dietary Adherence Score; UPFs (%TEI), contribution in percentage of total daily energy intake from ultra-processed foods. Superscript lowercase letters in the same row indicate significant differences among quintiles. Analysis adjusted for sex, age, country, family income, family ISCED and total daily energy intake.

Figure Legends

Figure 1. Flow chart of participants included in final analysis.

Figure 2. Descriptions of the NOVA classification process.

Supplemental Figure 1. Differences in usual energy and nutrients intake among countries in the different age groups. Countries: BEL, Belgium; CYP, Cyprus; ESP, Spain; EST, Estonia; GER, Germany; HUNG, Hungary; ITA, Italy; SWE = Sweden.