TESIS DE LA UNIVERSIDAD
DE ZARAGOZA

2024

459

Sondos Mahmoud Eid Flieh

Asociación entre el tamaño de las porciones de los alimentos, la obesidad y las complicaciones metabólicas en niños y adolescentes

Director/es

Moreno Aznar, Luis Alberto
González Gil, Esther María
Miguel Berges, María Luisa

ISSN 2254-7606

Prensas de la Universidad
Universidad Zaragoza

Universidad de Zaragoza
Servicio de Publicaciones

ISSN 2254-7606

Tesis Doctoral

ASOCIACIÓN ENTRE EL TAMAÑO DE LAS PORCIONES DE LOS ALIMENTOS, LA OBESIDAD Y LAS COMPLICACIONES METABÓLICAS EN NIÑOS Y ADOLESCENTES

Autor

Sondos Mahmoud Eid Flieh

Director/es

Moreno Aznar, Luis Alberto
González Gil, Esther María
Miguel Berges, María Luisa

UNIVERSIDAD DE ZARAGOZA
Escuela de Doctorado

Programa de Doctorado en Ciencias de la Salud y del Deporte

2023

Food portion sizes, obesity and related metabolic complications in children and adolescents.

Asociación entre el tamaño de las porciones de los alimentos, la obesidad y las complicaciones metabólicas en niños y adolescentes.

Author

Sondos Mahmoud Eid Flieh

DIRECTORES

Luis Alberto Moreno Aznar

Esther María González Gil

María Luisa Miguel Berges

Doctoral thesis 2022/2023

Departamento de
Fisiatría y Enfermería
Universidad Zaragoza

Work hard in silence, let success make the noise….

To my parents, my brothers and my sister.

To Mohammad, Pilar & Layar.

Prof. Dr. Luis A. Moreno Aznar
Catedrático de la Universidad de Zaragoza
Departamento de Fisiatría y Enfermería
Facultad de Ciencias de la Salud

CERTIFICA:

Que la tesis doctoral titulada "**Asociación entre el tamaño de las porciones de los alimentos, la obesidad y las complicaciones metabólicas en niños y adolescentes**" que presenta Dña. **SONDOS MAHMOUD EID FLIEH** para el juicio posterior del Tribunal que designe la Universidad de Zaragoza, ha sido realizada bajo mi dirección, siendo expresión de la capacidad técnica e interpretativa de su autora en condiciones tan aventajadas que la hacen merecedora del Título de Doctor, siempre y cuando así lo considere el citado Tribunal.

Fdo. Luis A. Moreno Aznar
En Zaragoza, a 30 de Mayo del 2023

International Agency for Research on Cancer
World Health Organization

Dra. Esther M. GONZÁLEZ-GIL
Investigadora postdoctoral
Nutrition and Metabolism Branch
International Agency for Research on Cancer
World Health Organization. Lyon. France

ESTHER M. GONZÁLEZ-GIL, INVESTIGADORA POSTDOCTORAL de la Agencia Internacional de Investigación en Cáncer- Organización Mundial de la Salud.

CERTIFICA:

Que la Tesis Doctoral titulada "**Asociación entre el tamaño de las porciones de los alimentos, la obesidad y las complicaciones metabólicas en niños y adolescentes.**" que presenta Dña. **SONDOS MAHMOUD EID FLIEH** al superior juicio del Tribunal que designe la Universidad de Zaragoza, ha sido realizada bajo mi dirección, siendo expresión de la capacidad técnica e interpretativa de su autora en condiciones tan aventajadas que le hacen merecedora del Título de Doctora, siempre y cuando así lo considere el citado Tribunal.

Fdo.: Esther M. González-Gil
En Lyon, a 30 de Enero de 2023

Dra. María Luisa Miguel Berges

Departamento de Fisiatría y Enfermería
Facultad de Ciencias de la Salud
Universidad de Zaragoza, España

MARÍA LUISA MIGUEL BERGES, CATEDRÁTICO DE LA UNIVERSIDAD DE ZARAGOZA

CERTIFICA:

Que la Tesis Doctoral titulada "Asociación entre el tamaño de las porciones de los alimentos, la obesidad y las complicaciones metabólicas en niños y adolescentes." que presenta Dña. **SONDOS MAHMOUD EID FLIEH** al superior juicio del Tribunal que designe la Universidad de Zaragoza, ha sido realizada bajo mi dirección, siendo expresión de la capacidad técnica e interpretativa de su autora en condiciones tan aventajadas que le hacen merecedora del Título de Doctora, siempre y cuando así lo considere el citado Tribunal.

Fdo.: María Luisa Miguel Berges
En Zaragoza, a 07 de Mayo de 2023

List of publications

This Doctoral Thesis is a compendium of previously published or accepted scientific works. The articles that constitute this thesis are detailed below:

I. **Flieh S**, González Gil E, Miguel-Berges ML, Moreno Aznar LA. Food portion sizes, obesity, and related metabolic complications in children and adolescents. Tamaño de las porciones de alimentos, obesidad y complicaciones metabólicas asociadas en niños y adolescentes. Nutr Hosp. 2021;38(1):169-176. doi:10.20960/nh.03118.

II. **Flieh SM**, Hebestreit A, Pohlabeln H, Miguel-Berges ML, González-Gil EM, Russo P, Molnár D, Wijnant K, Lissner L, Do S, Solea T, Veidebaum T, and Moreno LA. The association between psychosomatic and emotional status and selected food portion sizes, in European children and adolescents: IDEFICS/I.Family study. (Submitted to Nutrition Journal)

III. **Flieh SM**, Miguel-Berges ML, Huybrechts I, Breidenasse C, Grammatikaki E, Le Donne C, Manios Y, Widhalm K, Molnár D, Stehle P, Kafatos A, Dallongeville J, Molina-Hidalgo C, Gómez-Martínez S, Gonzalez-Gross M, De Henauw S, Béghin L, Kersting M, Moreno LA, and González-Gil EM. Food portion sizes and their relationship with energy, and nutrient intakes in European adolescents: the HELENA study. Nutrition. 2022; 106:111893. doi:10.1016/j.nut.2022.111893

IV. **Flieh SM,** Miguel-Berges ML, González-Gil EM, et al. The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study. Nutrients. 2021;13(3):954. Published 2021 Mar 16. doi:10.3390/nu13030954.

V. **Flieh SM**, Miguel-Berges ML, Huybrechts I, Castillo MJ, Gonzalez-Gross M, Marcos A, Gottrand F, Le Donne C, Widhalm K, Molnár D, Stehle P, Kafatos A, Dallongeville J, Gesteiro E, Abbeddou S, Moreno LA and González-Gil EM. Associations between food portion sizes, insulin resistance, VO2 max and metabolic syndrome in European adolescents: the HELENA study. Nutrition, Metabolism and Cardiovascular Diseases. 2022; Volume 32, Issue 9, Pages 2061-2073. https://doi.org/10.1016/j.numecd.2022.05.017.

Content

List of Abbreviations

ANCOVA	Analysis of Covariance
BMI	Body Mass Index
ED	Energy Density
FAS	Family Affluence Scale
FMI	Fat Mass Index
GI	Glycaemic Index
HC	Hip Circumference
HDLc	High-Density Lipoprotein Cholesterol
HELENA	Healthy lifestyle in Europe by Nutrition in Adolescence-Cross sectional Study
HOMA-IR	Homeostasis Model Assessment of Insulin Resistance
IDEFICS	Identification and Prevention of Dietary- and Lifestyle- Induced Health Effects in Children and Infants
IPAQ-A	International Physical Activity Questionnaire- Adolescents
ISCED	International Standard Classification of Education
KINDL	Emotional Well-being and Self-esteem of the Child score
MS	Metabolic Syndrome
MSM	Multiple Source Method
MVPA	Moderate and Vigorous Physical Activity
NLE	Negative Life Events score
OR	Odds Ratio
PA	Physical Activity
PS	Portion sizes
QUICKI	Quantitative Insulin-Sensitivity Check Index
SACANA	Self-Administered Children, Adolescents, and Adult Nutrition Assessment
SACINA	Self- Administered Children and Infant Nutrition Assessment
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
T0	Baseline measurement of IDEFICS
T1	Follow up measurement of IDEFICS
T3	Follow up measurement of I. Family
TC	Total Cholesterol
TEI	Total Energy Intake

VO2 max	Maximal Oxygen Uptake
WC	Waist Circumference
YANA-C	Young Adolescents’ Nutrition Assessment on Computer

Abstract

Childhood obesity is a worldwide public health concern. Obesity in children is linked to cardiometabolic complications that are already present during childhood. This condition could be triggered by high energy-dense (ED) food consumption, in conjunction with other obesogenic risk factors, such as a sedentary lifestyle and insufficient physical activity.

The effect of food portion sizes (PS) on total energy intake has been already observed with different types of foods and beverages, mainly high ED foods, regardless of demographic characteristics such as age, gender, income level, or body mass index (BMI). Although a direct causal link between PS and obesity remains controversial, some health and dietetic organizations recommend moderate food PS.

Therefore, the **general objectives** of this Doctoral Thesis are; 1) To clarify food PS concept, estimation method, and to discuss previous research on their relation with obesity, and related metabolic complications in children and adolescents. 2) To assess the relation between psychosomatic and emotional status and selected food PS. 3) To identify which foods PS mainly influence on nutrients intake and total energy intake. 4) To analyze the influence of large food portions size on development of obesity in childhood and adolescence. 5) To analyze the effect of foods PS on insulin resistance and other metabolic complications.

This Doctoral thesis has been performed considering two large European studies: IDEFICS/I. Family study (Identification and Prevention of Dietary- and Lifestyle induced Health Effects in Children and Infants) and HELENA study (Healthy Lifestyle in Europe by Nutrition in Adolescence).

In our first article, which aims to review the available evidence for the impact of food PS on the development of obesity in children and adolescents; we found that there are no long-term, randomized, controlled trials to assess the exposure to large portions of food and its effects on adiposity. Therefore, there is an urgent need to develop a well-articulated research framework that systematically test the interaction between a selection of food PS and the development of obesity, insulin resistance, and metabolic syndrome in both children and adolescents.

In the IDEFICS/I. Family study, information from more than 16.000 children aged between 2 to 10 years, from eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden) was obtained in 2007. These children were re-evaluated two times after the beginning of the study in the year 2009, and 2013. In the second article performed

with data from the IDEFICS/I. Family study, the aim was to assess the association between psychosomatic and emotional status and selected food PS, we found that in cross-sectional analysis, higher well-being, was associated with consumption of smaller PS from ‘sweet bakery products’, ‘savory snacks’, and ‘fruit and vegetable juices’ at the age 2-10 years, in both genders. In the longitudinal analysis (T3-T0), we found that females with higher emotional and peer problems tend to consume higher PS from sugar-fatty food products. Moreover, higher peer problems were associated with large PS from ‘bread and rolls’, ‘margarine and lipids’, and ‘dairy products’ in all genders and age groups.

In the HELENA study, performed between 2006 and 2007, more than 3.000 adolescents from ten European cities (Athens, Heraklion, Dortmund, Ghent, Lille, Pecs, Rome, Stockholm, Vienna and Zaragoza), were assessed. The age of participants ranged between 12.5 to 17.5. With data from this study, the associations between food PS and nutrients intake, obesity and related metabolic complication were evaluated.

Results from the third article aim to examine the relationship between food PS from various food groups with the intake of macronutrients and micronutrients in European adolescents. Results suggest that large portions from ‘rice and other grains’, ‘starch roots and potatoes’ and ‘meat substitutes, nuts, and pulses’ were associated with increased carbohydrates and fiber intake. Larger portions from ‘cheese’ and ‘butter and animal’s fat’ were significantly associated with higher fat intake. Lower intakes of some vitamins and micronutrients were noticed when larger portions of high energy-dense foods such as ‘desserts and pudding’, ‘margarines and vegetable oils’ and ‘butter and animal fats’ were consumed.

In the fourth article, which aim to investigate the associations between PS from most frequently consumed high-ED foods and obesity, it was observed that in male plausible reporters’, PS from ‘Breakfast cereals’ showed a significant and positive association with BMI. Also, it was found that PS from ‘Carbonated soft drinks’ in males and ‘Bread and rolls’ in females were associated with higher probability of having obesity, while ‘Sweet bakery products’ were associated with lower probability of having obesity in females.

In the fifth article, the main objective was to investigate the potential effect of food PS on IR and a quantitative score of metabolic risk in European adolescents. A clear association between larger PS from ‘vegetables’ in both genders, and ‘milk, yoghurt, and milk beverages’ in males were associated with higher VO2 max, while large PS from ‘margarines and vegetable oils’ were associated with lower VO2 max. Moreover, it was observed that males who consumed larger PS from ‘fish’; ‘meat substitutes, nuts, pulses’; ‘cakes, pies, biscuits’; and ‘sugar, honey, jams, chocolate’ have a higher metabolic risk score. In addition, males with low HOMA-IR values consumed large PS from ‘vegetables’, and ‘milk, yoghurt, and milk beverages’. Also, it was found that females with low HOMA-IR values consumed large PS from ‘breakfast cereals’, while those with high HOMA-IR values, consumed large PS from ‘butter and animal fats’.

In summary, findings from this Doctoral Thesis suggest that PS had the strongest effect on the amount of food consumed and energy intake, obesity and development of metabolic complications in children and adolescents. The effect of PS on total energy intake has been observed with different types of foods and beverages, especially with high ED foods. Moreover, the influence of large PS was persistent and happened regardless of demographic characteristics such as age, gender, and income level.

Psychosomatic and emotional status could be a trigger to consume large PS from sweet-fatty ED foods in childhood and adolescence life stage. Also, energy intakes increase with elevated energy content of food as provided by the major sources of dietary energy: carbohydrates, proteins, and fat. Among food items with high fat content, larger portions of ‘cheese’ and ‘butter and animal fat’ were significantly associated with a higher fat intake. Also, lower intakes of some vitamins and micronutrients were observed when larger portions of high ED foods were consumed. Moreover, we found that large PS from ‘carbonated soft and isotonic drinks’ and ‘bread and rolls’ were associated with higher probability of having obesity in adolescents independently of gender. In addition, we found that large PS from ‘vegetables’, ‘fruits’, ‘dairy products’ were associated with higher VO2 max and lower probability of having obesity. The results show no significant association between food PS and HOMA-IR index, and all of metabolic risk score components. Children and adolescents should be trained in their emotional coping skills such as problem-solving thinking or asking help instead of seeking solace in food. These findings call for consideration of individual psychological states when aiming to decrease unhealthy dietary habits. In addition, to enhance the nutritional status of children by educating parents about the role of large PS on nutrients intake and obesity.

Resumen

La obesidad infantil es una preocupación de salud pública mundial. La obesidad en los niños está relacionada con complicaciones cardiometabólicas que ya están presentes durante la infancia. Esta condición podría ser desencadenada por el consumo de alimentos de alta densidad energética (DE), junto con otros factores obesogénicos, como un estilo de vida sedentario y una actividad física insuficiente.

El efecto del tamaños de las porciones de alimentos (PA) en el consumo total de energía ya se ha observado con diferentes tipos de alimentos y bebidas, principalmente alimentos de alta DE, independientemente de las características demográficas como la edad, el género, el nivel de ingresos o el índice de masa corporal (IMC). Aunque un vínculo causal directo entre PA y obesidad sigue siendo controvertido, algunas organizaciones de salud y dietética recomiendan un tamaño moderado de las porciones de alimentos.

En el estudio IDEFICS / I. Family, se obtuvo información de más de 16.000 niños de entre 2 y 10 años, de ocho países europeos (Bélgica, Chipre, Estonia, Alemania, Hungría, Italia, España y Suecia) en 2007. Estos niños fueron reevaluados dos veces después del comienzo del estudio en 2009 y 2013. En el segundo artículo realizado con datos del estudio IDEFICS / I. Family, el objetivo fue evaluar la asociación entre el estado psicosomático y emocional y el tamaño de las porciones de alimentos seleccionados, encontramos que en el análisis transversal, un mayor bienestar estaba asociado con el consumo de porciones más pequeñas de "productos dulces de panadería", "snacks salados" y "jugos de frutas y verduras" a la edad de 2-10 años, en ambos géneros. En el análisis longitudinal (T3-T0), encontramos que las mujeres con mayores problemas emocionales y de pares tienden a consumir porciones más grandes de alimentos con azúcar y grasa. Además, los mayores problemas de pares estaban asociados con porciones grandes de "pan y rollos", "margarina y lípidos" y "productos lácteos" en todos los géneros y grupos de edad.

En el estudio HELENA, realizado entre 2006 y 2007, se evaluaron a más de 3.000 adolescentes de diez ciudades europeas (Atenas, Heraklion, Dortmund, Gante, Lille, Pecs, Roma, Estocolmo, Viena y Zaragoza). La edad de los participantes oscilaba entre 12.5 y 17.5. Con los datos de este estudio, se evaluaron las asociaciones entre el tamaño de las porciones de alimentos y el consumo de nutrientes, la obesidad y las complicaciones metabólicas relacionadas.

Los resultados del tercer artículo tienen como objetivo examinar la relación entre el PA de los alimentos de varios grupos alimenticios con el consumo de macronutrientes y micronutrientes en adolescentes europeos. Los resultados sugieren que las porciones grandes de "arroz y otros granos", "raíces y patatas almidonadas" y "sustitutos de carne, nueces y legumbres" estaban asociadas con un mayor consumo de carbohidratos y fibra. Porciones más grandes de "queso" y "mantequilla y grasas animales" se asociaron significativamente con un mayor consumo de grasa. Se observaron ingestas más bajas de algunas vitaminas y micronutrientes cuando se consumieron porciones más grandes de alimentos de alto contenido energético, como "postres y pudines", "margarinas y aceites vegetales" y "mantequilla y grasas animales".

En el cuarto artículo, que tiene como objetivo investigar las asociaciones entre el PA de los alimentos de alto contenido energético más consumidos y la obesidad, se observó que en los informadores plausibles masculinos, el PA de "cereales para el desayuno" mostró una asociación significativa y positiva con el IMC. Además, se encontró que el PA de "bebidas gaseosas carbonatadas" en los hombres y "pan y rollos" en las mujeres estaban asociados con una mayor probabilidad de tener obesidad, mientras que los "productos dulces de panadería" estaban asociados con una menor probabilidad de tener obesidad en las mujeres.

En el quinto artículo, el objetivo principal fue investigar el posible efecto del PA de los alimentos en la IR y una puntuación cuantitativa de riesgo metabólico en adolescentes europeos. Se observó una clara asociación entre porciones más grandes de "verduras" en ambos sexos y "leche, yogur y bebidas lácteas" en los hombres con un mayor VO2 máx, mientras que porciones más grandes de "margarinas y aceites vegetales" se asociaron con un menor VO2 máx. Además, se observó que los hombres que consumieron porciones más grandes de "pescado"; "sustitutos de carne, nueces y legumbres"; "pasteles, tartas, galletas" y "azúcar, miel, mermeladas, chocolate" tenían una mayor puntuación de riesgo metabólico. Además, se encontró que los hombres con valores bajos de HOMA-IR consumían porciones más grandes de "verduras" y "leche, yogur y bebidas lácteas". También se descubrió que las mujeres con valores bajos de HOMA-IR consumían porciones más grandes de "cereales para el desayuno", mientras que aquellas con valores altos de HOMA-IR consumían porciones más grandes de "mantequilla y grasas animales".

En resumen, los hallazgos de esta tesis doctoral sugieren que el PA tuvo el mayor efecto en la cantidad de alimentos consumidos y la ingesta de energía, la obesidad y el desarrollo de complicaciones metabólicas en niños y adolescentes. El efecto del PA en la ingesta de energía total se ha observado con diferentes tipos de alimentos y bebidas, especialmente con alimentos de alto contenido energético. Además, la influencia de las porciones más grandes fue persistente y ocurrió independientemente de las características demográficas como la edad, el género y el nivel de ingresos.

El estado psicosomático y emocional podría ser un desencadenante para consumir porciones más grandes de alimentos dulces y grasos de alto contenido energético en la etapa de la infancia y la adolescencia. Además, las ingestas de energía aumentan con el contenido energético elevado de los alimentos proporcionados por las principales fuentes de energía dietética: carbohidratos, proteínas y grasas. Entre los alimentos con alto contenido de grasa, porciones más grandes de "queso" y "mantequilla y grasas animales" se asociaron significativamente con un mayor consumo de grasa. Además, se observaron ingestas más bajas de algunas vitaminas y micronutrientes cuando se consumieron porciones más grandes de alimentos de alto contenido energético. Además, encontramos que las porciones más grandes de "bebidas gaseosas carbonatadas" y "pan y rollos" estaban asociadas con una mayor probabilidad de tener obesidad en los adolescentes independientemente del género. Además, encontramos que las porciones más grandes de "verduras", "frutas", "productos lácteos" estaban asociadas con un mayor VO2 máx y una menor probabilidad de tener obesidad. Los resultados no muestran ninguna asociación significativa entre el PS de los alimentos y el índice HOMA-IR, ni todos los componentes de la puntuación de riesgo metabólico. Los niños y adolescentes deben ser entrenados en sus habilidades de afrontamiento emocional, como el pensamiento de resolución de problemas o pedir ayuda en lugar de buscar consuelo en la comida. Estos hallazgos llaman la atención sobre el estado psicológico individual cuando se trata de disminuir los hábitos alimenticios poco saludables. Además, para mejorar el estado nutricional de los niños educando a los padres sobre el papel de las porciones más grandes en la ingesta de nutrientes y la obesidad.

1. Introduction

According to the World Health Organization (WHO), nearly over 340 million children and adolescents aged between 5-19 years were diagnosed as having overweight or obesity in 2016 (1). The prevalence of overweight and obesity within these ages has risen dramatically from just 4% in 1975 to over 18% in 2016 (1). In children, obesity is considered as the most common cause of insulin resistance (2), dyslipidemia (3), and type 2 diabetes (4). Obesity results from a combination of factors, including the reduced opportunity for physical activity (PA), the increase of sedentary time, and increased availability of high ED foods. A healthy diet is essential for both good health and nutritional status as in the context of obesity prevention strategies, by choosing an adequate amount of food from various food groups (5).

A large body of evidence shows that the PS of some foods, especially those consumed in restaurants, has increased dramatically over the last 30 years, synchronous with the recent rise in obesity prevalence in children (6) and in adolescents (7). Clearly, individuals need effective strategies to better regulate their energy intake in the face of the widespread highly palatable, high ED foods (8). Increased PS of foods commonly served are consider as a major component of the food environment that has contributed to the excess of energy consumed and the development of obesity (9). The consumption of large PS, especially from high ED foods, has been identified as a major cause of excessive total energy intake (10). Abundant clinical studies show that increasing PS leads to increased energy intake in children and adolescents (11, 12), mostly from high ED foods (13). This finding is called as “portion sizes effect” or “portion sizes response”. Noteworthy, this impact has been observed with packaged snacks (14), high ED casseroles (12), unit foods like sandwiches (15), and beverages (16). Additionally, the PS effect has been shown in restaurants and offices (17), also it has been noticed even if participants are served unpalatable foods or with manipulation of plate size (18).

Also, food PS could be a trigger to develop cardiometabolic disorders, insulin resistance, impaired glucose tolerance and type 2 diabetes which are considered as ominous public-health issues in all age groups (2, 4). As previously mentioned, studies found that childhood obesity is also associated with hypertension, dyslipidemia, chronic inflammation, increased blood clotting tendency, endothelial dysfunction, and hyperinsulinemia (3, 19). These clustering of cardiovascular diseases risk factors, is also known as the insulin resistance syndrome or metabolic syndrome, which has been identified in pre-pubertal children (20).

Even though, insulin resistance is a key component of the metabolic syndrome; recently an increasing trend of metabolic syndrome prevalence in children and adolescents has been well-recognized, and its association with obesity has been studied extensively (21, 22). The relation between diet and metabolic syndrome among children and adolescents remains poorly understood. In adults, studies have shown that following dietary patterns high in fruits and vegetables are generally associated with lower prevalence of the metabolic syndrome (23, 24). Although the development of obesity in genetically stable populations was accelerated rapidly (4), unfortunately, studies examining the association between diet, especially PS, and insulin resistance, metabolic syndrome in children and adolescents are not available. It is still not clear whether individual dietary components, or diet in general can independently affect metabolic syndrome in this age group.

1.1. Food portion sizes definition and estimation

A portion is defined as the amount of food that a subject choose to eat for a meal or snack or the amount of a food that they decide to eat, or serve to an individual, in a single eating occasion (25). The size of a food portion can be identified as the weight or volume of household measures such as: tablespoons, hand measures or size, of a reference object (26). The concept of PS widely vary between countries, across different population groups and according to both individual and environmental factors (26). For example, a PS may reflect a person’s own choice, the choice of the food producer in a restaurant, or it may be the recommendation from a health professional, or even the governments. PS also reflects ways of eating; for instance, in some cultures the hand-based portion is used to self-serve or measure portions of foods for others (27).

Various methods are used to assess dietary intake such as, single or multiple 24-hour dietary recalls, estimated dietary records, diet history and food frequency questionnaires. However, since these methods rely on individual’s memory, there is a certain challenge in determining food intake, especially in relation with the accurate estimation of food PS. For this reason, to estimate PS, there are several options: direct weigh of the amount of food consumed by the participant or the estimation of the sizes of food portions via visual comparisons to household measures, food models or photographs.

Direct weighing of food portions

Because foods must be weighed before consumption, weighing methods, for determining PS, can be only used with prospective dietary assessment methods and using properly calibrated scales (28). Weighing should be done by investigators or by participants. Although weighed food records are an accurate traditional dietary assessment method, it is time consuming, cumbersome for participants and costly to implement, so it is not usually done in large epidemiological studies.

Visual estimation of weights and size

Direct observation, using visual estimation, is a non-intrusive method of estimating food portions providing an acceptable alternative (29). To apply this method, researchers should be trained to estimate PS by monitoring the weights of foods consumed by participants. Accuracy of estimation could vary by type and quantity of food (30). Several studies revealed a good correlation between visual estimates and actual weight (30). In Belgium-Flanders, the Young Adolescents' Nutrition Assessment on Computer (YANA-C) was developed to account for the diet and estimate the PS (31). In this tool, standardized photographs were available to assist in PS estimation, they found that photographs of food items can serve as a good aid in ranking subjects (31); Even though, observers could differ on their ability to estimate food weights visually, as they tend to overestimate the weight of the foods consumed and to underestimate plate wastes which could induce to potential bias in estimating the sizes of foods with high volume but low weight (29). Noteworthy, a wide range of methods have been described to quantify outcomes related to PS in research studies, including surveillance and epidemiological analyses, clinical and nutritional studies and research on eating behaviour (32). The most frequently used measurements are food models, photographs or household measures (33).

Household measures

Even though some foods, like eggs, oranges, or soft drinks, can be recorded in units, other food items are often measured in volume such as cups or tablespoons (33). These measures are familiar and easy to use. However, volume measures could produce considerable error and individual variability in estimating portion’s weights (34), as foods can be packed tightly or loosely and certain foods, such as meats and pastries, and not conform to measuring devices (35). Household food measures have led to significant under- or over-estimations of actual portion's weight (33). Consequently, household measures are not accurate for individuals, but they are still used to produce acceptable data for group estimations in epidemiological studies.

Food models

The food models are also known as fake food models; they are geometric shapes of food samples. Some studies found that having realistic models closer to real food is a better option for children (36). On the other hand, a systematic underreporting of intake was found when three-dimensional plastic food models are used to represent servings, and the magnitude of this underreporting varied across food items. In contrast, when larger-sized food models were used, participants tend to be more accurate in reporting their intake of foods (37).

Photographs

In studies that involve telephone recalls or self-administrated dietary surveys the two-dimensional pictures of food shapes were as effective as three-dimensional models in supporting participants to estimate PS (38). Food photographs of various PS have been reported to be useful in some studies (39), but poor correlations to actual measurements were detected in others (40).

1.2. Factors affecting food portion sizes estimation.

Several studies have been conducted to examine the influence of some specific characteristics of foods, study subjects and interviewers on the accuracy of PS estimations.

Food Characteristics

- Food type: It is important to know which foods are more reliable to estimate the size of their portions. High errors have been reported for some foods such as, cakes, salads and butter on toasts (41), amorphous foods, such as spaghetti or apple sauce (42), or fish, rice, steak, and cheese (37). However, some studies indicate no consistent association between size estimations and food type (43).
- Food size: Some studies found greater difficulties in estimating PS as the size of the portions increased (44). In addition, some investigators reported that large plates are

harder to estimate (18), but others did not report any difference related to plate size (43).

Subject characteristics

- Age: It plays an important role in the estimation of PS. Previous studies suggested that children are not able to estimate PS very accurately, even when prompted with visual aids (45). In contrast, recent studies found that children can estimate food PS with an accuracy approaching that of adults (46). However, high school and college students have also reported difficulties when estimating PS (47).
- Gender: the influence of gender on PS estimation has been argumentative, even though some studies report that women are better estimators (28), others report minimal or no differences (37). These differences among genders may reflect a skill attributed to their greater experience in measuring food as a function of their reference system, or a biological response to the higher energy needs of men versus women (48).
- Cultural background: Cultural background can influence how people perceive and estimate PS. People from cultures that emphasize larger portions may overestimate PS more than those from cultures that emphasize smaller portions, for example, some cultures the hand-based portion is used to self-serve or measure portions of foods for others in order to ensure that everyone gets an equal portion of food (27).

1.3. Psychosomatic and emotional status and selection of food portion sizes

Metabolic needs are not the only factor that influences food intake (49), but emotional states, motivations, and self-regulatory processes also play an important role (50). In this sense, negative affect and cognitive control can override the body's natural energy balance, leading to either reduced or increased food intake in order to cope with stress and negative emotions (51, 52).

In 2005, the Mental Health Foundation acknowledged that diet can have a considerable effect on mental health, which is often overlooked (53). Stressors during childhood may arise from multiple events in the daily life environment such as school and family (54). Regular exposure to stressful situations may influence a child's behaviour and have consequences on both their physical and mental health (54). It has been observed that an inability to cope with or suppress negative emotions is linked to increased food consumption, particularly of sugary and fatty foods (55). Moreover, a two-way relationship has been proposed between emotion and eating, where emotions control eating and vice versa (52).

Emotional eating, which is defined as the tendency to overeat in response to negative emotions such as anxiety or irritability (56), has been observed to be on the rise. This concept is derived from the psychosomatic theory (57), which suggests that emotional eaters are unable to differentiate hunger from the physiological state accompanying negative emotions. This emotion-driven impulsiveness has been linked to the type of snack food consumed (sweet and fat) rather than the energy intake of food consumed per snacking occasion (58).

External factors and emotional states can have an effect on food intake (59). It was observed that those who had higher scores in terms of dietary restraint or emotional disinhibition ate more when presented with larger PS (59), implying that both positive and negative moods can be linked to greater food and calorie consumption in different groups (59). Following this, during meal planning, individuals experiencing elevated psychosomatic status may select larger PS, given that expectations of satiety delivered from a food is one of the strongest predictors of PS (60).

Prior studies in adults suggest the contributions of psychosomatic to unhealthy eating behaviours, such as increased preference for palatable higher energy foods and consumption of a higher fat diet (61). A systematic review conducted by O'Neil et al. found a cross-sectional association between poor psychosocial well-being and energy dense foods, such as refined grains, processed meat and snacks, diet- and sugar rich soft drinks, fried food and foods high in saturated fat and sugar, in children and adolescents (62). Additionally, a positive correlation between emotional status and the frequency of consumption of sweets and fatty foods was observed in children, which may lead to overweight, even though the study did not quantify the portion sizes of the consumed food (63). These findings suggests that when individuals are experiencing elevated emotional status, they may select larger portion sizes in order to achieve sufficient satisfaction or satiety for coping with negative moods (64). This is supported by the fact that expectations of satiety delivered from a food is one of the strongest predictors of PS (60). However, the relationship between emotional status and dietary intake, mainly PS, has not been examined in children and adolescents.

1.4. Relationships of food portion sizes with dietary patterns, energy, and nutrient intakes

Childhood and adolescence are both critical periods in which rapid cognitive development and physical growth occurred (65). During childhood, the nutritional demands increase and the adequate energy intake along with the consumption of nutrient-dense foods are essential (66).

Dietary patterns undergo many changes during lifespan regarding dietary diversity, nutrients intake, and PS (67). Increased PS of foods and high ED drinks commonly served are consider as a major component of the food environment that has contributed to the excess of energy consumed (9, 68). In children and adolescents, larger food PS have been associated with increased intake of specific nutrients and/or a decrease of the intake of some micronutrients as a result of the composition from the food itself; for example, when children consume large PS of sugary sweets, total sugar increase but, on the other hand, the intake of many micronutrients' decrease (69).

In the same vein, children with excess of energy consumption, may suffer from nutrients deficiency (70). For example, iron intakes decreased when more sweets, sugar-sweetened beverages and sweetened grains products were consumed and increased with higher intakes of non-sweetened cereals (71). Moreover, unsuitable nutritional profile in terms of foods, macronutrients, and micronutrients during adolescence, is associated with adverse health outcomes in later adult life (66). For example, regular consumption of cow's milk is very important during childhood due to their high content of protein, fat, calcium, and vitamin D that help to maintain good health (72). Noteworthy, micronutrient deficiencies like vitamin D, calcium, and potassium, can lead to a wide range of health problems, such as hyperparathyroidism, rickets, osteomalacia (73), and hypertension (74) in children and adolescents.

Since most European countries met under half of the WHO recommended nutrient intake (RNI) for micronutrients, such as iron or vitamin D), widespread nutrition issues could exist across Europe (70). Macronutrients compliance to RNI was globally poor, meanwhile micronutrients compliance was slightly better; however, girls and children over 10 years showed less attainment (70). On the other hand, selected micronutrients intake has been examined in Central and Eastern European countries and it has been found that these countries lacked intake information across all ages, particularly in children, as compared with other European countries (75). Also, a recent review showed that less than a third of European countries reported the energy and nutrient intakes for their children and adolescents (76).

Most studies focus on the effect of PS from high ED foods on energy intake and on BMI to manage the obesity epidemic (25, 77); the effect of food PS on nutrients intake is not usually addressed. Knowledge on adolescents' association between PS and intakes of energy, macronutrients and micronutrients is essential for monitoring trends as well as for nutritional interventions.

1.5. Food portion sizes, energy density, obesity and related metabolic complications.

1.5.1. Food Portion Sizes and Obesity

Apart from increasing sports activities, there are several components of the food environment supporting energy over nutrition (78), being food PS probably one of the most relevant factors (68). Previous studies have found that the PS of some pre-packed foods, as well as menu sizes consumed in restaurants, have increased dramatically over the last 30 years, concurred with the recent increase in obesity prevalence (13, 79). Specifically, increased PS of foods commonly served in restaurants and market is considered as a major component of the food environment that contributes to the excess energy consumption particularly from high ED foods (9, 68).

Energy density (ED) refers to the amount of energy in each weight of food and/or beverage (kcal/g) (80), and mainly depends on the fat and water content of the food (81). The World Cancer Research Fund has classified food that contain 60–150 kcal/100 grams as low ED foods characterized through high water and fibre content. Medium ED foods are containing 100–225 kcal/100 g and high ED foods are containing more than 225–275 kcal/100 g (82). This classification is one of the most commonly used by several studies (25, 83) to group specific food items by its energy content.

Epidemiologic studies in European adults have found only a limited relationship between PS from high ED foods and the actual BMI (84). Rippin et al. (84) also found limited evidence on the association between PS of ED foods and BMI in subgroups of adults analysed from the French and UK national dietary surveys. An intervention study focusing on the effect of large PS on body weight by a midday meal manipulation in adults noticed that the weight changes were not significant over time or between test periods (85). In this study, a midday meal manipulation with a four-week trial, showed that larger portions were associated with a 0.64 ± 1.16 kg weight gain whereas the change on the standard portions group was 0.06 ± 1.03 kg (85); the weight changes were not significant over time or between test periods.

In children, a cross-sectional study found that PS of milk, bread, cereal, juice, and peanut butter, had a high contribution to children's daily energy intake; moreover they found that the high PS z-scores were positively linked with both, energy intake and body weight (86). Moreover, in British adolescents, PS of high ED foods from high-fibre breakfast cereals, cream and carbonated soft drinks were positively associated with a higher BMI (25).

Another study conducted in children and adolescents found that PS and energy content consumed per meal were significantly associated with BMI percentile in boys 6 to 11 years and in children 12 to 19 years. However, no relationships were found in children 3 to 5 years and girls aged 6 to 11 years (87). Moreover, a French cross-sectional study focused on children, aged between 3–11, observed that overweight in children aged 3–6 years was positively associated with PS of biscuits and sweetened pastries. Also significant positive trends were observed for PS of croissant-like pastries and meat (88). In the same vein, in children, it was observed that when girls consumed large portions of snack foods in the absence of hunger at 5 and 7 years of age, they had 4.6 times more probabilities of having overweight at both ages than boys (89).

Although, several studies observed a positive relationship between increasing PS and obesity in children (86, 89), these studies cannot be taken as proof of causality in children, mainly because most of them are a cross-sectional studies, and they are not reflecting eating in a free-living context. Consequently, long-term studies are needed to determine the potential causal link between increasing PS and obesity.

1.5.2. Food portion sizes and cardiometabolic health

Dietary factors are environmental determinants of both adiposity, insulin resistance, and the components of metabolic syndrome (MS) (90). In adults, studies have shown that dietary patterns characterized by high intakes of fruits and vegetables are generally associated with a low prevalence of the metabolic syndrome (23, 24).

Diet composition, in particular, carbohydrate type and amount of fat intake may also influence insulin resistance (91). In children it has been found that total energy, fat, saturated fat, and protein intakes were significant predictors of fasting insulin and quantitative insulin-sensitivity check index (QUICKI), independent of age and body mass index (BMI) (92). Studies found that increased consumption of margarine, sweets (candies, lollipops, jellies, traditional fruit in heavy syrup) and savoury snacks (chips, cheese puffs and not home-made popcorn) was associated with high homeostasis model assessment of insulin resistance (HOMA-IR) index value in children and adolescents (93, 94). Additionally, it was previously shown that sugar intake in the form of sugar-sweetened beverages was associated with insulin resistance in adolescents (95). Data from children indicated that short absorption time which follows the consumption of sugar may impair blood glucose control and may result in hyperinsulinemia and peripheral insulin resistance (96). Frequent intake of obesogenic foods such as crackers, chips, and cooked ham was observed in adolescents with MS (97). Moreover, a 'Western' dietary pattern was associated with a greater risk for metabolic syndrome, among female adolescents (98). However, there is no studies focus on PS and its relationship with insulin resistance and metabolic syndrome in children and adolescents.

2. Objectives

The general objectives of this Doctoral Thesis are to explore, in previous research, the connection between food portion sizes and energy intake, obesity and metabolic complications in children and adolescents. To explore how psychosomatic and emotional status effect on food portion sizes selection. Moreover, to identify which portion sizes of food groups mainly influence total energy intake in childhood and adolescence and to assess the effect of large food portion sizes on the development of obesity. Additionally, to analyse the effect of food portion sizes on insulin resistance and other metabolic complications.

The specific objectives of each of the five articles included in this Doctoral Thesis are the following:

Manuscript I: Food portion sizes, obesity, and related metabolic complications in children and adolescents.

Objectives: The main objective of this narrative review was to provide evidence for the impact of food portion sizes on obesity development, in children and adolescents. Specifically, in this narrative review we focus on the relation between food portion sizes, total energy intake, obesity, and some metabolic syndrome features such as insulin resistance in children and adolescents.

Manuscript II: The association between psychosomatic and emotional status and selected food portion sizes in European children and adolescents: IDEFICS/I. Family study.

Objectives: To investigate the cross-sectional and longitudinal influence of psychosomatic and emotional status on food portion sizes from different food groups. Also, to investigate which food groups are the most associated with psychosomatic and emotional status.

Manuscript III: Food portion sizes and their relationship with energy, and nutrient intakes in European adolescents: the HELENA study.

Objectives: To examine the relationship between food portion sizes from various food groups with the intake of macronutrients and micronutrients, and to identify which food groups mainly influence total energy intake in a sample of European adolescents.

Manuscript IV: The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study.

Objectives: To investigate the association between portion sizes from most frequently consumed high ED foods and obesity in a sample of European adolescents considering a set of relevant confounders.

Manuscript V: Associations between food portion sizes, insulin resistance, VO2 max and metabolic syndrome in European adolescents: the HELENA study.

Objectives: To investigate the influence of food portion sizes on insulin resistance and a quantitative score of metabolic risk in European adolescents.

2. Objetivos

Los objetivos generales de esta Tesis Doctoral son explorar, en investigaciones previas, la conexión entre el tamaño de las porciones de alimentos y el consumo de energía, la obesidad y las complicaciones metabólicas en niños y adolescentes. Valorar cómo el estado psicosomático y emocional afecta la selección del tamaño de las porciones de alimentos. Además, identificar qué tamaño de las porciones de los grupos de alimentos influyen principalmente en la ingesta total de energía en la infancia y la adolescencia y evaluar el efecto de las porciones grandes de alimentos en el desarrollo de la obesidad. Además, analizar el efecto del tamaño de las porciones de comida sobre la resistencia a la insulina y otras complicaciones metabólicas.

Los objetivos específicos de cada uno de los cinco artículos incluidos en esta Tesis Doctoral son los siguientes:

Manuscrito I: Tamaño de las porciones de alimentos, obesidad y complicaciones metabólicas relacionadas en niños y adolescentes.

Objetivos: El objetivo principal de esta revisión narrativa fue proporcionar evidencia del impacto de las porciones de alimentos en el desarrollo de la obesidad en niños y adolescentes. Específicamente, en esta revisión narrativa se describe la relación entre las porciones de alimentos, la ingesta energética total, la obesidad y algunas características del síndrome metabólico como la resistencia a la insulina, en niños y adolescentes.

Manuscrito II: Asociación entre el estado psicosomático y emocional y el tamaño de las porciones de alimentos seleccionados, en niños y adolescentes europeos: IDEFICS/I. Family.

Objetivos: Investigar, en el análisis transversal y longitudinal, la influencia del estado psicosomático y emocional en el tamaño de las porciones de diferentes grupos de alimentos. Además, investigar qué grupos de alimentos son los más asociados con el estado psicosomático y emocional.

Manuscrito III: Tamaño de las porciones de alimentos y su relación con la ingesta de energía y nutrientes en adolescentes europeos: el estudio HELENA.

Objetivos: Examinar la relación entre las porciones de varios grupos de alimentos, con la ingesta de macronutrientes y micronutrientes, e identificar qué grupos de alimentos influyen principalmente en la ingesta total de energía, en una muestra de adolescentes europeos.

Manuscrito IV: Asociación entre el tamaño de las porciones de alimentos de alta densidad energética y la composición corporal en adolescentes europeos: el estudio HELENA.

Objetivos: Investigar la asociación entre las porciones de alimentos con elevada densidad energética consumidos con mayor frecuencia y la obesidad, en una muestra de adolescentes europeos considerando un conjunto de factores de confusión relevantes.

Manuscrito V: Asociaciones entre el tamaño de las porciones de alimentos, la resistencia a la insulina, el VO2 máx. y el síndrome metabólico en adolescentes europeos: el estudio HELENA.

Objetivos: Investigar la influencia de las porciones de alimentos en la resistencia a la insulina y una puntuación del riesgo metabólico en adolescentes europeos.

3. Material and methods

3.1. Narrative methodology (article I)

The strategy for bibliographic search focused on articles published in the English language from 1952 to December 2019 (including online). The databases used included PubMed, Web of Knowledge, Scopus, Science Direct, and online books. In addition, citations in reviews and paths within databases were also incorporated. Key terms included: portion sizes, food size, food type, dietary estimation method, portion sizes estimation, food photography, food model, household measures, obesity, food choice, dietary intake, body mass index (BMI), energy-dense food, energy intake, emotional eating, insulin resistance, diabetes, children, adolescents, satiety, appetite, exposure, reward, model, and pressure to eat. Inclusion criteria were manuscripts from all age groups, and cross sectional, longitudinal and clinical trials. The methodology is based on analysis, synthesis, interpretation, and relevant comparisons. We identify some key areas for further investigation, propose assumptions based on prior studies that provide detailed views of how food PS affects obesity, and related metabolic complications, and explore the main factors that influence these relationships.

3.2. IDEFICS/I. Family study (Article II)

3.2.1. Study design and sampling

The analysis was conducted using data from the "Pan-European IDEFICS/I. Family children cohort", the IDEFICS (Identification and prevention of Dietary and lifestyle induced health EFfects in Children and infantS) recruited a total of 16,229 children aged between 2 and 9.9 years old at baseline (T0) (99). They were examined from autumn 2007 to spring 2008 in a community based baseline survey (T0) in eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden) and follow-up in 2009–2010 (T1) and 2013-2014 in the "Investigating the determinants of food choice, lifestyle and health in European children, adolescents and their parents" (I. Family) (T3) study (100, 101). The final included samples in the follow-up comprised 11,041 and 6,055 children from the original IDEFICS cohort in T1 and T3, respectively (101). The general purpose of both studies IDEFICS and I. Family was to understand the mechanisms of childhood obesity and how to prevent it and to identify determinants of eating habits, lifestyles, and health in European children and their families (101). More details about study design, sampling, and procedures of IDEFICS/I. Family have been described elsewhere (100, 101).

Out of the total sample 7,355 in T0, 3869 in T1, and 2971 children in T3 (in each measurement time new participants were added) met the criteria of availability of at least one 24-HDR with plausible reporters, and the full variables for this study: body mass index (BMI), parental education, emotional well-being and self-esteem of the child during the last week score (KINDL), and data about emotional and peer problems over the last 6 months. A flow chart for the selection of the total sample can be found in **Figure 1**.

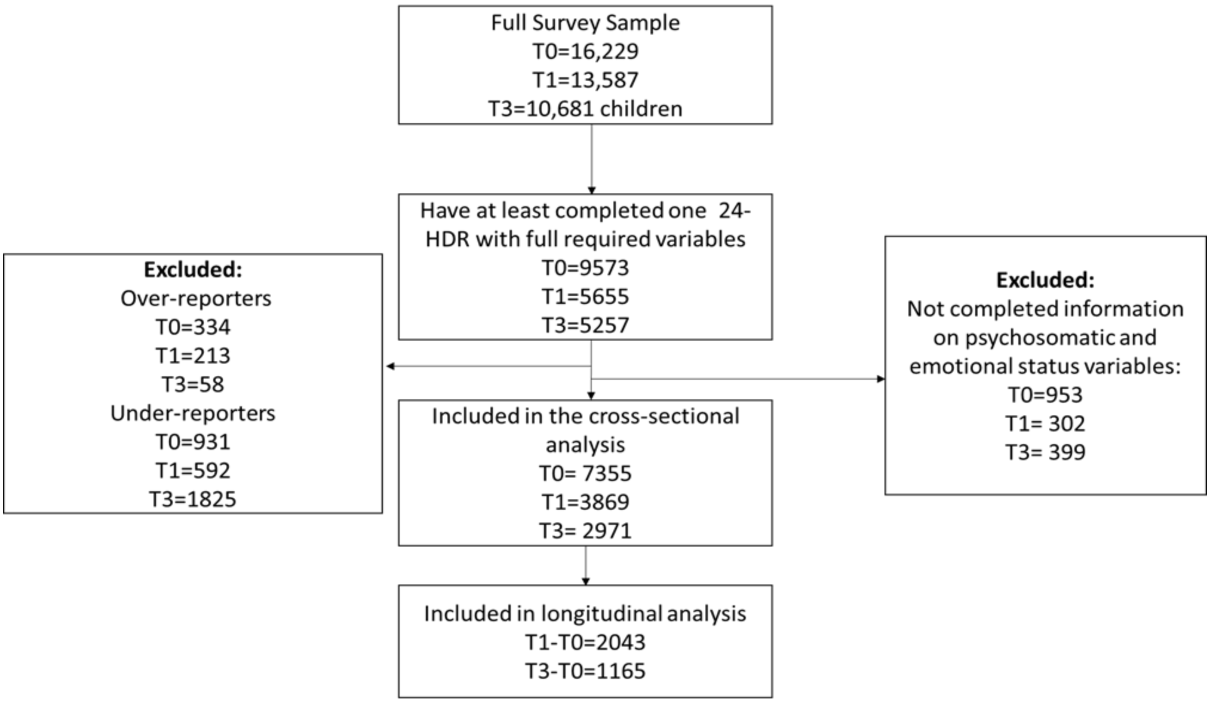


Fig. 1 Study flowchart. T0: Baseline measurement of IDEFICS. T1: Follow up measurement of IDEFICS. T3: Follow up measurement of I. Family.

3.2.2. Ethics committees

The IDEFICS/I. Family study was carried out in accordance with the Declaration of Helsinki (1975), and the ethical guidelines of the Edinburgh review of 2000. Approval was obtained from all the local ethical committees in the centres where the study was carried out. All the children were informed and gave their oral consent while the parents read an information letter and signed a consent to participate in the study. In Aragón, the Ethics Committee (CEICA) approved the performance of all the measures.

3.2.3. Socioeconomic and demographic factors

Data on parental education and income was collected from the parental questionnaire. The education level is based on the International Standard Classification of Education (102) for cross-country comparability and was used to determine the highest level of either parents' education (103). Levels 1–3 represent upper secondary education (classified as lower education level) and levels 4–6 represent post-secondary education (classified as higher education level). Country-specific income levels were assigned with reference to the average net equivalence income, considering the median income and poverty line. Levels 1–5 represent lower income level and levels 6–9 represent higher income level.

3.2.4. Evaluation of psychosomatic and emotional symptoms

Psychosomatic and emotional symptoms (104) in children were described by two variables: emotional well-being and self-esteem of the child during the last week, emotional problems and frequent occurrence of headaches, stomach-aches or sickness over the last 6 months.

1. <u>Emotional well-being and self-esteem of the child during the last week:</u> Parents were asked to complete the emotional and self-esteem subscales of the 'KINDL Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents', a questionnaire which assesses the child's quality of life in multiple dimensions (physical well-being, emotional well-being, self-esteem, family, friends and everyday functioning subscale) and which was incorporated in the IDEFICS parental questionnaire (105). The questionnaire had previously been tested for its reliability and validity (105). The items of the emotional and self-esteem subscales were scored from 1 (never) to 4 (often or always) with reversals according to the wording of the question and summed to a total score with a high value indicating high well-being (105, 106).
2. <u>Emotional and peer problems over the last 6 months:</u> Assessed using the Emotional Symptoms Scale of the SDQ. The peer problem score included: to what extent do the following characterizations apply to your child? (1) rather solitary, tends to play alone, (2) has at least one good friend, (3) generally liked by other children (4) picked on or bullied by other children, and (5) gets on better with adults than with other children. The emotional problem score included: To what extent do the following characterizations apply to your child? (1) often complains of headaches, stomach-aches or sickness, (2) many worries or often seems worried, (3) often unhappy, depressed or tearful, (4) nervous in new situations, easily loses confidence, and (5) many fears, easily

scared. Items were scored from 0 ‘not true’ to 2 ‘certainly true’ and summed to total scores ranging from 0 to 10 where a high value indicated more difficulties or life struggles. In accordance with the SDQ manual the emotional and peer problem scores were divided into: ‘inconspicuous’, ‘borderline’ and ‘abnormal’. Thereafter, a dichotomized variable was created consisting of poor well-being (including both ‘borderline’ and ‘abnormal’ groups) versus the remaining children with no detectable (‘inconspicuous’) poor wellbeing (107). Cut-off values for No detectable emotional problems were ≤ 3 and, and for No detectable peer problems ≤ 2. The internal consistency of the scale in the present study was good (Cronbach’s $\alpha = 0.87$).

3.2.5. Dietary evaluation and calculation of the food portion sizes.

Dietary intake of the previous 24 h was assessed using the computer-assisted 24-h dietary recalls (24-HDR), called SACINA (‘Self- Administered Children and Infant Nutrition Assessment’) in T0 and T1 and SACANA (“Self-Administered Children, Adolescents, and Adult Nutrition Assessment”) in T3 (108). SACANA was the revised and extended web-based version of the SACINA online 24-HDR.

The SACINA software was based on the previously designed and validated ‘YANA-C’ (‘Young adolescents’ nutrition assessment on computer’) developed for Flemish adolescents and further adapted to European adolescents in the HELENA study (109). SACINA was developed to assess the children’s absolute energy and nutrient intake, the percentage contribution from food and drinks to total energy and nutrient intake, as well as portion sizes and food groups during the previous 24 h. In a subsample, in T0 and T1, two 24-HDR were recorded, but to not lose participants in this study, only the first 24-HDR was considered in each child (also in T3). Parents or other caregivers as proxy respondents for children’s diet gave information on amount (g) and type of all foods and drinks that were consumed during the previous day, starting with the first intake after waking up in the morning. In T3, this was done by the children themselves with the help of a parent from the age of 8 y. The required time frame for one interview was 20–30 min (108). School meals, drinks and snacks consumed the day prior to the 24-HDR were assessed using a standardized observer sheet, completed by trained personnel, attending the school canteen the day of the recall. School meal data were merged with the parentally reported 24-HDR data to enhance the completeness of dietary recalls (110). Incomplete interviews were excluded if the proxy did not know about at least one main meal or in case of missing school meal information.

The validity of proxy-reported energy intake from the 24-HDR was tested using the doubly labelled water technique in young children. SACANA was validated twice. The instrument was found to be valid to assess energy intake at group level (111). Accurate estimation of PS was assisted using standardized photographs. SACINA was structured according to six meal occasions (with possibility to add more snack occasions): breakfast, mid-morning snack, lunch, afternoon snack, evening meal and evening snack, together with questions related to a range of chronological daily activities to help to remember (110).

Misreporting (over and underreporting) is a well-known problem in dietary assessment. In this study misreporting were measured by calculating the individual ratio of the energy intake and the basal metabolic rate (EI/BMR) and comparing this ratio with the age- and sex-specific EI/BMR for children using Goldberg cut-offs which considered of good predictive value and thus they are an appropriate alternative for characterizing misreporting in the absence of objective validation data; more information's were described elsewhere (112).

Portion sizes calculation and food group selection

All nutrients and energy values were expressed per 100 g edible portion. Standard units were taken from McCance and Widdowson's (113) food composition tables. The methodology used in this study to calculate the PS of a food group was to divide the total intake of items in grams consumed in a 24h-recall by the number of eating occasions. This same approach has been used in several studies of food PS in children and adolescents (25, 77) and it provides data on a per-consumer basis, rather than per-capita. To analyse a specific food group, only participants who consumed this food group were included in the analysis. For the purpose of this study, in the case of mixed dishes, each dish was re-classified by the main food component according to the ingredient present in the highest proportion, after cooking. Alcoholic drinks and soya beverages were excluded from the analysis due to infrequent consumption (more than 85 % of the sample did not report consumptions).

In accordance with the World Cancer Research Fund (82), which identified foods with an energy density of 225–275 kcal/100g as high-ED foods, we chose food items that had been previously identified as having the greatest contribution to energy intake and a positive association with BMI in Europe and other countries (25, 77)

In this study food items were selected based on their ED, clustered in groups and each food groups containing subgroups according to their nutritional values: 1) cereals and cereal products, 2) sugar and sugar products 3) fats and savoury snacks 4) non-alcoholic beverages and soups 5) dairy products and similar. Dietary data were analysed for average energy intake in kilocalories (kcal) and kilojoules (kJ), macronutrients (g), and percentages of energy (114).

3.2.6. Anthropometric measurements

Weight, in kilograms, and height, in centimetres, were measured by trained personnel according to a standardized protocol with participants barefoot and in underwear. Body weight was assessed in fasting status on a calibrated scale (Tanita electronic scale model BC 420 SMA with an adapter; Tanita Europe GmbH) to the nearest 0.1 kg. Height of the children was measured with a calibrated stadiometer (Seca telescopic height-measuring stadiometer model 225; Seca) to the nearest 0.1 cm (115). Finally, BMI was calculated as body weight in kilograms divided by the square of height in meters. BMI Z-scores and BMI categories were estimated according to Cole et al (116).

3.3. HELENA study (articles III-V)

3.3.1. Study design and sample

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study was a cross-sectional multi-centre study (CSS) that took place in 2006-2007 and was designed to evaluate the nutritional status of the European adolescent population. Adolescents were aged between 12.5–17.5 years and were recruited in 10 European cities: Heraklion and Athens (Greece), Ghent (Belgium), Dortmund (Germany), Pécs (Hungary), Rome (Italy), Lille (France), Vienna (Austria), Stockholm (Sweden), and Zaragoza (Spain) (117). The main objective of HELENA-CSS was to obtain reliable and comparable data from randomly selected European adolescents (n=3528, 52.3% girls), using wide relevant health and nutrition-related parameters which included: anthropometric measurements, physical activity, dietary intake, food choices and preferences, lipid and glucose metabolism, serum vitamins and minerals status, physical fitness and genetic markers (118). The inclusion criteria for the main study were participants who did not involve concurrently in another clinical trial, ages less than 17.5 or greater than 12.5 years, and being free from any acute infection lasting less than 1 week before the inclusion process, have complete weight and height measurements, and have completed at least 75% of the rest of the tests (119).

A subgroup of 1,089 adolescents, from the 10 participant cities were randomly chosen to participate in the blood extraction. As blood parameters have much less variability than the rest of the variables, a smaller sample is sufficient to be representative. The size of the subgroups (approximately 100 adolescents in each city) was chosen taking into account the means of the 57 immunological parameters, since they were the blood measurements that presented a greater variability among all the parameters included in the study.

The general methodology of the study as well as the procedures developed to carry it out have been previously described (119). A detailed manual of operations was thoroughly read by all the researchers involved in fieldwork before the data collection process, in addition the instructions and questionnaires that were given to participants for every measurement were translated into their local language (120).

3.3.2. Ethics committees

The HELENA study was conducted in accordance with the ethical guidelines of the Helsinki Declaration (1975), in its 2000 Edinburgh revision, and in accordance with the epidemiological research legislation of each of the participating countries. All the local ethics committees of the centres where the study was developed approved the protocol and study development. In Aragón, permission to carry out the study was obtained from the Ethics Committee (CEICA). Informed consent was obtained from the participating adolescents and their parents/guardians.

3.3.3. Socioeconomic and demographic factors

A general questionnaire with socioeconomic status (SES), health outcomes, and nutritional status were fulfilled by the participants. Family affluence scale was used as indicator of the adolescents' material affluence and a predictor of their health outcomes, the FAS is typically scored on a scale of 0 to 8, with higher scores indicating higher levels of affluence then re-categorization into three levels include: low (from 0 to 2), medium (from 3 to 5) and high (from 6 to 8). The education level of the adolescent parents was reported as primary education, lower secondary education, higher secondary education, or higher education/university degree. More detailed description about the SES has been reported elsewhere (121).

3.3.4. Dietary evaluation and calculation of the food portion sizes.

The HELENA Dietary Assessment Tool (HELENA-DIAT) was used to assess adolescent's dietary consumption. This software was used as a self-administered computerized 24-h recall, and it was developed and validated originally in Flemish adolescents and, then, in the HELENA-CSS (109). HELENA-DIAT comprised the intake from six meal occasions: breakfast, morning snack, lunch, afternoon snack, evening meal and evening snack. It included two non-consecutive 24h recalls based on a weekday and one weekend day, one week apart. A well-trained dietitian assessed the adolescents and helped them to complete the 24-hr recall.

In total, about 800 photographs were available in the program. The participants could select visually from photographs the consumption amount and indicate the one closer to their actual intake. Furthermore, they could type in a textbox their intake amount from each food item. However, the participants can remove or modify the selected items at any time. Also, for foods that could be sizing by household measurements like cups, several portions appeared on the screen and the participants choose their consumption amount by clicking directly on the portion. In case of foods eaten in combination with other food items such as 'French fries and mayonnaise', a box was shown on the screen to remind them to include this additional food item (122). To calculate energy and nutrient intakes, data from HELENA-DIAT were linked to the German Food Code and Nutrient Database (Bundeslebensmittelschlüssel, version II.3.1) (123). Taking into account occasionally consumed foods, the usual dietary intake of foods and nutrients were estimated by the multiple source method (MSM) (124). The MSM, firstly calculated individual's dietary intake and then build the population distribution based on the data. After applying the MSM method, dietary data were analysed for average energy intake in kilocalories, kilojoules, and macronutrients (carbohydrates, proteins, and fat) in grams.

Based on European food groups classification system, about 4179 foods and beverages, in the form of recipes or as individual food, were aggregated to 29 food groups (109, 125). As part of the general HELENA analysis and based on the nutritional composition of food groups some of them were further re-aggregated for PS analysis according to their nutritional value; for example, all types of meat were combined into the 'Meat' group. However, four food groups were excluded from the analysis such as 'soya beverages', due to very low consumption (more than the 85 % of the sample did not report consumption).

PS were established by the total intake of items in grams included in each food group and consumed in the 24h-recall, divided by the number of eating occasions of these consumed items. In this thesis, the average amount was calculated from the two days included in the 24h-recall by each meal occasion. For example, if an individual consumed 200g of meat for lunch in the first day and 200g in the lunch of the second day, then his/her PS at lunch from this food item was 200g, and if an individual consumed 200g of meat only in lunch and did not consume meat in any other meal, his/her PS was 200g. Various studies have adapted the same methodology, such as the study of food PS effect on overweight in children and adults (88, 126). Thus, these data represent per-consumer averages, not per capita averages.

3.3.5. Anthropometric Measurements

All anthropometric measurements were collected by standard methodology and by trained employees (120). Telescopic height-measuring instrument (model 225; SECA, Germany) was used to measure height to the nearest 0.1 cm, barefoot with the head oriented in the Frankfurt plan. Body weight was measured in underwear and without shoes by an electronic scale (model 871; SECA, Hamburg, Germany) to the nearest 0.1 kg. The BMI was calculated by dividing body weight in kilograms by squared body height in meters. International Obesity Task Force criteria was used to classify the obesity status (116). Children were classified into the normal-weight, overweight and obesity categories. Also, skinfold thicknesses were measured in triplicate with a Holtain Caliper (Crymmych, UK) from six body sites (triceps, subscapular, right side at biceps, suprailia, thigh, and medial calf) to the nearest 0.2 mm, and then, the average of the three measures was used (127). In order to obtain total body fat, the six-skinfold thicknesses were summed. Body fat percentage was estimated from skinfold measurements, using the formula of Slaughter et al. (127). The fat mass index (FMI) has been calculated by dividing body fat mass (kg) by the square of height in meters (128). Waist (WC) and hip (HC) circumferences were also measured in triplicate, to the nearest 0.1 cm with an anthropometric tape (SECA 200, Germany); the average of the three measures was used. WC was measured at the midpoint between the lowest rib and the iliac crest (129) and considered a marker of abdominal fat. HC was measured at a level parallel to the floor, at the largest circumference of the buttocks.

3.3.6. Physical activity measurement

Accelerometers (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) were used to obtain an objective measurement of physical activity. The devices were placed on the lower back of the participants, under the clothes using an elastic belt, for seven consecutive days. The participants were given instructions to wear the instrument when they wake-up and to remove it for water-based activities and sleeping (130).

Using manufacturer software, data were downloaded to a computer and analysed later by software based on Visual Basic. Time spent in moderate and vigorous PA (MVPA) was determined using the cut-off point of 2000 cpm, to generate the various indices, the number of days per week were multiplied by minutes per day to produce minutes per week for each activity (131). More detailed information has been reported elsewhere (130).

3.3.7. Cardiorespiratory fitness

Cardiorespiratory fitness was measured by the progressive 20-m shuttle run test (132). This test required subjects to run back and forth between two lines set 20 m apart following a running pace determined by audio signals and with an initial speed of 8.5 km h-1 increasing by 0.5 km h-1 every minute (1 min equals 1 stage). The test was finished when the adolescent failed to reach the end lines concurrent with the audio signals on two consecutive occasions and the final score was computed as the number of stages completed (precision of 0.5 stages). Maximal oxygen uptake (133) was estimated using the formula described by Léger et al. (1984).

3.3.8. Blood samples

Briefly, fasting blood samples were collected by venepuncture at school between 8:00 and 10:00 after a 10-h overnight fast. Whole blood samples for the hemogram were sent directly to the local laboratory of each country to be analysed. Concentrations of triglycerides, total cholesterol (134), high-density lipoprotein cholesterol (HDLc), and glucose were measured in fresh serum enzymatically on the Siemens Dimension RxL Max Integrated Chemistry System (Dade Behring, Schwalbach, Germany) using the manufacturer's reagents and instructions at the University Hospital in Bonn (Germany). TC/HDLc ratio was calculated. Insulin (135) was measured by a solid-phase two-site chemiluminescent immunometric assay with an Immulite 2000 analyzer (DPC Biermann GmbH, Bad Nauheim, Germany). More details about blood handling procedures have been described elsewhere (136). The intra-assay coefficients of variation were <3.3% and the inter-assay coefficients <3.9% for all parameters.

3.3.9. Metabolic risk score

The HOMA-IR index was calculated as (fasting insulin (pmol/l)/6.945 * fasting glucose (137)/22.5) (138). The cut-off value for HOMA-IR was based on the 90th percentile by sex and age. A quantitative insulin sensitivity check index (QUICKI) was calculated as QUICKI = 1/log insulin (lIU/mL) + log glucose(mg/dl) (139). Systolic blood pressure was measured with an automatic oscilometric device (M6, HEM-7001-E, Omron). A continuous clustering metabolic risk score was computed using the following variables: systolic blood pressure, triglycerides, TC/HDL-c ratio, HOMA-IR index, and the sum of six skinfolds and VO2max based on the one by Andersen et al (140), that has been used in previous HELENA studies (94, 141). VO2max was multiplied by -1 to indicate higher metabolic risk with increasing value. Z-scores were calculated for each risk factor variable by gender, and then all individual Z-scores were summed to create a clustered risk score. The lower the metabolic risk the better the overall CVD risk factor profile.

The summary of the included articles of this Doctoral Thesis are described below. Samples were selected based on having all necessary information in each article (Figure 2).

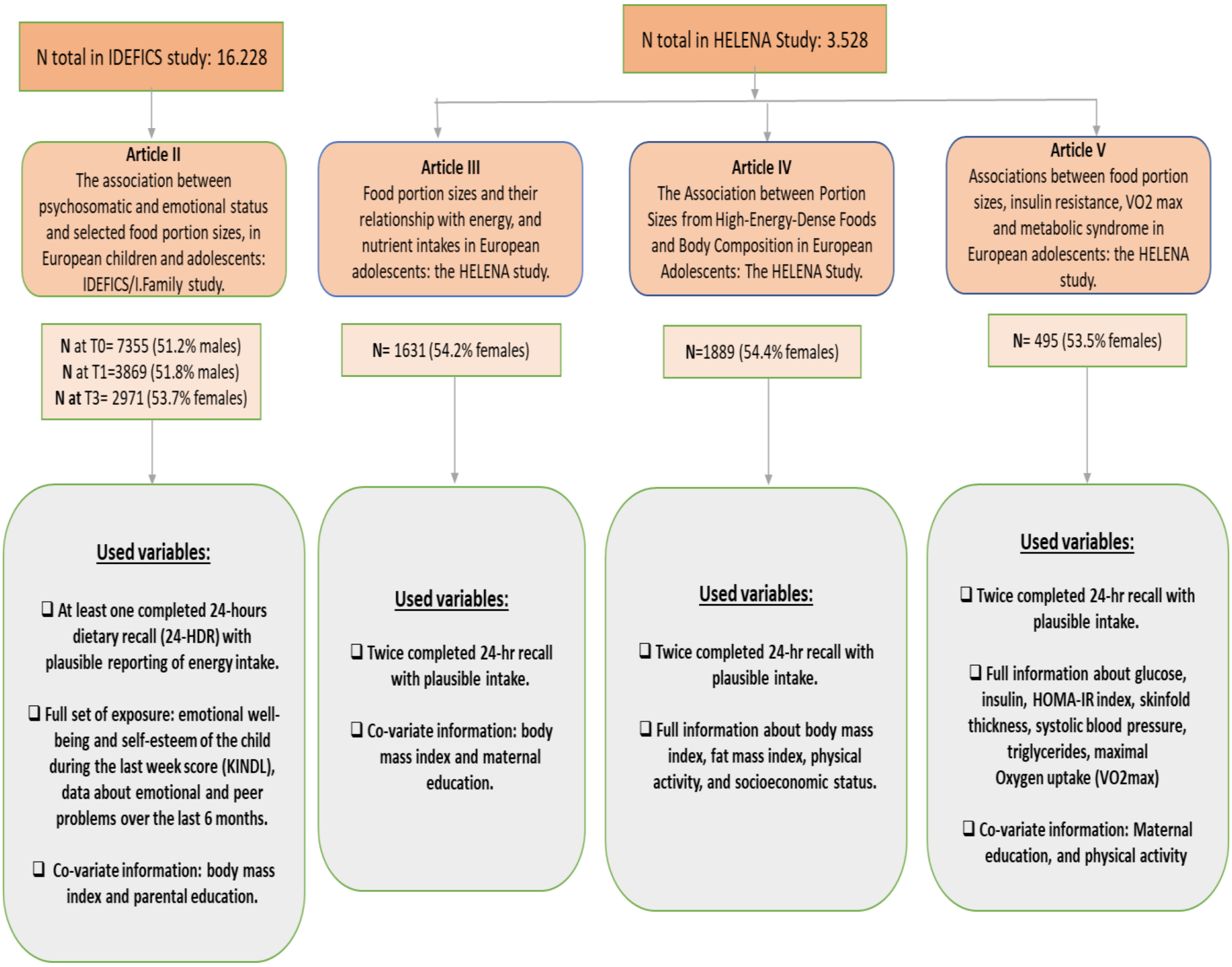


Figure 2: Summary of thesis framework.

3.4. Statistical analysis

The statistical analysis of all articles included in this Doctoral Thesis has followed a similar scheme. In an exploratory manner, a Kolmogorov-Smirnov test was initially carried out on all the articles, to assess the normality of the distribution of the continuous variables and, in the event of non-compliance, the pertinent transformation to the normality of the variable was carried out. Similarly, in all articles a descriptive table is presented with the main characteristics of the participants stratified by sex except for the fifth manuscript. These tables show the mean values with standard deviation for those continuous variables or percentages for those qualitative of all the markers and variables that have been used in the rest of the analyses. Student's t-test was used to assess gender differences in continuous variables, while the chi-square test was used to assess differences in qualitative variables.

Article I was a narrative review, so no statistical analysis was applied.

In article II, to explore the association between psychosomatic and emotional measurements (KINDL and SDQ), and food PS cross-sectionally, multivariable multilevel linear regression models were performed for the period T0, T1 and T3 using psychosomatic and emotional status as independent variables, and food PS as dependent variables, considering country as random effect.

Moreover, subjects with complete information in the three measurement times underwent longitudinal analysis to measure the association between psychosomatic and emotional status (delta value) and food PS (delta values) between T0 and T1 as well as between T0 and T3. The association between psychosomatic and emotional status variables and these delta values were analysed via multivariable multilevel linear regression models and considering country as random effect.

All of regression models were stratified between age and gender for period (T3-T0) and only by gender for period (T1-T0) also, adjusted by parental education and BMI. The Holm-Bonferroni adjustment method was employed to reduce the likelihood of type 1 errors. This method is more powerful than the single step Bonferroni. The procedure involves ordering the significant results from the smallest to the largest P-value, testing the smallest probability, and applying a simple equation (alpha/ (number of tests performed-rank after ordering+1). If the first test is significant, the second smallest probability is tested, and so on. The procedure ends when the first nonsignificant test is generated. A significance level of $p \leq 0.017$ was used after adjusted for multiple testing.

Analyses were carried out using IBM–SPSS (v25, SPSS Inc., Chicago, IL, USA), and Stata (v13.0, College Station, TX: StataCorp LP, USA). P-values of 0.05 were used as representing statistical significance for all tests. The figures and graphics have been made with power point (Microsoft).

In article III, to assess the relation between the amount of PS from food groups and energy, macronutrients and micronutrients, multivariable linear regression analysis was carried out, with food PS amount as independent variables and nutrients intake as the dependent variable, adjusting for age, gender, maternal education, BMI and using country as a level. PS data for each food item were split by tertiles to create relatively 'small' (T1), 'medium' (T2) and 'large' (T3) PS categories. In order to avoid bias caused by differences in energy intake, all nutrients' intakes were energy adjusted to easily compare the intake per 10 megajoule (MJ). The non-significant differences between gender for PS intake from food groups and nutrients intake using Student's t test justify why we did not separate the analysis by gender. For all food groups consumed, mean values were compared across PS tertiles (T1 vs. T2 vs. T3).

A one-way between-groups analysis of covariance (ANCOVA) was used to test for significant differences in means across tertiles adjusting for gender, age, BMI and using maternal education as covariable. Tukey post-hoc comparison test was used for normally distributed ($p < 0.05$). Moreover, Kruskal–Wallis test with Mann–Whitney U test comparisons were used for the data were not normally distributed ($p < 0.05$). Finally, in order to reduce the probability of Type 1 errors, the Holm–Bonferroni adjustment method was applied manually to significant results by ordering them from the smallest to the largest p-value and testing the smallest probability then applied a simple equation (i.e., α / (number of tests performed – rank after ordering + 1). If the first test was significant, then the second smallest probability was tested, and so on. When the first non-significant test had been generated the procedure ended. This method is more powerful than the single-step Bonferroni.

In article IV, to assess the relation between food PS from high ED food groups and BMI, and fat mass index (FMI), multivariable linear regression analysis was carried out, using BMI and FMI as the dependent variables and food PS as the independent variable in both genders. Ordinal logistic regression models were carried out to determine the association between BMI categories (normal weight vs. overweight and obesity, combined) as dependent variable and PS from ED food groups between gender. Finally, a sensitivity analysis was carried out for all samples in order to detect any potential differences in the results after adjustment for misreporting. All regression analyses were adjusted for age, total energy intake (TEI), physical activity, and SES, because it was considered as important predictors of the outcome.

In article V, ANCOVA was used to determine the mean differences and standard deviations of food PS from the studied food groups by HOMA-IR cut off categories and metabolic risk score median cut off categories between gender, using maternal education as covariable for all participants.

The association between PS from food groups, as independent variables, and HOMA-IR, systolic blood pressure, triglycerides, TC/HDL-c ratio, the sum of six skinfolds and VO2 max, and the metabolic risk score, as dependent variables, was assessed by multilinear regression analysis. All regression models were adjusted for age, maternal education, PA, total energy intake, BMI and city as dummy variable. To avoid multiple testing all analysis were performed individually.

4. Results

The results of this Doctoral Thesis are shown in the form of scientific articles in the following order:

Article I: Food portion sizes, obesity, and related metabolic complications in children and adolescents. (Narrative review)

Article II: The association between psychosomatic and emotional status and selected food portion sizes, in European children and adolescents: IDEFICS/I. Family study.

Article III: Food portion sizes and their relationship with energy, and nutrient intakes in European adolescents: the HELENA study

Article IV: The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study.

Article V: Associations between food portion sizes, insulin resistance, VO2 max and metabolic syndrome in European adolescents: the HELENA study.

ISSN (electrónico): 1699-5198 - ISSN (papel): 0212-1611 - CODEN NUHOEQ S.V.R. 318

Nutrición Hospitalaria

Revisión

Food portion sizes, obesity, and related metabolic complications in children and adolescents

Tamaño de las porciones de alimentos, obesidad y complicaciones metabólicas asociadas en niños y adolescentes

Sondos M. Flieh[1], Esther M. González-Gil[2,5], María L. Miguel-Berges[1], and Luis A. Moreno Aznar[1,3-5]

[1]Growth, Exercise, Nutrition and Development (GENUD) Research Group. Universidad de Zaragoza. Instituto Agroalimentario de Aragón (IA2). Zaragoza, Spain. [2]Department of Biochemistry and Molecular Biology II. Instituto de Nutrición y Tecnología de los Alimentos. Centro de Investigación Biomédica (CIBM). Universidad de Granada. Granada, Spain. [3]Instituto de Investigación Sanitaria de Aragón (IIS Aragón). Zaragoza, Spain. [4]Facultad de Ciencias de la Salud (FCS). Universidad de Zaragoza. Zaragoza, Spain. [5]Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y la Nutrición (CIBERObn). Instituto de Salud Carlos III. Madrid, Spain

Abstract

Keywords:

Food portion sizes. Energy intake. Obesity. Insulin resistance. Metabolic syndrome. Emotional eating. Children. Adolescence.

The purpose of this narrative review is to provide evidence for the impact of food portion sizes on the development of obesity in children and adolescents. Strategies are needed on portion size estimation and on the relationship of portion size with certain health problems such as obesity, insulin resistance, and emotional eating in all age groups, in order to provide information for parents, teachers, and health professionals aiming to promote healthy eating. A wide range of controlled laboratory studies have found that portion size (PS) had the strongest effect on the amount of food consumed. The effect of PS on total energy intake has been already observed with different types of foods and beverages, especially with energy-dense foods. The influence of large PS was persistent and happened regardless of demographic characteristics such as age, gender, income level, or body mass index. Although a direct causal link between PS and obesity remains controversial, some health and dietetics organizations recommend to moderate PS, especially for energy-dense foods. Research studies in both laboratory and free-living contexts are needed to determine the causal link between increased PS, obesity, and related metabolic complications in children and adolescents.

Resumen

Palabras clave:

Tamaño de las porciones de alimentos. Ingesta de energía. Obesidad. Resistencia a la insulina. Síndrome metabólico. Alimentación emocional. Niños. Adolescencia.

El objetivo de esta revisión narrativa es proporcionar evidencia actual sobre el impacto del tamaño de las porciones de alimentos sobre el desarrollo de la obesidad en niños y adolescentes. Son necesarias estrategias sobre la estimación del tamaño de las porciones y su relación con ciertos problemas de salud como la obesidad, la resistencia a la insulina y la alimentación emocional en todos los grupos de edad, a fin de proporcionar una comunicación efectiva para los padres, los profesores y los profesionales de la salud, teniendo por objetivo promover una alimentación saludable. Varios son los estudios que encontraron asociaciones positivas entre el tamaño de la porción y la cantidad de alimentos consumidos. También se ha observado que el tamaño de la porción influye en la ingesta total de energía, especialmente en el caso de los alimentos de elevada densidad energética, siendo este efecto independiente de las características demográficas, como la edad, el género, el nivel socioeconómico o el índice de masa corporal. La relación causal entre el tamaño de las porciones y la obesidad sigue siendo controvertida; algunas organizaciones de salud y dietética recomiendan moderar los tamaños de las porciones, especialmente tratándose de alimentos de elevada densidad energética. Por ello se necesitan más estudios a corto y largo plazo que puedan determinar la relación causal entre el aumento del tamaño de las porciones, la obesidad y las complicaciones metabólicas asociadas en niños y adolescentes.

Received: 08/04/2020 • Accepted: 02/06/2020

Conflicts of interest: the authors declare none.

Flieh SM, González-Gil EM, Miguel-Berges ML, Moreno Aznar LA. Food portion sizes, obesity, and related metabolic complications in children and adolescents. Nutr Hosp 2021;38(1):169-176

DOI: http://dx.doi.org/10.20960/nh.03118

Correspondence:

Esther M. González-Gil. Department of Biochemistry and Molecular Biology II. Instituto de Nutrición y Tecnología de los Alimentos. Centro de Investigación Biomédica (CIBM). Universidad de Granada. Av. del Conocimiento, s/n. 18016 Granada, Spain
e-mail: esthergg@ugr.es

INTRODUCTION

The key of healthy eating seems to consist in choosing an appropriate and adequate amount of food from various food groups. A healthful diet is essential for both good health and nutritional status, and represents a key component of obesity prevention strategies. According to WHO, nearly over 340 million children and adolescents aged between 5 and 19 years were diagnosed with overweight or obesity in 2016 (1). In addition, the prevalence of overweight and obesity within these population groups has risen dramatically from 4 % in 1975 to over 18 % in 2016 (1). A large amount of evidence shows that the portion size (PS) of some foods, especially those consumed in restaurants, has increased dramatically over the last 30 years, along with the prevalence of obesity (2,3), a trend that started in the 1970s and persists nowadays. With a view to invert this situation, individuals need effective strategies to regulate their energy intake in spite of the widespread availability of highly palatable, energy-dense foods (4). Increased PS of commonly served foods is considered a major factor that has contributed to excessive energy consumption and, consequently, to the development of obesity (3,5). Obesity is considered the most common cause of insulin resistance in children (6), as well as of dyslipidemia (7) and type-2 diabetes (8). In the public health setting, research data about food intake, both in individuals and populations, serve as the basis for nutrition monitoring and food policies (5). In this narrative review we focus on the relation between food PS, total energy intake, obesity, and some metabolic syndrome features such as insulin resistance in children and adolescents.

SCOPE AND METHODOLOGY OF THIS REVIEW

The strategy for bibliographic search focused on articles published in the English language from 1952 to December 2019 (including online). The databases used included PubMed, Web of Knowledge, Scopus, Science Direct, and online books. In addition, citations in reviews and paths within databases were also incorporated. Key terms included: portion size, food size, food type, dietary estimation method, portion size estimation, food photography, food model, household measures, obesity, food choice, dietary intake, body mass index (BMI), energy-dense food, energy intake, emotional eating, insulin resistance, diabetes, children, adolescents, satiety, appetite, exposure, reward, model, and pressure to eat.

FOOD PORTIONS. DEFINITION AND ESTIMATION

A portion is defined as the amount of food that we choose to eat for a meal or snack, or the amount of a food that we decide to eat or serve to an individual on a single eating occasion (9). The size of a food portion can be identified as the weight or volume of household measures such as: tablespoons, hand measures, or size of a reference object (10). The concept of PS varies widely between countries, across different population groups, and according to both individual and environmental factors (10). For example, a PS may reflect a person's own choice, the choice of the food producer in a restaurant, or a recommendation by a health professional or the government. PS also reflects ways of eating—for instance, in some cultures the hand-based portion is used to self-serve or measure portions of foods for others (11).

Various methods are used to assess dietary intake, such as single or multiple 24-hour dietary recalls, estimated dietary records, diet history, and food frequency questionnaires. However, since these methods rely on an individual's memory, there is a certain challenge in determining food intake, especially in relation to accurate estimation of food PS. To estimate PS several options are available: directly weighing the amount of food consumed by the participant or estimating the size of food portions via visual comparisons to household measures, food models, or photographs.

Directly weighing food portions

Because foods have to be weighed before consumption, weighing methods for determining portion sizes can only be used with prospective dietary assessment methods and using properly calibrated scales (12). The weighing should be done by investigators or by participants. Although weighed food records are an accurate traditional dietary assessment method, it is time consuming, cumbersome for participants, and costly to implement.

Visual estimation of weights and size

Direct observation using visual estimation is a non-intrusive method of estimating food portions that provides an acceptable alternative (13). To apply this method, observers should be trained to estimate PS by monitoring the weights of foods consumed by participants. The accuracy of estimations may vary according to the type and quantity of food (14). Several studies revealed a good correlation between visual estimates and actual weight (14). Even so, observers may differ on their ability to estimate food weights visually, as they tend to overestimate the weight of the foods consumed and to underestimate plate wastes, which may result in potential bias when estimating sizes of foods with a high volume but low weight (13). Of note, a wide range of methods have been described to quantify outcomes related to PS in research studies, including surveillance and epidemiological analyses, clinical and nutritional studies, and research on eating behaviors (15). The most frequently used measurements are food models, photographs, and household measures (16).

Household measures

Even though some foods, like eggs, oranges, or soft drinks, can be recorded in units, other food items are often measured in volumes such as cups or tablespoons (16). These measures are familiar and easy to use. However, volume measures may produce considerable error and individual variability in estimating portion weights (17) because foods can be packed tightly or loosely, and certain foods, such as meats and pastries, do not conform to measuring devices (18). Household food measures have led to significant under- or over-estimations of actual portion weight (16). Cons0equently, household measures are not accurate for individuals, but they are still used to produce acceptable data for group estimations in epidemiological studies.

Food models

Food models are also known as fake food models; they are geometric shapes of food samples. Some studies found that having realistic models closer to real food is a better option for children (19). On the other hand, a systematic underreporting of intake was found when three-dimensional plastic food models were used to represent servings, and the magnitude of this underreporting varied across food items. In contrast, when larger-sized food models were used, participants tended to be more accurate in reporting their intake of foods (20,21).

Photographs

In studies that involve telephone recalls or self-administrated dietary surveys, two-dimensional pictures of food shapes were as effective as three-dimensional models in supporting participants to estimate PS (22). Food photographs of various PSs have been reported to be useful in some studies (23), but poor correlations to actual measurements were detected in others (24).

FACTORS AFFECTING FOOD PORTION SIZES ESTIMATIONS

Several studies have been conducted to examine the influence of some specific characteristics of foods, study subjects, and interviewers on the accuracy of PS estimations.

Food characteristics

Food type

It is important to know which foods are more reliable to estimate the size of their portions. Significant errors have been reported for some foods such as cakes, salads, butter on toast (25), and amorphous foods such as spaghetti or apple sauce (26), as well as for fish, rice, steak, and cheese (20). However, some studies indicate no consistent association between size estimations and food type (27).

Food size

Some studies found greater difficulties in estimating PS as portion size increases (28). In addition, some investigators reported that large plates are harder to estimate (29), but others did not report any differences related to plate size (27).

Subject characteristics

Age

Previous studies suggested that children are not able to estimate PS very accurately, even when prompted with visual aids (30). In contrast, recent studies found that children can estimate food PS with an accuracy approaching that of adults (31). However, high-school and college students have also reported difficulties when estimating PS (32).

Gender

The influence of gender on PS estimation has been argumentative, even though some studies report that women are better estimators (12), others report minimal or no differences (20). These differences between genders may reflect a skill attributed to the greater experience of women in measuring food as a function of their reference system, or a biological response to the higher energy needs of men versus women (33).

RELATIONSHIP BETWEEN FOOD PORTION SIZE AND TOTAL ENERGY INTAKE

The consumption of large PSs, especially from high energy-dense foods, has been identified as a major cause of excessive total energy intake (34). Laboratory studies show that increasing PS leads to increased energy intake in adults (35-37), mostly for high energy-density (HED) foods (2,3,34), in children and adolescents over 3 years of age (38-42). This finding is called the "portion size effect" or portion size response. This association has been observed in both laboratory and free-living studies, binding the consumption of large PSs with increased energy intakes across a variety of foods, ages, and body weights (3,43). Interestingly, this impact has been observed with packaged snacks (35), energy-dense casseroles (36,40), unit foods like sandwiches (44) and beverages (45), and even with low energy-dense foods like fruits and vegetables. Additionally, the effect of PS has been also observed in restaurants and offices (46,47), even if participants were served unpalatable foods (48) or with manipulation of plate size (49). To systematically assess the effect of PS on energy intake, several studies were conducted (Table I). A study assessed four US nationally representative surveys from 1977 to 2006 for three age groups (2-6-, 7-12-, and 13-18-year-olds), and found that, in all age groups, larger PSs of pizza were linked with higher energy intakes at eating occasions, whereas in 7-12- and 13-18-year-olds higher energy intakes at meals correspond with larger PSs of sugar-sweetened beverages (SSBs), French fries, or salty snacks (38). In another

Table I. Studies assessing PS and its effect on total energy intake in children and adolescents

Author/year	Country	Participant characteristics	Study design	Main outcome
Fisher JO, et al. (2007). Ref (42)	USA	59 low-income Hispanic and African American preschool-aged children	A within-subjects experimental design	– Doubling the PS of several entrées and a snack served during a 24-h period increased energy intake from those foods by 23 % (180 kcal) among children ($p < 0.0001$)
Fisher JO, et al. (2007). Ref (39)	USA	53 children aged between 5 and 6 years	A 2 x 2 within-subjects design	– Effects of PS ($p < 0.0001$) and ED ($p < 0.0001$) on entrée energy intake were independent but promoted meal consumption – Effects did not vary by sex, age, entrée preference, or body mass index z-score
Orlet Fisher J, et al. (2003). Ref (40)	USA	30 children with an age range of 2.9-5.1 years	A within-subjects crossover design	– Doubling an age-appropriate portion of an entrée increased entrée and total energy intakes at lunch by 25 % and 15 %, respectively
Rolls BJ, et al. (2000). Ref (41)	USA	32 pre-school children aged between 3 and 4.3 years	Within-subject crossover	– Older children consumed a greater amount of energy when serving a large portion ($p < 0.002$)
Piernas C, Popkin B. (2011). Ref (38)	USA	Four US nationally representative surveys from 1977 to 2006 were analyzed (n = 31,337); age groups: 2-6, 7-12, and 13-18 year-olds)	Cross-sectional study	– In all age groups, a larger PS of pizza was linked with higher energy intakes at eating occasions during which pizzas were consumed – In 7-12 and 13-18 year-olds, higher energy intakes at meals corresponded with larger PSs of SSBs, French fries, or salty snacks

study, when a PS of 250 or 500 g of a macaroni and cheese entrée was served at a dinner meal to children, the effects of the entrée's PS ($p < 0.0001$) and energy density ($p < 0.0001$) on energy intake were independent but promoted meal consumption (39). The same result was noticed with a large portion ($p < 0.002$), when serving three different sizes (small, medium, large) of macaroni and cheese to children at lunchtime (41). In the study by Fisher JO et al., when preschool-aged children doubled the PS of several entrées (breakfast, lunch, dinner) and a snack during a 24-h period, there was an increase in energy intake from those foods by 23 % (180 kcal) ($p < 0.0001$) (42). Consequently, these studies showed that the PS effect was strongly and consistently observed across food types, environmental conditions, and study populations.

FOOD PORTION SIZES AND EMOTIONAL EATING

There are several factors that affect food intake, including metabolic needs (50), emotional states, motivations, and self-regulatory processes (51). To maintain energy balance, cognitive control responds by reducing or increasing food intake in order to cope with stress and negative emotions (52,53). However, it seems likely that consumption of large food portions, with high energy density, facilitates the increase of energy intake (54). Some studies found that external factors and emotional states, and their scores for dietary curb, were significant predictors of food intake. They also found that subjects who scored high on dietary restraint or emotional disinhibition increased their food intake in the presence of larger PSs, which means that a negative or positive mood was significantly associated with greater food and calorie intake across groups (51). In children, a positive association was observed between emotional eating and the frequency of sweet and fatty food consumption, which may contribute to the development of overweight (55), even though the study did not quantify the PS of the consumed food. The relationship between emotional eating and dietary patterns, mainly PS, has not been examined in young children. More studies are needed to analyze the possible influence of emotional eating on food intake in response to dietary manipulations of food PS and energy density.

FOOD PORTION SIZES AND OBESITY, RELATED METABOLIC COMPLICATIONS

FOOD PORTION SIZES AND OBESITY

Although PS has been increasing over time, the effect on weight has not been clearly predictable. Several short-term controlled feeding trials, and epidemiological studies, assessed the association between food PS and body weight, as well as some adiposity indices, showing mixed findings.

In adults, several studies were performed. A midday meal manipulation with a four-week trial showed that larger portions were associated with a weight gain of 0.64 ± 1.16 kg, whereas this change in the standard portions group was 0.06 ± 1.03 kg (56); these weight changes were not significant over time or between test periods. Even so, Rippin et al. (57) found limited evidence on the association between the PS of energy dense foods and BMI in subgroups analyzed from the French and UK national dietary surveys. To assess body weight changes during PS manipulation, an intervention study observed a non-significant increase in body weight after providing a 50 % larger lunch for 1 month (56). However, possibly the PS effect was too small to result in weight change due to the small sample size of the study, and the fact that only one meal of the day was manipulated with controlled PS throughout the intervention period. In another short-term study, a significant increase in mean body weight, for men and women, was observed after larger portions were served on all eating occasions (58). However, these findings are based on cross-sectional analyses, and it still remains unclear whether the association between PS and obesity is causal or associative only. Meanwhile an effective weight loss was well documented with meal replacement products and portion-controlled entrées (59).

Several studies observed a positive relationship between increasing PS and obesity in children (60,61) and adolescents (9,62) (Table II). Fisher JO and Birch LL study on girls, aged between 5 and 7 years, found that those who ate large amounts of snack

Table II. Studies assessing PS effect on BMI and obesity in children and adolescents

Author/year	Country	Participant characteristics	Study design	Dietary assessment method	Main outcome
Huang TT, et al. (2004). Ref (63)	USA	Children and adolescents (3 to 19 years old, n = 8048)	Cross-sectional	Two 24-hour dietary recalls	– In the plausible sample, reported EI, meal PS, and meal energy were positively associated with BMI percentile in boys 6 to 11 years old and in children 12 to 19 years old – No relationships were found in children 3 to 5 years and girls 6 to 11 years old
Lioret S, et al. (2009). Ref (64)	France	748 French children aged 3 to 11 years	Cross-sectional	A 7-day food record	– Overweight in children aged 3-6 years was positively correlated to PS of croissant-like pastries and other sweetened pastries – PS of liquid dairy products were inversely associated with overweight in children aged 7-11 years
Fisher JO, Birch LL. (2002). Ref (60)	USA	192 girls, assessed when they were 5 and 7 years of age.	Experimental study	Child Feeding Questionnaire. Standard ad libitum lunch	– The girls who ate large amounts of snack foods in the absence of hunger at 5 and 7 years of age were 4.6 times more likely to be overweight at both ages
McConahy KL, et al. (2002). Ref (61)	USA	1100 children from two national samples aged from 1 to 2 years	Cross-sectional	Two nonconsecutive 24-hour dietary recalls	– Gradual increases in portions of milk, bread, cereal, juice, and peanut butter, which together contribute the major children's daily energy intake – Average PS Z-scores were positively related to both body weight and energy intake, but not number of eating occasions and/or foods
Albar SA, et al. (2014). Ref (9)	UK	A representative sample of 636 adolescents aged 11 to 18 years	Multivariable regression analysis	A 4-day estimated food diary	– The PS of a limited number of high energy-dense foods (high-fibre breakfast cereals, cream and high-energy carbonated soft drinks were positively associated with a higher BMI among all adolescents after adjusting for misreporting

foods in the absence of hunger were 4.6 times more likely to be overweight (60). This was confirmed by another study conducted in children and adolescents, which found that PS and energy content per meal were significantly associated with BMI percentile in boys 6 to 11 years of age and in children 12 to 19 years of age. However, no relationships were found among children 3 to 5 years and girls 6 to 11 yearsof age (63). Another French study on children aged between 3 and 11 years, taken from the 1998-1999 cross-sectional study, observed that overweight in children aged 3 to 6 years was positively associated with the PS of biscuits ($p = 0.0392$) and sweetened pastries ($p = 0.0027$). Also significantly positive trends were observed for PSs of croissant-like pastries ($p = 0.0568$) and meat ($p = 0.0574$) (64). In UK adolescents, there was also a positive association between PS of biscuits and cakes and BMI (9).

Unfortunately, these studies cannot be taken as proof of causality in children, mainly because they are not reflecting their eating in a free-living context. Consequently, long-term studies are needed to determine the causal link between increasing PS and obesity. However, these studies concluded that reducing PS may be an effective tool for weight control.

FOOD PORTION SIZES, GLYCEMIC INDEX, AND INSULIN RESISTANCE

In 1981 the glycemic index (GI) concept was proposed by Jenkins and colleagues to describe the rate of carbohydrate absorption after a meal (65). GI is defined as 'the area under the glucose response curve after consumption of 50 g of carbohydrates from a test food divided by the area under the curve after consumption of 50 g of carbohydrates from a control food, either white bread or glucose' (66). Food PS has a major effect on the glycemic index value because glycemic responses are related to carbohydrate load (65). The usefulness of glycemic load (GL) is based on the idea that a high GI food consumed in small portions would have the same effect on blood sugar as larger portions of a low GI food (66,67). Although the effect of PS on GI was mentioned from 1981, there are no experimental studies measuring the effect of PS on GI in children and adolescents.

Insulin resistance, impaired glucose tolerance, and type-2 diabetes are considered ominous public-health issues in all age groups (6,8). Studies found that childhood obesity causes hypertension, dyslipidemia, chronic inflammation, a tendency to increased blood clotting, endothelial dysfunction, and hyperinsulinemia (7,68-70). The clustering of cardiovascular disease risk factors, known as the insulin resistance syndrome, has been identified in pre-pubertal children (71).

Insulin resistance is a key component of the metabolic syndrome, in turn a cluster of cardiometabolic factors with increasing prevalence in children and adolescents, and associated with obesity (72,73). The relationship between metabolic syndrome and diet among children and adolescents remains poorly understood. In adults, studies have shown that dietary patterns characterized by high intakes of fruits and vegetables are generally associated with a lower prevalence of the metabolic syndrome (74,75). Although the development of obesity in genetically stable populations has been increasing (8), studies examining insulin resistance, metabolic syndrome, and their association with diet, especially PS in children and adolescents, are still scarce. It is still unknown whether individual dietary components, or overall diet can independently affect metabolic syndrome in this age group.

The flow diagram of the underlying factors affected by PS are found in figure 1. High PS is related to obesity and other metabolic

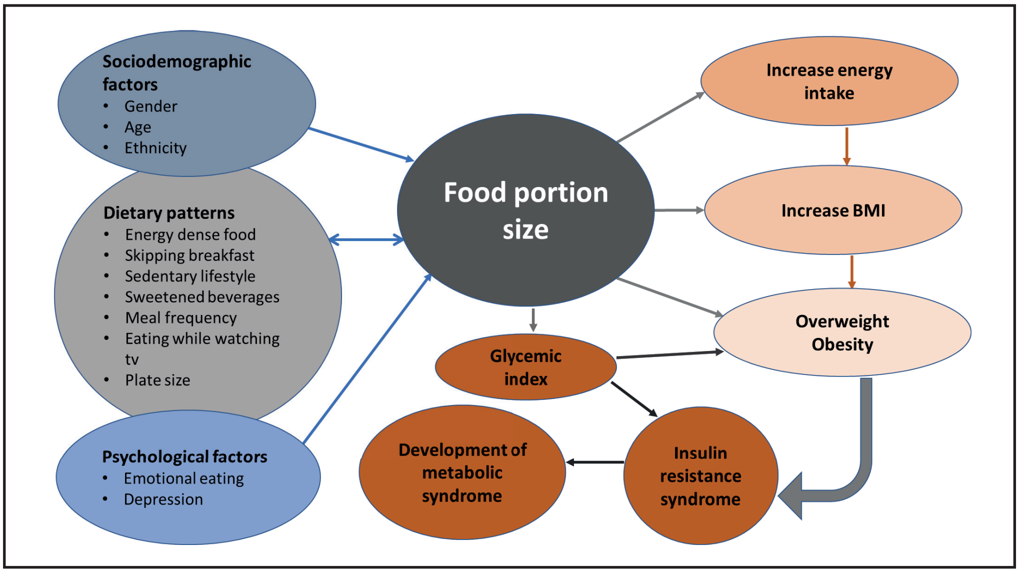


Figure 1.

Summary of factors that affect PS and lead to the development of obesity.

complications, whereas many factors such as sociodemographic parameters (gender, age), dietary patterns including energy-dense food, skipping breakfast, and sedentary lifestyle, alongside with psychological factors like emotional eating, were found to have a direct effect on the consumption of large food PSs. As illustrated in figure 1, there is an interchangeable relation between dietary patterns and food PS. For example, the consumption of energy-dense foods was linked with large PSs and vice versa. Furthermore, once a larger portion is chosen, energy intake and—consequently—BMI will increase. Similarly, high food PSs increase glycemic index levels, thus contributing to both insulin resistance and metabolic syndrome. Of note, increasing energy intake could cause an increase in BMI and the development of overweight and obesity, which in turn could contribute to insulin resistance and metabolic syndrome.

CONCLUSION

Food and drink PS has been increasing in recent years. However, it has not been possible to establish a direct causal link between large food PS, especially in the case of energy-dense foods, and obesity as well as certain metabolic syndrome features. To date there are no long-term, randomized, controlled trials to assess the exposure to large portions of food and its effects on body weight. Clearly, there is an urgent need to develop a well-articulated research framework that systematically tests the interaction between selection of food PS and development of obesity, insulin resistance, and metabolic syndrome in both children and adolescents.

REFERENCES

1. World Health Organisation. Obesity and overweight. Available from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
2. Brien SA, Livingstone MB, McNulty BA, Lyons J, Walton J, Flynn A, et al. Secular trends in reported portion size of food and beverages consumed by Irish adults. Br J Nutr 2015;113(7):1148-57. DOI: 10.1017/S0007114515000276
3. Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. Am J Public Health 2002;92(2):246-9. DOI: 10.2105/AJPH.92.2.246
4. Lewis HB, Ahern AL, Jebb SA. How much should I eat? A comparison of suggested portion sizes in the UK. Public Health Nutr 2012;15(11):2110-7. DOI: 10.1017/S1368980012001097
5. Prentice AM, Jebb SA. Fast foods, energy density and obesity: a possible mechanistic link. Obes Rev 2003;4(4):187-94. DOI: 10.1046/j.1467-789X.2003.00117.x
6. Sinha R, Fisch G, Teague B, Tamborlane WV, Banyas B, Allen K, et al. Prevalence of impaired glucose tolerance among children and adolescents with marked obesity. N Engl J Med 2002;346(11):802-10. DOI: 10.1056/NEJMoa012578
7. Tounian P, Aggoun Y, Dubern B, Varille V, Guy-Grand B, Sidi D, et al. Presence of increased stiffness of the common carotid artery and endothelial dysfunction in severely obese children: a prospective study. Lancet 2001;358(9291):1400-4. DOI: 10.1016/S0140-6736(01)06525-4
8. Ludwig DS, Ebbeling CB. Type 2 diabetes mellitus in children: primary care and public health considerations. JAMA 2001;286(12):1427-30. DOI: 10.1001/jama.286.12.1427
9. Albar SA, Alwan NA, Evans CE, Cade JE. Is there an association between food portion size and BMI among British adolescents? Br J Nutr 2014;112(5):841-51. DOI: 10.1017/S0007114514001548
10. Thompson FE, Byers T. Dietary assessment resource manual. J Nutr 1994;124(11 Suppl):2245s-317s.
11. Peter Herman C, Polivy J, Pliner P, Vartanian LR. Mechanisms underlying the portion-size effect. Physiol Behav 2015;144:129-36. DOI: 10.1016/j.physbeh.2015.03.025
12. Burger KS, Kern M, Coleman KJ. Characteristics of self-selected portion size in young adults. J Am Diet Assoc 2007;107(4):611-8. DOI: 10.1016/j.jada.2007.01.006
13. Dubois S. Accuracy of visual estimates of plate waste in the determination of food consumption. J Am Diet Assoc 1990;90(3):382-7.
14. Gittelsohn J, Shankar AV, Pokhrel RP, West KP, Jr. Accuracy of estimating food intake by observation. J Am Diet Assoc 1994;94(11):1273-7. DOI: 10.1016/0002-8223(94)92459-7
15. Almiron-Roig E, Navas-Carretero S, Emery P, Martinez JA. Research into food portion size: methodological aspects and applications. Food Funct 2018;9(2):715-39. DOI: 10.1039/C7FO01430A
16. Faulkner GP, Livingstone MB, Pourshahidi LK, Spence M, Dean M, O'Brien S, et al. An evaluation of portion size estimation aids: precision, ease of use and likelihood of future use. Public Health Nutr 2016;19(13):2377-87. DOI: 10.1017/S1368980016000082
17. Pollard CM, Daly AM, Binns CW. Consumer perceptions of fruit and vegetables serving sizes. Public Health Nutr 2009;12(5):637-43. DOI: 10.1017/S1368980008002607
18. Britten P, Haven J, Davis C. Consumer research for development of educational messages for the MyPyramid Food Guidance System. J Nutr Educ Behav 2006;38(6 Suppl):S108-23. DOI: 10.1016/j.jneb.2006.08.006
19. Lanerolle P, Thoradeniya T, de Silva A. Food models for portion size estimation of Asian foods. J Hum Nutr Diet 2013;26(4):380-6. DOI: 10.1111/jhn.12063
20. Faggiano F, Vineis P, Cravanzola D, Pisani P, Xompero G, Riboli E, et al. Validation of a method for the estimation of food portion size. Epidemiology. 1992;3(4):379-82. DOI: 10.1097/00001648-199207000-00015
21. Yuhas JA, Bolland JE, Bolland TW. The impact of training, food type, gender, and container size on the estimation of food portion sizes. J Am Diet Assoc 1989;89(10):1473-7.
22. Subar AF, Crafts J, Zimmerman TP, Wilson M, Mittl B, Islam NG, et al. Assessment of the accuracy of portion size reports using computer-based food photographs aids in the development of an automated self-administered 24-hour recall. J Am Diet Assoc 2010;110(1):55-64. DOI: 10.1016/j.jada.2009.10.007
23. Boushey CJ, Spoden M, Zhu FM, Delp EJ, Kerr DA. New mobile methods for dietary assessment: review of image-assisted and image-based dietary assessment methods. Proc Nutr Soc 2017;76(3):283-94. DOI: 10.1017/S0029665116002913
24. Haraldsdottir J, Tjonneland A, Overvad K. Validity of individual portion size estimates in a food frequency questionnaire. Int J Epidemiol 1994;23(4):786-96. DOI: 10.1093/ije/23.4.787
25. Japur CC, Diez-Garcia RW. Food energy content influences food portion size estimation by nutrition students. J Hum Nutr Diet 2010;23(3):272-6. DOI: 10.1111/j.1365-277X.2010.01042.x
26. Slawson DL, Eck LH. Intense practice enhances accuracy of portion size estimation of amorphous foods. J Am Diet Assoc 1997;97(3):295-7. DOI: 10.1016/S0002-8223(97)00076-X
27. Sharp D, Sobal J. Using plate mapping to examine sensitivity to plate size in food portions and meal composition among college students. Appetite 2012;59(3):639-45. DOI: 10.1016/j.appet.2012.07.020
28. Wansink B, Wansink CS. The largest Last Supper: depictions of food portions and plate size increased over the millennium. Int J Obes (Lond) 2010;34(5):943-4. DOI: 10.1038/ijo.2010.37
29. Wansink B, Cheney MM. Super Bowls: serving bowl size and food consumption. JAMA 2005;293:1727-8. DOI: 10.1001/jama.293.14.1727
30. Szenczi-Cseh J, Horvath Z, Ambrus A. Validation of a food quantification picture book and portion sizes estimation applying perception and memory methods. Int J Food Sci Nutr 2017;68(8):960-72. DOI: 10.1080/09637486.2017.1309521
31. Baranowski T, Baranowski JC, Watson KB, Martin S, Beltran A, Islam N, et al. Children's accuracy of portion size estimation using digital food images: effects of interface design and size of image on computer screen. Public Health Nutr 2011;14(3):418-25. DOI: 10.1017/S1368980010002193
32. Bryant R, Dundes L. Portion Distortion: A Study of College Students. The Journal of Consumer Affairs 2005;39(2):399-408. DOI: 10.1111/j.1745-6606.2005.00021.x
33. Almiron-Roig E, Solis-Trapala I, Dodd J, Jebb SA. Estimating food portions. Influence of unit number, meal type and energy density. Appetite 2013;71:95-103. DOI: 10.1016/j.appet.2013.07.012

34. Wrieden W, Gregor A, Barton KL. Have food portion sizes increased in the UK over the last 20 years? Proceedings of The Nutrition Society 2008;67(OCE):E211. DOI: 10.1017/S0029665108008434
35. Kral TV, Roe LS, Rolls BJ. Combined effects of energy density and portion size on energy intake in women. Am J Clin Nutr 2004;79(6):962-8. DOI: 10.1093/ajcn/79.6.962
36. Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. Am J Clin Nutr 2002;76(6):1207-13. DOI: 10.1093/ajcn/76.6.1207
37. Rolls BJ, Roe LS, Meengs JS. Larger portion sizes lead to a sustained increase in energy intake over 2 days. J Am Diet Assoc 2006;106(4):543-9. DOI: 10.1016/j.jada.2006.01.014
38. Piernas C, Popkin BM. Increased portion sizes from energy-dense foods affect total energy intake at eating occasions in US children and adolescents: patterns and trends by age group and sociodemographic characteristics, 1977–2006. Am J Clin Nutr 2011;94(5):1324-32. DOI: 10.3945/ajcn.110.008466
39. Fisher JO, Liu Y, Birch LL, Rolls BJ. Effects of portion size and energy density on young children's intake at a meal. Am J Clin Nutr 2007;86(1):174-9. DOI: 10.1093/ajcn/86.1.174
40. Orlet Fisher J, Rolls BJ, Birch LL. Children's bite size and intake of an entree are greater with large portions than with age-appropriate or self-selected portions. Am J Clin Nutr 2003;77(5):1164-70. DOI: 10.1093/ajcn/77.5.1164
41. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year-old but not 3-year-old children's food intakes. J Am Diet Assoc 2000;100(2):232-4. DOI: 10.1016/S0002-8223(00)00070-5
42. Fisher JO, Arreola A, Birch LL, Rolls BJ. Portion size effects on daily energy intake in low-income Hispanic and African American children and their mothers. Am J Clin Nutr 2007;86(6):1709-16. DOI: 10.1093/ajcn/86.5.1709
43. Ello-Martin JA, Ledikwe JH, Rolls BJ. The influence of food portion size and energy density on energy intake: implications for weight management. Am J Clin Nutr 2005;82(1 Suppl):236s-41s. DOI: 10.1093/ajcn/82.1.236S
44. Rolls BJ, Roe LS, Kral TV, Meengs JS, Wall DE. Increasing the portion size of a packaged snack increases energy intake in men and women. Appetite 2004;42(1):63-9. DOI: 10.1016/S0195-6663(03)00117-X
45. Flood JE, Roe LS, Rolls BJ. The effect of increased beverage portion size on energy intake at a meal. J Am Diet Assoc 2006;106(12):1984-90. DOI: 10.1016/j.jada.2006.09.005
46. Diliberti N, Bordi PL, Conklin MT, Roe LS, Rolls BJ. Increased portion size leads to increased energy intake in a restaurant meal. Obes Res 2004;12(3):562-8. DOI: 10.1038/oby.2004.64
47. Geier AB, Rozin P, Doros G. Unit bias. A new heuristic that helps explain the effect of portion size on food intake. Psychol Sci 2006;17(6):521-5. DOI: 10.1111/j.1467-9280.2006.01738.x
48. Wansink B, Kim J. Bad popcorn in big buckets: portion size can influence intake as much as taste. J Nutr Educ Behav 2005;37(5):242-5. DOI: 10.1016/s1499-4046(06)60278-9
49. Wansink B, Painter JE, North J. Bottomless bowls: why visual cues of portion size may influence intake. Obes Res 2005;13(1):93-100. DOI: 10.1038/oby.2005.12
50. Elmquist JK, Coppari R, Balthasar N, Ichinose M, Lowell BB. Identifying hypothalamic pathways controlling food intake, body weight, and glucose homeostasis. J Comp Neurol 2005;493(1):63-71. DOI: 10.1002/cne.20786
51. Cardi V, Leppanen J, Treasure J. The effects of negative and positive mood induction on eating behaviour: A meta-analysis of laboratory studies in the healthy population and eating and weight disorders. Neurosci Biobehav Rev 2015;57:299-309. DOI: 10.1016/j.neubiorev.2015.08.011
52. Zheng H, Lenard NR, Shin AC, Berthoud HR. Appetite control and energy balance regulation in the modern world: reward-driven brain overrides repletion signals. Int J Obes (Lond) 2009;33(Suppl 2):S8-13. DOI: 10.1038/ijo.2009.65
53. Adam TC, Epel ES. Stress, eating and the reward system. Physiol Behav 2007;91(4):449-58. DOI: 10.1016/j.physbeh.2007.04.011
54. Macht M. How emotions affect eating: a five-way model. Appetite 2008;50(1):1-11. DOI: 10.1016/j.appet.2007.07.002
55. Michels N, Sioen I, Braet C, Eiben G, Hebestreit A, Huybrechts I, et al. Stress, Emotional Eating Behaviour and Dietary Patterns in Children. Appetite 2012;59(3). DOI: 10.1016/j.appet.2012.08.010
56. Jeffery RW, Rydell S, Dunn CL, Harnack LJ, Levine AS, Pentel PR, et al. Effects of portion size on chronic energy intake. Int J Behav Nutr Phys Act 2007;4:27. DOI: 10.1186/1479-5868-4-27
57. Rippin HL, Hutchinson J, Jewell J, Breda JJ, Cade JE. Portion Size of Energy-Dense Foods among French and UK Adults by BMI Status. Nutrients 2018;11(1). DOI: 10.3390/nu11010012
58. Kelly MT, Wallace JM, Robson PJ, Rennie KL, Welch RW, Hannon-Fletcher MP, et al. Increased portion size leads to a sustained increase in energy intake over 4 d in normal-weight and overweight men and women. Br J Nutr 2009;102(3):470-7. DOI: 10.1017/S0007114508201960
59. Heymsfield SB, van Mierlo CA, van der Knaap HC, Heo M, Frier HI. Weight management using a meal replacement strategy: meta and pooling analysis from six studies. Int J Obes Relat Metab Disord 2003;27(5):537-49. DOI: 10.1038/sj.ijo.0802258
60. Fisher JO, Birch LL. Eating in the absence of hunger and overweight in girls from 5 to 7 y of age. Am J Clin Nutr 2002;76(1):226-31. DOI: 10.1093/ajcn/76.1.226
61. McConahy KL, Smiciklas-Wright H, Birch LL, Mitchell DC, Picciano MF. Food portions are positively related to energy intake and body weight in early childhood. J Pediatr 2002;140(3):340-7. DOI: 10.1067/mpd.2002.122467
62. Wansink B, Payne CR, Shimizu M. The 100-calorie semi-solution: sub-packaging most reduces intake among the heaviest. Obesity (Silver Spring) 2011;19(5):1098-100. DOI: 10.1038/oby.2010.306
63. Huang TT, Howarth NC, Lin BH, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. Obes Res 2004;12(11):1875-85. DOI: 10.1038/oby.2004.233
64. Lioret S, Volatier JL, Lafay L, Touvier M, Maire B. Is food portion size a risk factor of childhood overweight? Eur J Clin Nutr 2009;63(3):382-91. DOI: 10.1038/sj.ejcn.1602958
65. Jenkins DJ, Wolever TM, Taylor RH, Barker H, Fielden H, Baldwin JM, et al. Glycemic Index of Foods: A Physiological Basis for Carbohydrate Exchange. The American journal of clinical nutrition 1981;34(3). DOI: 10.1093/ajcn/34.3.362
66. Wolever TM, Jenkins DJ, Jenkins AL, Josse RG. The Glycemic Index: Methodology and Clinical Implications. The American journal of clinical nutrition 1991;54(5). DOI: 10.1093/ajcn/54.5.846
67. Berra B, Rizzo AM. Glycemic Index, Glycemic Load, Wellness and Beauty: The State of the Art. Clinics in dermatology 2009;27(2). DOI: 10.1016/j.clindermatol.2008.04.006
68. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The Relation of Overweight to Cardiovascular Risk Factors Among Children and Adolescents: The Bogalusa Heart Study. Pediatrics 1999;103(6 Pt 1):1175-82. DOI: 10.1542/peds.103.6.1175
69. Ford ES, Galuska DA, Gillespie C, Will JC, Giles WH, Dietz WH. C-reactive protein and body mass index in children: findings from the Third National Health and Nutrition Examination Survey, 1988-1994. J Pediatr 2001;138(4):486-92. DOI: 10.1067/mpd.2001.112898
70. Ferguson MA, Gutin B, Owens S, Litaker M, Tracy RP, Allison J. Fat distribution and hemostatic measures in obese children. Am J Clin Nutr 1998;67(6):1136-40. DOI: 10.1093/ajcn/67.6.1136
71. Olza J, Gil-Campos M, Leis R, Bueno G, Aguilera CM, Valle M, et al. Presence of the Metabolic Syndrome in Obese Children at Prepubertal Age. Annals of nutrition & metabolism 2011;58(4). DOI: 10.1159/000331996
72. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. N Engl J Med 2004;350(23):2362-74. DOI: 10.1056/NEJMoa031049
73. Cruz ML, Weigensberg MJ, Huang TT, Ball G, Shaibi GQ, Goran MI. The metabolic syndrome in overweight Hispanic youth and the role of insulin sensitivity. J Clin Endocrinol Metab 2004;89(1):108-13. DOI: 10.1210/jc.2003-031188
74. Williams DE, Prevost AT, Whichelow MJ, Cox BD, Day NE, Wareham NJ. A cross-sectional study of dietary patterns with glucose intolerance and other features of the metabolic syndrome. Br J Nutr 2000;83(3):257-66. DOI: 10.1017/s0007114500000337
75. Pereira MA, Jacobs DR, Jr., Van Horn L, Slattery ML, Kartashov AI, Ludwig DS. Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. JAMA 2002;287(16):2081-9. DOI: 10.1001/jama.287.16.2081

The association between psychosomatic and emotional status and selected food portion sizes, in European children and adolescents: IDEFICS/I.Family study

Sondos M. Flieh[1], Antje Hebestreit[2], Hermann Pohlabeln[2], María L Miguel-Berges[1,3,11], Esther M. González-Gil[1,3,4,11*], Paola Russo[5], Dénes Molnár[6], Kathleen Wijnant[7], Lauren Lissner[8], Stefanie Do[2], Tonia Solea[9], Toomas Veidebaum[10], and Luis A. Moreno[1,3,4,11] on behalf of the IDEFICS/I.Family Consortium.

[1]Growth, Exercise, Nutrition and Development (GENUD) Research Group, Faculty of Health Sciences, University of Zaragoza, 50009 Zaragoza, Spain. Sondosnserat991@gmail.com ; mlmiguel@unizar.es ; esthergg@unizar.es ; lmoreno@unizar.es

[2]Leibniz Institute for Prevention Research and Epidemiology– BIPS, D-28359 Bremen, Germany. hebestr@leibniz-bips.de; pohlabel@leibniz-bips.de ; dostef@leibniz-bips.de

[3]Instituto Agroalimentario de Aragón (IA2), 50013 Zaragoza, Spain.

[4]Instituto de Investigación Sanitaria Aragón (IIS Aragón), 50009 Zaragoza, Spain

[5]Institute of Food Sciences, National Research Council, 83100 Avellino, Italy. prusso@isa.cnr.it

[6]Department of Pediatrics, Medical School, University of Pécs, H-7624 Pécs, Hungary. denes.molnar@aok.pte.hu

[7]Departments of Public Health and Primary Care, Ghent University, B-9000 Ghent, Belgium. Kathleen.wijnant@ugent.be

[8]Department of Public Health and Community Medicine/Epidemiology, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, 405 30, Gothenburg Sweden. lauren.lissner@gu.se

[9]Research and Education Institute of Child Health, 2035 Strovolos, Cyprus. toniasolea@yahoo.com

[10] National Institute for Health Development, Tallinn, Estonia. toomas.veidebaum@tai.ee

[11]CIBER Fisiopatología de la Obesidad y Nutrición, Instituto de Salud Carlos III, 28029 Madrid, Spain.

*Corresponding author: Esther M. González-Gil. esthergg@unizar.es; Growth, Exercise, Nutrition and Development (GENUD) Research Group, Department of health and sport sciences, University of Zaragoza, Zaragoza, Spain.

Funding

This study was done as a part of the IDEFICS study (http://www.ideficsstudy.eu/home.html), which was funded by the European Community within the Sixth RTD Framework Programme Contract No. 016181 (FOOD) with additional financial support from Epilife TEENS. These funders had no role in the design, analysis or writing of this article.

List of abbreviations:

KINDL: Emotional well-being during the last week score

PS: Portion size

SDQ: Strengths and Difficulties Questionnaire

Abstract

objective: This study aims to investigate the influence of psychosomatic and emotional status on food portion sizes (PS) consumption, from high energy dense food groups, in European children and adolescents.

Methods: 7,355 aged between 2-9.9 years at baseline (T0) (48.8% females); 3,869 after 2 years (T1) (48.2% females), and 2,971 (51.8% females) after 6 years of follow-up (T3) participants meeting the criteria from the IDEFICS/I. Family study were included. Psychosomatic and emotional status was measured using emotional and peer problems from the Emotional well-being during the last week score (KINDL) and Strengths and Difficulties Questionnaire (SDQ). PS were established by the amount of foods eaten per day (grams) in the 24 h-recall. The cross-sectional and longitudinal associations between emotional status indicators and PS from selected energy dense food groups were assessed by multilevel linear regression models.

Results: In (T0) cross-sectional analysis, higher KINDL score was associated with consumption of smaller PS from sweet bakery products, savoury snacks, and fruit and vegetable juices in both genders. In both the cross-sectional T3 and longitudinal analysis (T3-T0), we found that females with higher emotional and peer problems score tend to consume higher PS of sugar-fatty food products mainly in the age 10-17 years ($p<0.05$). In the longitudinal analysis, higher peer problem score was associated with large PS from bread and rolls, margarine and lipids, and dairy products in all genders and age groups ($p<0.05$).

Conclusion: In adolescents, psychosomatic and emotional status could be a trigger to consume large PS from sweet-fatty energy dense foods with generally stronger associations in females. Thus, nutritional interventions should focus on emotional status when aiming decreasing unhealthy dietary habits.

Keywords: food portion size, dietary intake, psychosomatic, emotional status, children, adolescents

Introduction

Metabolic needs are not the only factor that influences food intake [1], but Emotional states, motivations, and self-regulatory processes also play an important role [2]. In this sense, negative affect and cognitive control can override the body's natural energy balance, leading to either reduced or increased food intake in order to cope with stress and negative emotions [2, 3].

In 2005, the Mental Health Foundation acknowledged that diet can have a considerable effect on mental health, which is often overlooked [4]. Stressors during childhood may arise from multiple events in the daily life environment such as school and family [5]. Regular exposure to stressful situations may influence a child's behaviour and have consequences on both their physical and mental health [6]. It has been discovered that an inability to cope with or suppress negative emotions is linked to increased food consumption, particularly of sugary and fatty foods [7]. Moreover, a two-way relationship has been proposed between emotion and eating, where emotions control eating and vice versa [3].

Emotional eating, which is defined as the tendency to overeat in response to negative emotions such as anxiety or irritability [8], has been observed to be on the rise. This concept is derived from the psychosomatic theory [9], which suggests that emotional eaters are unable to differentiate hunger from the physiological state accompanying negative emotions. This emotion-driven impulsiveness has been linked to the type of snack food consumed (sweet and fat) rather than the energy intake of food consumed per snacking occasion [10].

Research has indicated that external factors and emotional states can have an effect on food intake [11]. It was observed that those who had higher scores in terms of dietary restraint or emotional disinhibition ate more when presented with larger portion sizes (PS) [11], implying that both positive and negative moods can be linked to greater food and calorie consumption in different groups [11].

A systematic review conducted by O'Neil et al. found a cross-sectional association between poor psychosocial well-being and energy dense foods, such as refined grains, processed meat and snacks, diet- and sugar rich soft drinks, fried food and foods high in saturated fat and sugar, in children and adolescents [12]. Additionally, a positive correlation between emotional status and the frequency of consumption of sweets and fatty foods was observed in children, which may lead to overweight [13], This suggests that when individuals are experiencing elevated emotional status, they may select larger portion sizes in order to achieve sufficient satisfaction or satiety for coping with negative moods [14]. This is supported by the fact that expectations of satiety delivered from a food is one of the strongest predictors of PS [15]. However, the relationship between emotional status and dietary intake, mainly PS, has not been examined in children and adolescents. Therefore, this study investigates the cross-sectional and longitudinal influence of psychosomatic and emotional status on selection of food PS from energy dense food groups.

Material and methods

Study design

The analysis was conducted using data from the European IDEFICS 'Identification and prevention of Dietary and lifestyle induced health EFfects in Children and infantS' and I.Family 'Investigating the determinants of food choice, lifestyle and health in European children, adolescents and their parents' cohort; 16,229 children aged between 2 and 9.9 years old at baseline (T0, 2007) were recruited from eight European countries [16]. These children were followed up in 2009–2010 (T1) and 2013-2014 (T3) within the I.Family project [16].

In order to ensure ethical standards, each country obtained ethical approval from the local authorities as established in the 1964 Declaration of Helsinki and its later amendments [17]. Parents signed an informed consent and children were asked to give verbal assent. More details about study design, sampling, and procedures of IDEFICS/I. Family have been described elsewhere [16, 18].

Study sample

Out of the total sample 7,355 in T0, 3,869 in T1, and 2,971 children in T3 met the criteria of availability of at least one complete 24-hours dietary recall (24-HDR) with plausible reporting of energy intake and the full set of exposure: (emotional well-being and self-esteem of the child during the last week score (KINDL), data about emotional and peer problems over the last 6 months); and co-variate information: (body mass index (BMI) and parental education). A flow chart for the selection of the total sample can be found in **Figure 1**.

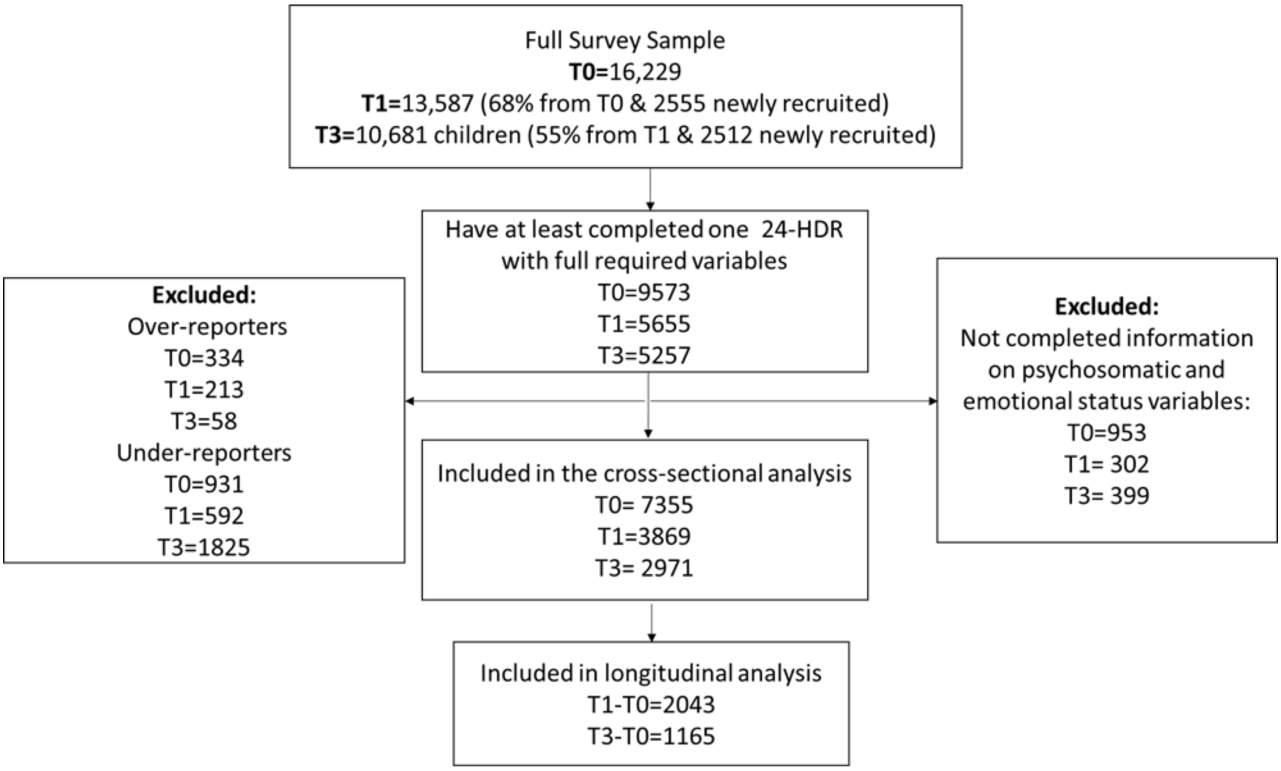


Fig. 1 Study flowchart

Assessment of psychosomatic and emotional symptoms

Psychosomatic and emotional symptoms in children were described by two variables: ‘emotional well-being and self-esteem of the child during the last week’, and ‘emotional problems and frequent occurrence of headaches, stomach-aches or sickness over the last 6 months’.

Emotional well-being and self-esteem of the child during the last week: Parents were asked to fill out the emotional and self-esteem subscales of the 'KINDL Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents' [19], which had previously been tested for its reliability and validity. This questionnaire assesses the child's quality of life in multiple dimensions and was included in the IDEFICS parental questionnaire [19]. The items of the emotional and self-esteem subscales were scored from 1 (never) to 4 (often or always) with reversals depending on the wording of the question and added up to a total score, with a high value indicating high well-being [19, 20].

Emotional and peer problems over the last 6 months: Emotional and peer problems were evaluated using the Emotional Symptoms Scale of the Strengths and Difficulties Questionnaire (SDQ) [21, 22] a validated tool developed for children aged 4 to 16 years. The IDEFICS study used the informant-rated version, which has been found to be highly correlated with the child-rated version [22]. The peer problems score included five questions: 1) Is your child rather solitary and tends to play alone? 2) Does your child have at least one good friend? 3) Is your child generally liked by other children? 4) Is your child picked on or bullied by other children? 5) Does your child get on better with adults than with other children?

The emotional problems score included five items, which were scored from 0 ‘not true’ to 2 ‘certainly true’ and summed to total scores ranging from 0 to 10. A high value indicated more difficulties or life struggles [22]. The items assessed were: 1) often complains of headaches, stomach-aches or sickness, 2) many worries or often seems worried, 3) often unhappy, depressed or tearful, 4) nervous in new situations, easily loses confidence, and 5) many fears, easily scared. Cut-off values for No detectable emotional problems were ≤ 3 and, and for No detectable peer problems ≤ 2. The internal consistency of the scale in the present study was good (Cronbach's α = 0.87).

Dietary assessment method

For the purpose of this study, dietary intake of the previous 24 h was assessed using the computer-assisted software for 24-HDR, called SACINA ('Self- Administered Children and Infant Nutrition Assessment') in T0 and T1 and SACANA ("Self-Administered Children, Adolescents, and Adult Nutrition Assessment") in T3 [23]. SACANA was the revised and extended web-based version of the SACINA online 24-HDR [24].

SACINA and SACANA were developed and validated to assess the children's and adolescents' absolute energy and nutrient intake, the percentage contribution from food and drinks to total energy and nutrient intake, as well as PSs and food groups during the previous 24 hr [25].

The issue of misreporting (both over and underreporting) is a well-documented phenomenon in dietary assessment [26]. In this study, misreporting was measured by calculating the individual ratio of energy intake and basal metabolic rate (EI/BMR) and comparing it to the age- and sex-specific EI/BMR for children using Goldberg cut-offs. These cut-offs are considered to have a good predictive value, making them an appropriate alternative for characterizing misreporting in the absence of objective validation data [27]. Further details can be found in the referenced source.

Portion sizes calculation and food group selection

The methodology used in this study to calculate the PS of a food group was to divide the total intake of items in grams consumed in a 24h-recall by the number of eating occasions. This same approach has been used in several studies of food PS in children and adolescents [28, 29]. and it provides data on a per-consumer basis, rather than per-capita. To analyse a specific food group, only participants who consumed this food group were included in the analysis. For the purpose of this study, in the case of mixed dishes, each dish was re-classified by the main food component according to the ingredient present in the highest proportion, after cooking. Alcoholic drinks and soya beverages were excluded from the analysis due to infrequent consumption (more than 85 % of the sample did not report consumptions).

In accordance with the World Cancer Research Fund (WCRF) [30], which identified foods with an energy density of 225–275 kcal/100g as high-ED foods, we chose food items that had been previously identified as having the greatest contribution to energy intake and a positive correlation to BMI in Europe and other countries [28, 29]

In this study food items were selected based on their ED, clustered in groups and each food groups containing subgroups according to their nutritional values: 1) cereals and cereals products, 2) sugar and sugar products 3) fats and savoury snacks 4) non-alcoholic beverages and soups 5) dairy products and similar. Dietary data were analysed for average energy intake in kilocalories (kcal) and kilojoules (kJ), macronutrients (g), and percentages of energy [31].

Parental education

Information regarding the parents' education and income was obtained from the parental questionnaire. The education level was based on the International Standard Classification of Education [32] which was used to determine the highest level of either parent's education

[33]. Levels 0-2 were classified as lower education level; 3-5 were classified as medium education level; and 6-8 were classified as higher education level.

Anthropometric measurements

Trained personnel measured the weight (in kilograms) and height (in centimetres) of participants in a standardized protocol while they were barefoot and in underwear. Body weight was assessed in a fasting state using a calibrated Tanita electronic scale model BC 420 SMA with an adapter (Tanita Europe GmbH) to the nearest 0·1 kg. Height was measured with a calibrated Seca telescopic height-measuring stadiometer model 225 (Seca) to the nearest 0·1 cm. BMI was calculated by dividing body weight in kilograms by the square of height in metres. According to Cole et al [34]. BMI Z-scores and BMI categories were then estimated.

Statistical analysis

Descriptive characteristics are presented as mean ± standard deviation for continuous variables (age, BMI, energy intake, emotional well-being and self-esteem of the child during the last week score (KINDL), emotional and peer problems over the last 6 months (SDQ)), and as number and percentage for categorical variables (gender, BMI categories and parental education).

To explore cross-sectionally the association between psychosomatic and emotional measurements (KINDL and SDQ), and food PS, multivariable multilevel linear regression models were performed for the period T0, T1 and T3 using psychosomatic and emotional status as independent variables, and food PS as dependent variables, considering country as random effect.

Moreover, longitudinal analysis was performed in subjects with complete information in the three measurement times, to evaluate the association between psychosomatic and emotional status (delta value) and food PS (delta values) between T1 and T0 as well as between T3 and

T0. The association between psychosomatic and emotional status variables and these delta values were analysed via multivariable multilevel linear regression models, considering country as random effect. The Holm-Bonferroni adjustment method was employed to reduce the likelihood of type 1 errors. This method is more powerful than the single step Bonferroni. The procedure involves ordering the significant results from the smallest to the largest P-value, testing the smallest probability, and applying a simple equation (alpha/(number of tests performed-rank after ordering+1). If the first test is significant, the second smallest probability is tested, and so on. The procedure ends when the first nonsignificant test is generated.

All regression models were stratified by age and gender for period (T3-T0) and only by gender for period (T1-T0). The models were adjusted by parental education and BMI. P-value of < 0.05 was considered the cut-off level for statistical significance. All analyses were performed with the IBM SPSS package v.25 (IBM Corp., New York, USA) and STATA software v.13 (College Station, TX, USA).

Results

General characteristics of study participants

Sample descriptive characteristics are presented in **Table 1**. A total of 7,355 in T0, 3,869 in T1, and 2,975 in T3 aged between 2 and 17 years old were included in this study. In baseline and T1 follow up more than half (51.0%) of the participants were males, while in T3 51.8 % were females. At baseline and T3 follow up more than 57% of the children had parents with lower educational level. Regarding psychosomatic and emotional status variables, all indicators were stable between baseline and follow-up.

Association between psychosomatic and emotional variables and portion size from specific food groups (cross-sectional analysis T0; T1; T3)

Table 2 illustrates the results of psychosomatic and emotional status and PS mean intake from the main contributing food groups in the period of T0. Higher KINDL scores were associated with consumption smaller PS from bread and rolls, sweet bakery product, savoury snacks, sauce, fruit and vegetables juices in both genders ($p<0.05$). Higher emotional problem score was positively associated with consumption larger PS from bread and rolls in males and chocolates in females, while was inversely associated with milk and yoghurt ($p<0.05$). Higher peer problem score was associated with consumption larger PS from bread and rolls, breakfast cereals, sweet bakery products, fruit and vegetable juices and milk and yoghurt in both genders ($p<0.05$). Moreover, higher peer problem score was associated with consumption larger PS from carbonated soft drinks in females.

In T1 **(Table S1),** a higher emotional problem score was associated with consumption larger PS from margarine and lipids in females ($p<0.05$), while higher peer problem score was associated with consumption larger PS from cheese in males and vegetable oils in both genders ($p<0.05$).,

Table S2 illustrates the results of psychosomatic and emotional status variables and PS mean intake from the main contributing food groups in T3. Higher KINDL score were associated with consumption smaller PS from sweet bakery products, savoury snacks, and fruit and vegetable juices in both genders in age 2-9.9 years. Moreover, higher KINDL score were associated with consumption smaller PS from chocolate in males and bread and rolls in females in the same age group ($p<0.05$).

Higher SDQ, which is a marker of emotional and peer problems score, was inversely associated with consumption larger PS from bread and rolls, pasta, breakfast cereals, and cheese in both genders and only in age 2-9.9 years. Meanwhile, higher emotional score was associated with consumption of larger PS from fruit and vegetable juices in males and chocolate in females in same age group ($p<0.05$). In females aged 10-17 years, higher emotional problems score was associated with consumption larger PS from bread and rolls, carbonated soft drinks, and dairy products group ($p<0.05$). In age 10-17 years, higher peer problem score was associated with larger PS from bread and rolls, sauces and dairy products group in both genders ($p<0.05$). In the same age group higher peer problem score was associated with larges PS from breakfast cereals, margarine and lipids, and carbonated soft drinks only in females.

Association between psychosomatic and emotional status variables and portion size from various food groups (longitudinal analysis T1-T0 and T3-T0).

In T1-T0, a higher KINDL score was associated with larger reported PS from milk and yoghurt in both genders, while higher emotional problem score was associated with consumption larger PS from chocolate, butter and animal fats in females ($p<0.05$) **(Table 3)**.

In T3-T0, higher KINDL score was associated with consumption larger PS from milk and yoghurt in both genders aged 2-9.9 years ($p<0.05$). Moreover, higher emotional problem score was associated with consumption larger PS from bread and rolls, margarine and lipids and dairy products in females aged 10-17 years **(Table 4)**.

Higher peer problem score was associated with consumption larger PS from bread and rolls and margarine and lipids, and dairy products in both genders and all age groups. In males aged from 2-9.9 years, higher peer problem score was associated with consumption larger PS from pasta, sugar, honey and jam, in males ($p<0.05$). In females of same age groups, higher peer problem score was associated with consumption larger PS from breakfast cereals and chocolate. At age 10-17 years, higher peer problem score was associated with consumption larger PS from butter and animal fats and sauces in both genders ($p<0.05$). In females of same age group, higher peer problem score was associated with consumption larges PS from breakfast cereals, sugar, honey and jams, non-chocolate confectionary and carbonated soft drinks.

Discussion

The main results suggest that there is an association between psychosomatic and emotional status and larger PS consumption of some food groups, both in children and adolescents. Cross-sectionally we found that higher emotional well-being was associated with consumption of smaller PS from high energy dense foods, mainly sweet-fatty foods and soft drinks, in school age children. Higher SDQ score, was inversely associated with consumption larger PS from bread and rolls, pasta, breakfast cereals, and cheese in both genders and only in school age children in T3-T0.

In cross-sectional and longitudinal analysis, we found that females with more emotional problems and more peer problems tend to consume more sugar-fatty food products at school age adolescents. However, in longitudinal analysis, a higher emotional well-being was associated with consumption of larger PS from milk and yoghurt in both genders in school age children. On the other hand, having more peer problems was associated with consumption of larger PS from bread and rolls and margarine and lipids, and dairy products in both genders and all age groups. These results were obtained after considering the adjustment for potential confounders BMI, parental education, and country as random effect.

Psychosomatic and emotional status and food portion sizes

The theory of emotional eating suggests that people may overeat in response to negative emotions [35]. Clinical studies have found that adults with higher emotional status tend to consume more high-fat snack foods [36] and more sweet-and-fatty foods [37] in response to their psychosomatic state, compared to those who are not as emotionally charged [36, 38]. It has been observed that emotional status is linked to greater intakes of high-density snack foods, such as cakes/biscuits/pastries, and breakfast cereals in most subgroups of adult participants [36, 38].

In adolescents, higher healthy diet scores at baseline predicted higher emotional scores at follow-up, while higher unhealthy diet scores at baseline predicted lower emotional scores at follow-up [39]. These findings are consistent with the results of another study which showed that, a high intake of fried foods, cakes, chocolate, biscuits, and soft drinks were associated with poorer behavioural and emotional problems scores in 14 year old adolescents [40]. Additionally, a previous I. Family analysis revealed that a higher perception of warmth at home was linked to a 16 % increase in fruit and vegetable consumption frequency [41] and energy-dense food consumption [10]. These results support our finding in which adolescent females with higher emotional and peer problems score tend to consume more sugar-fatty food products.

In our study we found that higher peer problem score was associated with large PS from bread and rolls, margarine and lipids, and dairy products in all genders and age groups. The same finding were observed in previous studies which found that participants who were in the top 33% on the SDQ hyperactivity sub-scale at age 7 years were eating a diet high in "junk food" in early childhood [42]. Moreover, positive associations were observed between problems and both sweet and fatty foods consumption, while a negative association was observed between life events and fruit and vegetables consumption in children [13]. Previous I. Family study found that emotion-driven impulsiveness is linked to the type of snack food consumed, regardless of age, sex, socio-economic status and BMI [10]. Therefore, it is proposed that the association between emotion-driven impulsivity and snacking behaviour may be influenced by transient self-control deficits, such as ineffective reaction inhibition and emotion regulation methods [10].

Cross-sectionally, we found that a higher KINDL score in children, was inversely associated with consumption of large PS from high energy dense foods, mainly sweet-fatty foods and non-alcoholic drinks. Recent longitudinal studies have suggested that the association between emotional status and depression and unhealthy eating habits over a long period of time is unlikely to be caused by the former leading to the latter [43] . This is in contrast to previous assumptions that emotional status and depression could be a contributing factor to unhealthy eating habits [43].

There are several potential explanations for our results; for instance, energy-dense foods that are typically high in fat and often contain added sugars are palatable, easily accessible, and convenient [44]. It has been demonstrated that consuming palatable foods can reduce negative mood in the short term, particularly among those with a high emotional status [45]. The mechanism behind this could be a difference in sensitivity to the reward properties of food between emotional eaters and non-emotional eaters [46, 47]. However, it is still unclear whether emotional eaters have a deficit of perceived reward [47] or heightened sensitivity to palatable food reward when in a negative mood [46]. It is also possible that emotional eaters consume such foods due to their ability to distract from negative emotions [48]. "Comfort foods" have been suggested to counteract the influence of the physiological effects of psychosomatic status [48] with emotional eaters having blunted hypothalamic–pituitary–adrenal axis reactivity and cortisol stress responses [49]. Finally, emotional eaters' preferences for energy-dense foods could be explained by the fact that pleasure may be derived from eating "forbidden" foods when cognitive control is impaired by negative affect [50].

Gender and age differences

In the current study, associations between emotional status and consumption of energy-dense snack foods were observed in both genders, with stronger associations in females. Adults of the female gender generally had higher emotional status scores than males [38, 51], and higher mean portion consumption of all energy-dense food groups, except for cheese and processed meat in response to emotional status [38]. Additionally, significant associations were found between emotional status and both salted fast food/pizza/quiches and sweetened cream desserts in adult males [38]. However, all previous studies in children and adolescents did not take into account gender differences, even though it is well known that males and females grow in different dietary patterns, especially during adolescence. Boys tend to increase their energy intake to increase satiety, while a significant percentage of females control their energy intake to control body weight [52]. Moreover, in the adolescent age group, meal size decreased among females, while it remained stable or increased among males, emphasizing the need to stratify by gender. One possible explanation is that comfort food preferences are influenced by gender, with females preferring sweet snack foods [53].

Our study revealed various associations between psychosomatic and emotional status and PS, depending on age. Several factors may explain the observed differences. For instance, the diet of primary school children is still largely determined by their parents [54], which could lead to psychosomatic children having a greater desire to eat, but not necessarily having access to the food [55]. Studies have demonstrated that children's diet and emotional behaviour are linked to their parents' [55, 56]. Additionally, a recent meta-analysis has indicated that there is a trend of diminishing influence from changing environments such as school and peers [57]. These findings explain our results of an inverse association between higher SDQ score and larger PS consumption from high energy dense foods in children only. In this context, age could be a significant factor, as in school age, children who perceive parental eating restriction could be more affected emotionally than the older group [56].

Strengths and limitations

This study is the first to explore the relationship between psychosomatic and emotional status and PS consumption from different food groups among European children and adolescents, while taking into account potential confounders such as BMI and parental education. The study's strength lies in its large, international sample of eight European countries, as well as its longitudinal nature which allows for a more comprehensive examination of emotional status and their relationship with food PS than has been done previously. To ensure accuracy, highly standardized and validated procedures were used to collect the sample and assess anthropometric measurements. However, there were some methodological issues. For instance, the study only assessed a limited number of psychosomatic and emotional outcomes, which were exclusively parent-reported and did not consider children's perspectives, which could lead to a large bias. Additionally, the IDEFICS/I. Family parental questionnaire did not allow for the examination of the severity of the psychosomatic and emotional status. Furthermore, selection or non-participation bias related to education or income level, as well as a response bias cannot be ruled out and may have influenced prevalence results in both directions [18].

Conclusion

According to the main results, emotional status may be a factor that leads to larger portion sizes of unhealthy food groups, particularly in female adolescents, which could be linked to overweight. Generally, children and adolescents tend to eat smaller portions of energy-dense food, which may be due to parental control of their food choices. However, it is important to teach children and adolescents how to cope with their emotions in a healthy way, such as problem-solving thinking or asking for help instead of using food as a source of comfort. These findings suggest that individual psychological states should be taken into account when attempting to reduce unhealthy dietary habits, particularly in females. Further research is needed to determine the causal links and investigate the mechanisms that connect emotional status, larger food portion sizes, and weight status.

Acknowledgements

The authors wish to thank the IDEFICS children and their parents for participating in this extensive examination. Further, we gratefully acknowledge the financial support of the European Community for the IDEFICS study and Epilife TEENS for salary support.

Authors' contributions

Flieh S analysed the data and prepared the manuscript; Moreno L, Miguel-Berges M, and González-Gil E supervised and commented on the manuscript at all stages; All authors read and approved the final manuscript.

Conflict of interest: "no conflicts of interest."

Ethics approval and consent to participate

Institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research, and the IDEFICS study passed the Ethics Review process of the Sixth Framework Programme (FP6) of the European Commission. Ethical approval was obtained from the relevant local or national ethics committees by each of the eight study centres. All parents or legal guardians of the participating children gave written informed consent to data collection, examinations, collection of samples, subsequent analysis and storage of personal data and collected samples. Additionally, each child gave oral consent after being orally informed about the modules by a study nurse immediately before every examination using a simplified text.

References

1. Nogueiras R. MECHANISMS IN ENDOCRINOLOGY: The gut-brain axis: regulating energy balance independent of food intake. European journal of endocrinology. 2021;185(3). doi:10.1530/EJE-21-0277
2. Zheng H, Lenard NR, Shin AC, Berthoud HR. Appetite control and energy balance regulation in the modern world: reward-driven brain overrides repletion signals. Int J Obes (Lond). 2009;33 Suppl 2:S8-13. doi:10.1038/ijo.2009.65
3. Macht M. How emotions affect eating: a five-way model. Appetite. 2008;50(1):1-11. doi:10.1016/j.appet.2007.07.002
4. Cornah D. Feeding minds: the impact of food on mental health. Ment Health Found. 2005 [updated 2006-06-01. Available from: https://www.mentalhealth.org.uk/sites/default/files/ Feeding-Minds.pdf.
5. Do S, Coumans J, Börnhorst C, Pohlabeln H, Reisch L, Danner U, et al. Associations Between Psychosocial Well-Being, Stressful Life Events and Emotion-Driven Impulsiveness in European Adolescents. Journal of youth and adolescence. 2022;51(6). doi:10.1007/s10964-021-01533-w
6. Washington T. Psychological stress and anxiety in middle to late childhood and early adolescence: manifestations and management. Journal of pediatric nursing. 2009;24(4). doi:10.1016/j.pedn.2008.04.011
7. Evers C, Marijn S, F, de Ridder D. Feeding your feelings: emotion regulation strategies and emotional eating. Personality & social psychology bulletin. 2010;36(6). doi:10.1177/0146167210371383
8. Du C, Adjepong M, Zan M, Cho M, Fenton J, Hsiao P, et al. Gender Differences in the Relationships between Perceived Stress, Eating Behaviors, Sleep, Dietary Risk, and Body Mass Index. Nutrients. 2022;14(5). doi:10.3390/nu14051045
9. BRUCH H. PSYCHOLOGICAL ASPECTS OF OVEREATING AND OBESITY. Psychosomatics. 1964;5. doi:10.1016/s0033-3182(64)72385-7
10. Coumans J, Danner U, Intemann T, De Decker A, Hadjigeorgiou C, Hunsberger M, et al. Emotion-driven impulsiveness and snack food consumption of European adolescents: Results from the I.Family study. Appetite. 2018;123.
11. Cardi V, Leppanen J, Treasure J. The effects of negative and positive mood induction on eating behaviour: A meta-analysis of laboratory studies in the healthy population and eating and weight disorders. Neurosci Biobehav Rev. 2015;57:299-309.
12. O'Neil A, Quirk S, Housden S, Brennan S, Williams L, Pasco J, et al. Relationship between diet and mental health in children and adolescents: a systematic review. American journal of public health. 2014;104(10).
13. Michels N, Sioen I, Braet C, Eiben G, Hebestreit A, Huybrechts I, et al. Stress, Emotional Eating Behaviour and Dietary Patterns in Children. Appetite. 2012;59(3).
14. George S, Khan S, Briggs H, Abelson J. CRH-stimulated cortisol release and food intake in healthy, non-obese adults. Psychoneuroendocrinology. 2010;35(4).
15. Lim E, Sim A, Forde C, Cheon B. The role of perceived stress and gender on portion selection patterns. Physiology & behavior. 2018;194.

16. 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(5).
17. The World Medical Association-Declaration of Helsinki 2000. Initiated:1964:17.C.
18. 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 (2005). 2011;35 Suppl 1.
19. Ravens-Sieberer U, Bullinger M. Assessing health-related quality of life in chronically ill children with the German KINDL: first psychometric and content analytical results. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 1998;7(5).
20. Dey M, Landolt M, Mohler-Kuo M. Health-related quality of life among children with mental disorders: a systematic review. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 2012;21(10).
21. Goodman R. Psychometric properties of the strengths and difficulties questionnaire. Journal of the American Academy of Child and Adolescent Psychiatry. 2001;40(11).
22. Goodman R, Meltzer H, Bailey V. The Strengths and Difficulties Questionnaire: a pilot study on the validity of the self-report version. European child & adolescent psychiatry. 1998;7(3).
23. Hebestreit AR, A. Huybrechts, I. Computer based 24-hour dietary recall: the SACINA program. Measurement tools for a health survey on nutrition, physical activity and lifestyle in children: the European IDEFICS Study,1st edn. Springer, Berlin. 2013.
24. Hebestreit A, Wolters M, Jilan H, Eiben G, Pala V. Web-Based 24-h Dietary Recall: The SACANA Program. In Instruments for Health Surveys in Children and Adolescents: SpringerLink; 2019.
25. 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(12).
26. 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. The international journal of behavioral nutrition and physical activity. 2016;13.
27. Tooze J, Krebs-Smith S, Troiano R, Subar A. The accuracy of the Goldberg method for classifying misreporters of energy intake on a food frequency questionnaire and 24-h recalls: comparison with doubly labeled water. European journal of clinical nutrition. 2012;66(5).
28. Flieh S, Miguel-Berges M, González-Gil E, Gottrand F, Censi L, Widhalm K, et al. The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study. Nutrients. 2021;13(3).
29. Albar SA, Alwan NA, Evans CE, Cade JE. Is there an association between food portion size and BMI among British adolescents? Br J Nutr. 2014;112(5):841-51.
30. World Cancer Research Fund (WCRFUK). Energy density: finding the balance for cancer prevention 2007 [Available from: http://www.wcrf-uk. org/PDFs/EnergyDensity.pdf. [access date:02/05/2022]
31. Hebestreit A, Börnhorst C, Barba G, Siani A, Huybrechts I, Tognon G, et al. Associations between energy intake, daily food intake and energy density of foods and BMI z-score in 2-9-year-old European children. European journal of nutrition. 2014;53(2).

32. UNESCO. International Standard Classification of Education. 2017 [Available from: http://www.uis.unesco.org/ Education/Documents/isced-2011-en.pdf. [access date:15/05/2022]
33. www.uis.unesco.org UIscoe. UNESCO International standard classifcation of education. www.uis.unesco.org 2013 [access date:02/05/2022]
34. Cole T, Bellizzi M, Flegal K, Dietz W. Establishing a Standard Definition for Child Overweight and Obesity Worldwide: International Survey. BMJ (Clinical research ed). 2000;320(7244).
35. KAPLAN H, KAPLAN H. The psychosomatic concept of obesity. The Journal of nervous and mental disease. 1957;125(2).
36. van Strien T, Herman C, Anschutz D, Engels R, de Weerth C. Moderation of distress-induced eating by emotional eating scores. Appetite. 2012;58(1).
37. Lampuré A, Schlich P, Deglaire A, Castetbon K, Péneau S, Hercberg S, et al. Sociodemographic, psychological, and lifestyle characteristics are associated with a liking for salty and sweet tastes in French adults. The Journal of nutrition. 2015;145(3).
38. Camilleri G, Méjean C, Kesse-Guyot E, Andreeva V, Bellisle F, Hercberg S, et al. The associations between emotional eating and consumption of energy-dense snack foods are modified by sex and depressive symptomatology. The Journal of nutrition. 2014;144(8).
39. Jacka F, Kremer P, Berk M, de Silva-Sanigorski A, Moodie M, Leslie E, et al. A prospective study of diet quality and mental health in adolescents. PloS one. 2011;6(9).
40. Robinson M, Kendall G, Jacoby P, Hands B, Beilin L, Silburn S, et al. Lifestyle and demographic correlates of poor mental health in early adolescence. Journal of paediatrics and child health. 2011;47(1-2).
41. Ghazy Elsayed H, Lissner L, Mehlig K, Thumann B, Hebestreit A, Pala V, et al. Relationship between perception of emotional home atmosphere and fruit and vegetable consumption in European adolescents: results from the I.Family survey. Public health nutrition. 2020;23(1).
42. Wiles N, Northstone K, Emmett P, Lewis G. 'Junk food' diet and childhood behavioural problems: results from the ALSPAC cohort. European journal of clinical nutrition. 2009;63(4).
43. Le Port A, Gueguen A, Kesse-Guyot E, Melchior M, Lemogne C, Nabi H, et al. Association between dietary patterns and depressive symptoms over time: a 10-year follow-up study of the GAZEL cohort. PloS one. 2012;7(12).
44. Vernarelli J, Mitchell D, Rolls B, Hartman T. Dietary energy density and obesity: how consumption patterns differ by body weight status. European journal of nutrition. 2018;57(1).
45. Klatzkin R, Nolan L, Kissileff H. Self-reported emotional eaters consume more food under stress if they experience heightened stress reactivity and emotional relief from stress upon eating. Physiology & behavior. 2022;243.
46. Bohon C, Stice E, Spoor S. Female emotional eaters show abnormalities in consummatory and anticipatory food reward: a functional magnetic resonance imaging study. The International journal of eating disorders. 2009;42(3).
47. Cimino S, Marzilli E, Tafà M, Cerniglia L. Emotional-Behavioral Regulation, Temperament and Parent-Child Interactions Are Associated with Dopamine Transporter Allelic Polymorphism in Early Childhood: A Pilot Study. International journal of environmental research and public health. 2020;17(22).
48. Gibson E. The psychobiology of comfort eating: implications for neuropharmacological interventions. Behavioural pharmacology. 2012;23(5-6).
49. van Strien T, Roelofs K, de Weerth C. Cortisol reactivity and distress-induced emotional eating. Psychoneuroendocrinology. 2013;38(5).

50. Yeomans M, Coughlan E. Mood-induced eating. Interactive effects of restraint and tendency to overeat. Appetite. 2009;52(2).
51. Konttinen H, Männistö S, Sarlio-Lähteenkorva S, Silventoinen K, Haukkala A. Emotional eating, depressive symptoms and self-reported food consumption. A population-based study. Appetite. 2010;54(3).
52. Askovic B, Kirchengast S. Gender differences in nutritional behavior and weight status during early and late adolescence. Anthropologischer Anzeiger; Bericht uber die biologisch-anthropologische Literatur. 2012;69(3).
53. Wansink B, Cheney M, Chan N. Exploring comfort food preferences across age and gender. Physiology & behavior. 2003;79(4-5).
54. Longbottom P, Wrieden W, Pine C. Is there a relationship between the food intakes of Scottish 5(1/2)-8(1/2)-year-olds and those of their mothers? Journal of human nutrition and dietetics : the official journal of the British Dietetic Association. 2002;15(4).
55. Brown R, Ogden J. Children's eating attitudes and behaviour: a study of the modelling and control theories of parental influence. Health education research. 2004;19(3).
56. van Strien T, Ouwens M. Effects of distress, alexithymia and impulsivity on eating. Eating behaviors. 2007;8(2).
57. Wang Y, Beydoun M, Li J, Liu Y, Moreno L. Do children and their parents eat a similar diet? Resemblance in child and parental dietary intake: systematic review and meta-analysis. Journal of epidemiology and community health. 2011;65(2).

Table 1. Descriptive characteristics at baseline (T0) and follow-up (T1 and T3) in study sample.

	Baseline T0	**Follow up T1**	**Follow up T3**	
	N=7355	**N=3869**	**N=1139**	**N=1832**
Age range	**2-9 years** 6.1 (1.8)	**2-11 years** 7.9 (1.8)	**2-9 years** 8.3 (1.1)	**10-17 years** 11.6 (1.4)
Sex				
Male	3764 (51.2%)	2006 (51.8%)	558 (49.0%)	868 (47.4%)
Females	3591 (48.8%)	1863 (48.2%)	581 (51.0%)	964 (52.6%)
BMI categories (n, %)[a]				
Underweight	792 (10.8%)	337 (8.7%)	89 (7.8%)	248 (13.5%)
Normal weight	5046 (68.6%)	2473 (63.9%)	812 (71.3%)	1164 (63.5%)
Overweight	1005 (13.6%)	697 (18.0%)	177 (15.5%)	321 (17.5%)
Obesity	512 (7.0%)	362 (9.4%)	61 (5.4%)	99 (5.5%)
Parental education (n, %)[a]				
Lower education level	594 (8.1%)	292 (7.5%)	57 (5.0%)	123 (6.7%)
Medium education level	3410 (46.4%)	1725 (44.6%)	451 (39.6%)	756 (41.3%)
Higher education level	3351 (45.5%)	1852 (47.9%)	631 (55.4%)	953 (52.0)
Energy intake (Kcal/day)	1563.61 (428.37)	1729.6 (436.5)	1650.9 (272.8)	1781.6 (272.3)
Emotional well-being during the last week score (KINDL)[b]	2.4 (1.0)	2.3 (1.0)	2.6 (1.1)	2.4 (1.0)
Emotional problems score (SDQ)[c]	1.5 (1.6)	1.6 (1.7)	1.3 (1.4)	1.2 (1.3)
Peer problems score (SDQ)[c]	3.2 (1.3)	4.3 (1.2)	3.2 (1.7)	3.1 (1.6)

Continuous variables are displayed with mean ± standard deviation, and categorical variables with absolute frequencies and percentage.

[a]. BMI: body mass index.

[b] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range:1-4, Interpretation: High value = high well-being

[c] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

Table 2: Cross-sectional associations between the psychosomatic and emotional status variables and the selected food portion sizes at T0.

	(T0) N= 7355											
	Emotional well-being during the last week score (KINDL)[a]				**Emotional problems score (SDQ)[b]**				**Peer problems score (SDQ)[b]**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	-0.101*	-11.966/-5.925	-0.104*	-11.800/-5.857	0.059*	1.346/5.115	0.016	-0.986/2.634	0.085*	3.513/8.249	0.080*	3.233/8.326
Breakfast cereals	-0.011	-1.996/1.331	-0.057	-4.342/0.010	0.019	-0.682/1.428	-0.009	-1.569/1.133	0.119*	1.633/4.367	0.106*	1.660/5.548
Pasta	0.001	-4.776/5.032	0.014	-3.492/6.124	0.023	-1.733/4.610	-0.026	-4.426/1.471	-0.074*	-8.807/-1.648	-0.077*	-9.648/-1.859
Rice and other cereals	-0.047	-11.033/2.017	-0.073	-11.865/-0.267	-0.017	-5.134/3.110	0.012	-2.963/4.231	0.031	-2.843/7.669	0.028	-3.053/7.137
Sweet bakery product	-0.114*	-15.955/-7.706	-0.095*	-12.487/-4.984	0.035	-0.349/4.842	0.018	-1.242/3.117	0.112*	5.538/11.666	0.096*	4.163/10.244
Savoury snacks	-0.119*	-12.100/-2.463	-0.208*	-18.035/-8.014	-0.023	-4.200/1.789	0.020	-2.184/3.581	0.054	-1.160 5.980	0.100*	0.843/8.354
sugar, honey, jam and syrup	0.041	-0.298/2.746	0.031	-0.712/2.810	0.006	-0.851/1.098	-0.026	-1.594/0.537	0.050	-0.004/2.408	-0.018	-2.033/0.994
confectionery non chocolate	-0.029	-4.247/2.153	-0.064	-4.108/0.546	0.014	-1.714/2.347	0.019	-1.049/1.681	0.071	-0.467/4.628	-0.029	-2.770/1.336
Chocolate	-0.068*	-4.214/-0.708	-0.048	-3.382/0.102	0.032	-0.353/1.749	0.071*	0.410/2.391	0.002	-1.258/1.382	0.038	-0.349/2.487
vegetable oils	0.144*	0.426/1.678	0.034	-0.363/0.814	0.082	-0.024/0.821	0.076	-0.061/0.642	0.048	-0.209/0.746	0.094	0.021/0.928
margarine and lipids	-0.002	-1.282/1.217	-0.007	-1.253/1.020	0.048	-0.230/1.389	0.065	-0.018/1.474	0.005	-0.907/1.055	0.022	-0.703/1.454
butter and animal fats	0.180*	1.832/5.559	0.046	-0.871/2.717	0.092	0.000/2.374	-0.041	-1.544/0.584	-0.010	-1.604/1.252	-0.025	-2.002/1.111
Sauces	-0.099*	-9.079/-3.018	-0.081*	-7.996/-1.878	-0.032	-3.166/00.734	-0.065*	-4.343/-0.456	0.029	-0.989/3.612	0.049	-0.058/5.127
fruit and vegetable juices	-0.146*	-71.921/-34.230	-0.087*	-53.615/-11.951	-0.015	-15.437/8.688	-0.043	-21.906/3.046	0.095*	12.483/42.284	0.090**	10.527/44.442
carbonated/soft/isotonic drinks	-0.029	-27.145/8.060	-0.053	-41.714/0.363	-0.038	-18.884/3.448	-0.008	-14.635/10.804	0.040	-3.458/24.567	0.070**	5.839/41.227

Milk, yogurt	0.003	-12.202/ 14.475	-0.040	-26.238/ -0.935	-0.027	-15.035/ 2.383	-0.052*	-18.282/ -2.650	0.073*	10.211/ 30.848	0.123*	24.516/ 45.706
Cheese	0.009	-2.370/ 3.490	0.044	-0.315/ 6.040	0.004	-1.808/ 2.161	0.023	-1.053/ 2.896	0.003	-2.174/ 2.465	-0.045	-5.196/ .0.234

N= number of participants. β: regression coefficient. CI: confidence interval; Adjusting for confounders: parental education, BMI and country as random effect. Level of significance was set to 0.05.

[a] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range: 1-4, Interpretation: High value = high well-being

[b] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

*: Represent the significant values accepted after Holm-Bonferroni adjustment method.

Table 3: Longitudinal associations between psychosomatic and emotional status variables and selected food portion sizes at T1-T0.

	DELTA (T1-T0) N=2043											
DELTA (T1-T0)	**Emotional well-being during the last week score (KINDL)[a]**				**Emotional problems score (SDQ)[b]**				**Peer problems score (SDQ)[b]**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	2.126	0.291/3.961	0.321	-1.476/2.118	0.783	-0.291/1.858	-0.563	-1.587/0.462	-0.210	-1.596/1.175	-0.778	-2.247/0.690
Breakfast cereals	0.013	-0.588/0.614	0.119	-0.528/0.766	-0.119	-0.471/0.233	-0.172	-0.541/0.197	-0.011	-0.464/0.443	0.055	-0.474/0.584
Pasta	0.662	-1.426/2.750	0.112	-1.903/2.126	-0.503	-1.726/0.72	-0.336	-1.484/0.812	0.377	-1.200/1.953	0.114	-1.532/1.761
Rice and other cereals	0.183	-1.545/1.910	0.339	-1.321/1.999	-0.406	-1.419/0.606	0.450	-0.497/1.396	-0.409	-1.713/0.895	-0.023	-1.380/1.334
Sweet bakery product	0.116	-1.914/2.146	-0.586	-2.462/1.29	0.093	-1.096/1.282	0.919	-0.150/1.988	0.883	-0.65/2.415	0.821	-0.712/2.354
Savoury snacks	-0.480	-1.194/0.233	-0.328	-1.043/0.388	-0.213	-0.631/0.205	-0.159	-0.566/0.249	-0.399	-0.937/0.140	-0.254	-0.839/0.330
sugar, honey, jam and syrup	0.415	-0.120/0.950	0.031	-0.559/0.621	0.020	-0.294/0.334	-0.004	-0.340/0.332	0.371	-0.033/0.775	-0.136	-0.618/0.346
confectionery non chocolate	-0.181	-0.584/0.222	-0.290	-0.641/0.061	0.038	-0.198/0.274	0.210	0.009/0.410	0.165	-0.139/0.469	-0.115	-0.401/0.172
Chocolate	-0.421	-1.079/0.237	-0.432	-1.091/0.227	0.204	-0.181/0.590	0.750*	0.373/1.125	-0.496	-0.993/0.001	0.542	0.002/1.080
vegetable oils	0.083	-0.023/0.190	0.046	-0.057/0.149	0.004	-0.058/0.066	0.041	-0.018/0.100	0.004	-0.076/0.084	-0.014	-0.098/0.071
margarine and lipids	-0.035	-0.351/0.280	-0.076	-0.371/0.220	-0.071	-0.256/0.113	0.093	-0.075/0.262	0.145	-0.093/0.383	0.026	-0.215/0.268
butter and animal fats	0.097	-0.148/0.342	0.112	-0.134/0.357	0.034	-0.110/0.177	0.216*	-0.356/0.075	-0.099	-0.284/0.086	-0.016	-0.217/0.185
Sauces	0.510	-0.706/1.726	0.563	-0.684/1.810	-0.337	-1.050/0.376	-0.287	-0.998/0.425	0.083	-0.835/1.001	0.059	-0.961/1.078
fruit and vegetable juices	-1.415	-1.762/0.933	1.591	-4.821/8.003	0.167	-3.553/3.887	0.888	-2.768/4.544	-4.342	-9.134/0.451	-0.861	-6.102/4.381

carbonated/soft/isotonic drinks	0.672	-0.908/1.252	-0.001	-7.262/7.260	-1.736	-5.592/2.120	1.644	-2.496/5.783	-5.097	-10.065/-0.128	-1.687	-7.622/4.248
Milk, yogurt	1.386*	-0.400/1.372	0.605*	-0.180/1.028	-3.931	-8.611/0.748	-1.341	-5.575/2.894	-0.374	-6.407/5.659	-0.625	-6.697/5.446
Cheese	0.269	-1.273/1.811	0.918	-0.620/2.456	-0.858	-1.762/0.046	-0.478	-1.355/0.399	0.191	-0.974/1.355	-1.239	-2.495/0.018

N= number of participants. β: regression coefficient. CI: confidence interval; Adjusting for confounders: parental education, BMI and country as random effect. Level of significance was set to 0.05.

[a] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range: 1– 4, Interpretation: High value = high well-being

[b] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

*: Represent the significant values accepted after Holm-Bonferroni adjustment method.

Table 4: Longitudinal associations between psychosomatic and emotional status variables and selected food portion sizes at T3-T0.

	DELTA (T3-T0) N=1165											
	Emotional well-being during the last week score (KINDL)[a]								**Emotional problems score (SDQ)[b]**			
DELTA (T3-T0)	**Age (2-9.9) years**				**Age (10-17) years**				**Age (2-9.9) years**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	1.663	-1.132/ 4.458	0.270	-2.262/ 2.802	3.596	-6.781/ 13.973	-0.061	-9.316/ 9.193	-2.839	-6.382/ 0.704	1.727	-1.532/ 4.986
Breakfast cereals	-0.047	-0.987/ 0.893	0.112	-1.136/ 1.360	-2.895	-7.146/ 1.357	0.497	-2.614/ 3.609	-0.034	-1.219/ 1.151	0.442	-1.171/ 2.055
Pasta	-0.060	-3.032/ 2.913	-0.206	-3.086/ 2.675	-2.661	-15.822/ 10.499	7.758	-2.917/ 18.433	0.232	-3.532/ 3.996	-0.467	-4.165/ 3.23
Rice and other cereals	-0.360	-3.040/ 2.320	0.030	-2.275/ 2.334	6.313	-4.404/ 17.03	4.717	-3.628/ 13.061	2.860	-0.522/ 6.243	1.457	-1.495/ 4.410
Sweet bakery product	-0.165	-3.065/ 2.735	-1.104	-3.733/ 1.524	5.108	-6.206/ 16.422	2.710	-7.827/ 13.247	-0.951	-4.611/ 2.709	-1.414	-4.781/ 1.953
Savoury snacks	-0.364	-1.39/ 0.663	-1.066	-2.079/ - 0.053	0.259	-3.152/ 3.67	1.911	-1.85/ 5.672	-0.499	-1.787/ 0.789	0.081	-1.207/ 1.368
Sugar, honey, jam and syrup	0.218	-0.620/ 1.057	0.002	-0.855/ 0.859	2.135	-0.704/ 4.975	1.033	-2.258/ 4.324	-1.115	-2.156/ - 0.074	-1.051	-2.134/ 0.032
Confectionery non chocolate	-0.380	-1.011/ 0.251	-0.522	-1.049/ 0.004	0.556	-1.588/ 2.701	-1.020	-2.901/ 0.861	0.196	-0.591/ 0.984	0.316	-0.343/ 0.975
Chocolate	-0.940	-1.968/ 0.088	-0.198	-1.169/ 0.773	1.135	-3.100/ 5.371	-2.451	-6.359/ 1.456	-0.428	-1.728/ 0.873	0.191	-1.051/ 1.433
Vegetable oils	0.162	0.023/ 0.301	0.018	-0.146/ 0.183	0.232	-0.379/ 0.842	-0.460	-1.123/ 0.203	0.017	-0.159/ 0.192	-0.078	-0.289/ 0.134
Margarine and lipids	0.089	-0.370/ 0.549	-0.029	-0.517/ 0.459	-0.029	-1.949/ 1.891	-0.696	-2.429/ 1.038	-0.556	-1.137/ 0.024	0.181	-0.446/ 0.808
Butter and animal fats	0.010	-0.373/ 0.393	0.207	-0.142/ 0.556	-0.077	-2.048/ 1.894	-0.533	-2.104/ 1.038	0.066	-0.415/ 0.548	-0.082	-0.528/ 0.363
Sauces	0.319	-1.425/ 2.062	0.755	-1.079/ 2.590	-2.378	-8.742/ 3.985	-1.544	-6.830/ 3.743	-0.039	-2.22/ 2.141	0.070	-2.260/ 2.399
Fruit and vegetable juices	0.661	-0.811/ -1.510	3.173	-5.997/ 12.343	0.449	-0.219/ 1.117	1.774	-0.738/ 3.285	-2.803	-14.266/ 8.660	1.316*	0.584/ 1.046
Carbonated/soft/isotonic drinks	3.676	-6.271/ 13.623	-1.346	-12.671/ 9.979	0.798	-2.497/ 1.094	0.130	-0.966/ 1.225	-0.107	-1.626/ 1.412	-3.518	-18.023/ 10.987

Milk, yogurt	1.472*	0.205/ 2.738	1.398*	0.127/ 1.669	0.235	-1.998/ 1.467	0.574	-1.614/ 0.762	-0.127	-0.582/ 1.328	-0.735	-1.125/ 0.654
Cheese	-1.301	-4.197/ 1.594	-0.106	-3.054/ 2.841	1.282	-17.336/ 19.901	2.484	-14.554/ 19.522	0.797	-2.883/ 4.477	2.410	-1.394/ 6.214

	DELTA (T3-T0) N= 1165											
	Emotional problems score (SDQ)[b]				**Peer problems score (SDQ)[b]**							
DELTA (T3-T1)	**Age (10-17) years**				**Age (2-9.9) years**				**Age (10-17) years**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	1.014	-0.143/ 1.171	0.435*	0.05/ 1.819	3.626*	1.591/ 5.659	3.565*	1.614/ 5.515	1.827*	0.63/ 2.023	1.625*	0.074/ 1.175
Breakfast cereals	3.940	-2.694/ 10.575	3.210	-1.637/ 8.057	0.789	0.107/ 1.470	1.844*	0.878/ 2.809	2.835	0.288/ 5.382	0.203*	0.318/ 3.088
Pasta	0.342	0.872/ 1.812	1.539	-2.122/ 1.199	3.034*	0.872/ 4.196	2.363	0.148/ 4.578	1.861*	0.031/ 2.690	1.016	0.505/ 1.526
Rice and other cereals	1.182	-1.538/ 2.903	1.433	-0.583/ 2.449	3.016*	1.074/ 4.958	2.170*	0.402/ 3.937	1.619	-0.818/ 12.056	1.317	-0.777/ 9.411
Sweet bakery product	1.426	-16.232/ 19.085	14.636	-1.786/ 31.059	1.219	-0.883/ 3.322	1.996	-0.02/ 4.013	0.118	-0.664/ 12.9	1.708	1.292/ 14.123
Savoury snacks	0.455	-4.869/ 5.779	1.427	-4.438/ 7.292	-0.538	-1.276/ 0.201	0.110	-0.66/ 0.879	1.465	-0.577/ 3.507	2.292	0.004/ 4.580
Sugar, honey, jam and syrup	3.166	-1.267/ 7.598	4.714	-0.411/ 9.84	0.909*	0.307/ 1.510	0.097	-0.552/ 0.746	2.000	0.300/ 3.698	2.719*	0.718/ 4.718
confectionery non Chocolate	-1.355	-4.701/ 1.992	2.999	0.067/ 5.931	0.222	-0.23/ 0.673	-0.099	-0.49/ 0.293	0.757	-0.528/ 2.042	1.829*	0.685/ 2.971
Chocolate	1.884	-4.725/ 8.492	1.101	-5.008/ 7.211	-0.086	-0.832/ 0.661	1.264*	0.519/ 2.007	0.861	-1.685/ 3.407	0.674	-1.715/ 3.064
Vegetable oils	0.381	-0.572/ 1.333	0.348	-0.688/ 1.385	0.027	-0.074/ 0.127	-0.063	-0.190/ 0.063	0.503*	0.137/ 0.868	0.072	-0.333/ 0.477
Margarine and lipids	1.922	-1.070/ 4.914	3.505*	0.806/ 6.202	0.506*	0.172/ 0.839	0.482*	0.106/ 0.857	0.427*	-0.726/ 1.580	2.470*	1.423/ 3.517
Butter and animal fats	1.589	-1.484/ 4.662	2.020	-0.430/ 4.470	0.268	-0.009/ 0.544	0.219	-0.048/ 0.485	1.878*	0.700/ 3.056	1.186*	0.229/ 2.143

Sauces	1.613	-1.304/ 2.530	8.819	0.588/ 17.049	0.424	-0.828/ 1.676	0.992	-0.403/ 2.386	5.869*	2.073/ 9.664	5.629*	2.423/ 8.834
Fruit and vegetable juices	2.646	-1.644/ 4.937	-6.359	-41.548/ 28.829	2.017	-4.564/ 8.599	7.894	0.872/ 14.915	17.363	-0.421/ 35.147	6.337	-7.423/ 20.098
Carbonated/soft/isotonic drinks	4.157	-2.155/ 12.468	2.238*	1.374/ 7.100	-6.661	-13.843/ 0.522	1.095	-7.589/ 9.779	2.219	1.398/ 5.039	5.131*	3.848/ 7.413
Milk, yogurt	2.431	-3.237/ 8.100	1.595*	0.419/ 3.769	1.952*	0.077/ 2.826	1.164*	0.546/ 2.782	1.915*	2.122/ 6.707	6.152*	4.576/ 8.728
Cheese	2.872	-1.143/ 5.886	43.086*	16.663/ 69.507	2.097*	-0.017/ 4.210	2.896*	0.616/ 5.175	2.900*	1.828/ 3.971	3.109*	2.991/ 4.226

N= number of participants. β: regression coefficient. CI: confidence interval; Adjusting for confounders: paternal education, BMI and using country as random effect. Level of significance was set to 0.017.

[a] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range: 1-4, Interpretation: High value = high well-being.

[b] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

*: Represent the significant values accepted after Holm-Bonferroni adjustment method.

Table S1: Cross-sectional associations between the psychosomatic and emotional status variables and the selected food portion sizes at T1.

	(T1) N=3869											
	Emotional well-being during the last week score (KINDL)[a]				**Emotional problems score (SDQ)[b]**				**Peer problems score (SDQ)[b]**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower/ Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**B**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	0.024	-1.529/ 4.076	-0.009	-3.268/ 2.376	0.058	0.098/ 3.425	0.011	-1.341/ 1.994	-0.012	-2.815/ 1.760	-0.049	-4.816/ 0.144
Breakfast cereals	-0.026	-3.903/ 2.283	0.014	-2.222/ 2.858	-0.039	-2.573/ 1.155	0.015	-1.332/ 1.732	0.073	-0.588/ 4.688	0.007	-2.186/ 2.501
Pasta	-0.073	-11.370/ 1.203	0.088	-1.095/ 12.725	-0.079	-7.573/ 0.728	0.116	0.311/ 10.079	0.110	1.050/ 11.456	-0.017	-6.544/ 4.660
Rice and other cereals	-0.134	-28.379/ 3.069	0.119	-4.341/ 27.417	-0.080	-14.113/ 5.378	0.169	-0.068/ 19.996	0.141	-3.342/ 25.569	0.006	-14.673/ 15.803
Sweet bakery product	-0.014	-5.975/ 4.159	0.022	-3.774/ 6.551	0.019	-2.469/ 3.980	0.042	-1.691/ 4.829	0.062	-0.915/ 7.768	0.033	-2.712/ 6.490
Savoury snacks	-0.172	-14.052/ 0.284	-0.034	-8.614/ 5.811	0.026	-4.315/ 5.556	-0.012	-5.645/ 4.974	0.032	-5.327/ 7.455	-0.073	-9.453/ 3.899
Sugar, honey, jam and syrup	0.078	-0.684/ 4.528	0.094	-0.567/ 5.559	-0.102	-2.950/ 0.111	0.010	-1.807/ 2.124	0.045	-1.267/ 3.272	-0.016	-3.124/ 2.328
Confectionery non chocolate	0.027	-5.891/ 7.651	0.322	2.944/ 11.188	-0.014	-4.738/ 4.219	0.228	0.532/ 5.001	0.112	-3.506/ 11.027	-0.114	-5.778/ 0.964
Chocolate	0.013	-1.990/ 2.669	-0.019	-3.076/ 2.053	-0.011	-1.624/ 1.275	0.106	0.108/ 3.220	0.034	-1.282/ 2.837	0.016	0.330/ 4.692
Vegetable oils	-0.070	-1.684/ 0.555	0.017	-0.843/ 1.085	0.030	-0.628/ 0.946	0.129	0.052/ 1.233	0.181*	0.320/ 2.353	0.192*	0.398/ 2.063
Margarine and lipids	-0.079	-5.155/ 1.649	0.175*	0.321/ 4.229	-0.058	-2.701/ 1.210	0.269	0.871/ 3.309	0.081	-1.282/ 4.580	-0.129	-3.782/ 0.130
Butter and animal fats	0.040	-3.397/ 4.983	-0.019	-3.718/ 3.046	0.131	-0.847/ 3.850	-0.210	-4.635/ -0.188	-0.045	-4.583/ 2.818	0.226	0.852/ 7.178
Sauces	-0.053	-5.603/ 1.321	0.000	-3.235/ 3.228	0.013	-1.884/ 2.504	-0.016	-2.375/ 1.705	0.041	-1.565/ 4.385	0.020	-2.227/ 3.485
Fruit and vegetable juices	-0.099	-31.095/ 1.189	0.049	-9.933/ 24.345	0.020	-8.225/ 11.873	0.123	0.205/ 22.082	0.001	-14.326/ 14.544	-0.005	-16.803/ 15.230
Carbonated/soft/isotonic drinks	0.101	-1.114/ 57.723	0.015	-24.198/ 31.354	0.040	-11.044/ 24.530	0.063	-8.004/ 25.633	0.048	-13.226/ 36.710	0.036	-17.467/ 34.188
Milk, yogurt	0.063	-1.045/ 27.381	0.044	-5.126/ 20.476	-0.070	-17.562/ 0.087	-0.030	-11.136 4.994	0.064	-0.533/ 24.010	0.018	-8.330/ 13.919

Cheese	-0.001	-8.062/ 7.946	0.065	-1.422/ 12.500	-0.064	-9.116/ 1.291	0.050	-1.931/ 7.248	0.170*	7.798/ 21.672	0.003	-5.827/ 6.323

N= number of participants. β: regression coefficient. CI: confidence interval; Adjusting for confounders: parental education, BMI and country as random effect. Level of significance was set to 0.05.

[a] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range: 1-4, Interpretation: High value = high well-being

[b] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

*: Represent the significant values accepted after Holm-Bonferroni adjustment method.

Table S2: Cross-sectional associations between the psychosomatic and emotional status variables and the selected food portion sizes at T3.

	(T3) N=2971											
	Emotional well-being during the last week score (KINDL)[a]								**Emotional problems score (SDQ)[b]**			
	Age (2-9.9) years				**Age (10-17) years**				**Age (2-9.9) years**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	-3.121	-6.176/ -0.065	-4.613*	-7.479/ -1.745	2.728	-8.005/ 13.461	-1.216	-10.929/ 8.497	1.435	-0.481/ 3.352	-0.320	-2.013/ 1.373
Breakfast cereals	0.108	-0.822/ 1.039	0.193	-1.155/ 1.541	-3.868	-8.177/ 0.442	-0.028	-3.215/ 3.159	-0.708*	-1.291/ -0.124	-1.092*	-1.886/ -0.296
Pasta	1.778	-1.425/ 4.980	1.555	-1.528/ 4.639	-4.992	-18.761/ 8.777	3.320	-7.848/ 14.487	-4.902*	-6.905/ -2.898	-5.576*	-7.387/ -3.764
Rice and other cereals	-4.436*	-7.185/ -1.687	-2.866	-5.23/ -0.501	-8.566	-20.093/ 2.961	-6.740	-15.653/ 2.172	-1.718	-3.443/ 0.007	-0.196	-1.592/ 1.199
Sweet bakery product	-9.117*	-12.208/ -6.025	-9.256*	-12.101/ -6.409	3.335	-8.221/ 14.89	-0.905	-11.982/ 10.172	0.709	-1.237/ 2.656	0.000	-1.687/ 1.687
Savoury snacks	-2.542*	-3.568/ -1.515	-3.621*	-4.65/ -2.591	-0.211	-3.626/ 3.203	0.776	-3.071/ 4.623	-0.301	-0.946/ 0.345	-0.052	-0.662/ 0.558
Sugar, honey, jam and syrup	-0.075	-0.900/ 0.751	-0.313	-1.164/ 0.538	0.773	-2.068/ 3.615	-1.096	-4.492/ 2.300	-0.335	-0.852/ 0.183	-0.285	-0.787/ 0.217
Confectionery non chocolate	-0.268	-0.881/ 0.345	-0.329	-0.844/ 0.185	-0.409	-2.567/ 1.749	-2.412	-4.376/ -0.449	-0.116	-0.500/ 0.269	0.193	-0.110/ 0.497
Chocolate	-1.510*	-2.536/	-0.930	-1.897/	-0.508	-4.973/	-4.349	-8.534/	0.328	-0.315/	0.781*	0.210/

		-0.483		0.037		3.957		-0.163		0.972		1.352
Vegetable oils	0.172	0.028/ 0.315	0.047	-0.122/ 0.216	0.218	-0.397/ 0.834	-0.320	-1.012/ 0.372	-0.063	-0.153/ 0.027	-0.064	-0.164/ 0.036
Margarine and lipids	0.279	-0.194/ 0.751	0.475	-0.035/ 0.985	-0.820	-2.828/ 1.188	-1.220	-3.05/ 0.609	-0.057	-0.354/ 0.239	0.023	-0.277/ 0.324
Butter and animal fats	-0.026	-0.410/ 0.359	0.176	-0.177/ 0.528	-1.775	-3.855/ 0.305	-1.282	-2.942/ 0.378	-0.010	-0.251/ 0.231	-0.151	-0.358/ 0.057
Sauces	0.003	-1.700/ 1.707	0.121	-1.687/ 1.929	-4.648	-11.022/ 1.727	-5.937	-11.397/ -0.477	-1.212	-2.280/ -0.143	-1.169	-2.235/ -0.102
Fruit and vegetable juices	-3.261*	-4.659/ -3.862	-2.327*	-3.965/ -1.688	14.313	-15.854/ 44.48	1.299	-22.584/ 25.182	8.746*	2.819/ 14.671	2.259	-3.440/ 7.958
Carbonated/soft/isotonic drinks	-5.300	-15.379/ 4.779	-7.453	-19.084/ 4.178	26.407	-21.402/ 74.216	-6.950	-40.778/ 26.878	-0.698	-7.022/ 5.625	2.960	-3.902/ 9.823
Milk, yogurt	-7.370	-20.224/ 5.484	-9.941	-21.969/ 2.087	-7.527	-46.945/ 31.891	-10.854	-43.262/ 21.553	-5.629	-13.691/ 2.433	-1.834	-8.932/ 5.265
Cheese	1.185	-1.974/ 4.344	1.999	-1.200/ 5.198	-4.372	-22.957/ 14.213	0.109	-17.342/ 17.559	-5.797*	-7.771/ -3.822	-5.131*	-7.012/ -3.250

	(T3) N=2971											
	Emotional problems score (SDQ)[b]				**Peer problems score (SDQ)**[b]							
	Age (10-17) years				**Age (2-9.9) years**				**Age (10-17) years**			
	Males		**Females**		**Males**		**Females**		**Males**		**Females**	
Food groups	**β**	**Lower /Upper**	**β**	**Lower /Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower/ Upper**	**β**	**Lower /Upper**
Bread and rolls	11.740	1.147/ 22.331	1.290*	0.657/ 2.921	0.166	-1.644/ 1.975	0.923	-0.848/ 2.693	1.312*	0.889/ 2.735	1.050*	0.402/ 2.698
Breakfast cereals	4.460	0.197/ 8.721	1.711	-0.812/ 4.233	-1.222*	-1.771/ -0.671	-1.128*	-1.958/ -0.296	2.727	0.127/ 5.327	3.171*	1.284/ 5.058
Pasta	2.685*	1.172/ 3.198	5.961	-2.883/ 14.804	-9.825*	-11.697/ -7.951	-5.406*	-11.287/ -7.525	1.841*	0.589/ 2.091	4.806	-1.840/ 11.451
Rice and other cereals	3.618	-7.802/ 15.038	1.104	-5.968/ 8.176	-2.045	-3.673/ -0.416	-0.980	-2.440/ 0.479	2.065	-4.901/ 9.031	0.371	-4.944/ 5.687
Sweet bakery product	3.558	-7.877/ 14.993	3.896	-4.880/ 12.671	0.207	-1.630/ 2.045	0.777	-0.987/ 42.541	3.457	-3.516/ 10.430	4.627	-1.965/ 11.218
Savoury snacks	0.936	-2.442/ 4.314	1.818	-1.229/ 4.864	0.027	-0.582/ 0.636	0.603	-0.035/ 1.241	1.170	-0.889/ 3.230	1.978	-0.310/ 4.265

Sugar, honey, jam and syrup	0.267	-2.545/ 3.079	2.369	-0.318/ 5.056	-0.577	-1.065/ -0.088	-0.594	-1.119/ -0.068	1.606	-0.106/ 3.317	2.400	0.382/ 4.416
Confectionery non chocolate	-0.275	-2.410/ 1.861	0.369	-1.191/ 1.930	-0.234	-0.597/ 0.129	-0.443*	-0.760/ -0.125	0.641	-0.660/ 1.943	1.431*	0.261/ 2.601
Chocolate	1.280	-3.137/ 5.698	2.750	-0.570/ 6.070	-1.237*	-1.844/ -0.629	-0.235	-0.832/ 0.362	1.410	-1.283/ 4.104	0.325	-2.174/ 2.824
Vegetable oils	0.496	-0.111/ 1.104	-0.147	-0.695/ 0.401	-0.159*	-0.243/ -0.073	-0.251*	-0.355/ -0.146	0.337	-0.033/ 0.708	-0.153	-0.565/ 0.259
Margarine and lipids	0.360	-1.628/ 2.347	1.836*	0.389/ 3.283	0.065	-0.214/ 0.345	-0.268	-0.583/ 0.046	0.631	-0.581/ 1.842	2.745*	1.669/ 3.821
Butter and animal fats	0.322	-1.739/ 2.384	0.649	-0.667/ 1.965	-0.229	-0.456/ 0.005	-0.015	-0.233/ 0.202	1.322	0.067/ 2.576	0.815	-0.173/ 1.803
Sauces	5.582	-0.722/ 11.886	5.208	0.883/ 9.532	-2.812*	-3.817/ -1.806	-2.026*	-3.140/ -0.911	5.371*	1.536/ 9.206	4.679*	1.432/ 7.925
Fruit and vegetable juices	0.074	-1.733/ 1.880	-0.649	-19.578/ 18.280	5.222	-0.374/ 10.819	1.516*	3.562/ 15.469	1.100	-2.087/ 3.287	1.113	-4.099/ 2.325
Carbonated/soft/isotonic drinks	1.524	-1.784/ 1.832	0.693*	0.064/ 1.321	-5.001*	-14.963/ 3.037	2.143	-5.035/ 9.320	0.440	0.633/ 1.246	1.737*	0.886/ 1.588
Milk, yogurt	0.672	-13.301/ 6.645	1.001*	0.488/ 2.512	-0.587	-8.199/ 7.025	-0.645	-8.069/ 6.779	1.669*	0.007/ 1.331	1.272*	0.284/ 1.259
Cheese	1.573	-1.786/ 3.932	1.006*	1.327/ 4.684	-1.109*	-1.922/ -0.294	-1.904*	-1.823/ -1.985	1.785*	0.639/ 2.930	3.900*	0.748/ 4.051

N= number of participants. β: regression coefficient. CI: confidence interval; Adjusting for confounders: paternal education, BMI and country as random effect. Level of significance was set to 0.05.

[a] KINDL: Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents, Range: 1-4, Interpretation: High value = high well-being

[b] SDQ: Strengths and Difficulties Questionnaire. Cut-off values for No detectable emotional problems ≤ 3 and, No detectable peer problems ≤ 2

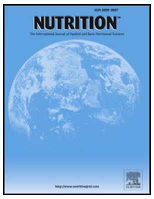
*: Represent the significant values accepted after Holm-Bonferroni adjustment method.

Nutrition 106 (2023) 111893

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com



Applied nutritional investigation

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

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

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

ARTICLE INFO

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

Keywords:
Food portion size
Dietary intake
Macronutrient
Micronutrient
Adolescent

ABSTRACT

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

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

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

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

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

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

Introduction

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

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

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

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

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

Methods

Study design

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

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

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

Study sample

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

Sociodemographic data

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

Dietary assessment

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

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

Dietary assessment of energy and macro- and micronutrients

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

Portion size calculation

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

Selection of foods and nutrients

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

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

Statistical analysis

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

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

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

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

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

Results

General characteristics of study participants and portion size characteristics

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

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

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

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

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

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

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

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

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

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

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

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

Association between food portion size and nutrient intake

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

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

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

Table 3

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

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

%TE, energy adjusted per total intake percentage; β, regression coefficient; CI, confidence interval.

Adjusted for confounders: Age, sex, maternal education, body mass index, and using country as level. Boldface values indicate significance accepted after Holm–Bonferroni adjustment method.

*Significant results.

Table 4

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

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

β, regression coefficient; CI, confidence interval.

Adjusted for confounders: Age, sex, maternal education, body mass index, and using country as level. Boldface values indicate significance accepted after Holm–Bonferroni adjustment method.

*Significant results.

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

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

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

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

Discussion

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

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

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

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

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

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

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

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

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

Conclusions

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

Acknowledgements

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

Supplementary materials

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

References

[1] Gale C, O'Callaghan F, Godfrey K, Law CM, Martyn CN. Critical periods of brain growth and cognitive function in children. Brain 2004;127:321–9.

[2] Lassi Z, Moin A, Bhutta Z. Nutrition in middle childhood and adolescence. In: Bundy DAP, de Silva N, Horton S, Jamison DT, Patton GC, editors. Child and adolescent health and development, 3rd ed., Washington (DC): The International Bank for Reconstruction and Development/The World Bank; 2017.

[3] World Health Organization. European food and nutrition action plan 2015−2020. Available at: https://www.euro.who.int/en/publications/abstracts/european-food-and-nutrition-action-plan-20152020−2014. Accessed June 2021.

[4] Kearney J. Food consumption trends and drivers. Philos Trans R Soc Lond B Biol Sci 2010;365:2793–807.

[5] Albar SA, Alwan NA, Evans CE, Cade JE. Is there an association between food portion size and BMI among British adolescents? Br J Nutr 2014;112:841–51.

[6] Flieh S, González Gil E, Miguel-Berges M, Moreno Aznar LA. Food portion sizes, obesity, and related metabolic complications in children and adolescents. Nutr Hosp 2021;38:169–76.

[7] Lyons J, Walton J, Flynn A. Food portion sizes and dietary quality in Irish children and adolescents. Public Health Nutr 2015;18:1444–52.

[8] Rippin H, Hutchinson J, Jewell J, Breda JJ, Cade JE. Child and adolescent nutrient intakes from current national dietary surveys of European populations. Nutr Res Rev 2019;32:38–69.

[9] Fernández Fernández E, Martínez Hernández J, Martínez Suárez V, Moreno Villares JM, Collado Yurrita LR, Hernández Cabria M, et al. Consensus document: Nutritional and metabolic importance of cow's milk. Nutr Hosp 2014;31:92–101.

[10] Holick M. Vitamin D deficiency. N Engl J Med 2007;357:266–81.

[11] Geleijnse J, Grobbee D, Hofman A. Sodium and potassium intake and blood pressure change in childhood. BMJ 1990;300:899–902.

[12] Novaković R, Cavelaars AEJM, Bekkering GE, Roman-Viñas B, Ngo J, Gurinović M, et al. Micronutrient intake and status in Central and Eastern Europe compared with other European countries, results from the EURRECA network. Public Health Nutr 2013;16:824–40.

[13] Rippin H, Hutchinson J, Evans C, Jewell J, Breda JJ, Cade JE. National nutrition surveys in Europe: A review on the current status in the 53 countries of the WHO European region. Food Nutr Res 2018;62:1362.

[14] Flieh S, Miguel-Berges M, González-Gil E, Gottrand F, Censi L, Widhalm K, et al. The association between portion sizes from high-energy dense foods and body composition in European adolescents: The HELENA study. Nutrients 2021;13:954.

[15] Moreno L, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L, et al. Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. Public Health Nutr 2008;11:288–99.

[16] de Henauw S, Gottrand F, Bourdeaudhuij ID, González-Gross M, Leclercq C, Kafatos A, et al. Nutritional status and lifestyles of adolescents from a public health perspective. The HELENA Project—Healthy Lifestyle in Europe by Nutrition in Adolescence. J Public Health 2007;15:187–97.

[17] Béghin L, Castera M, Manios Y, Gilbert CC, Kersting M, de Henauw S, et al. Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA cross-sectional study. Int J Obes (Lond) 2008;32:S12–8.

[18] Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 1991;45:569–81.

[19] United Nations Educational, Scientific and Cultural Organization. International standard classification of education. Available at: http://www.uis.unesco.org/Education/Documents/isced-2011-en.pdf. Accessed April 2, 2021.

[20] Vereecken CA, Covents M, Sichert-Hellert W, Alvira JMF, Le Donne C, De Henauw S, et al. Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. Int J Obes (Lond) 2008;32:S26–34.

[21] Julián-Almárcegui C, Bel-Serrat S, Kersting M, Vicente-Rodriguez G, Nicolas G, Vyncke K, et al. Comparison of different approaches to calculate nutrient intakes based upon 24-h recall data derived from a multicenter study in European adolescents. Eur J Nutr 2016;55:537–45.

[22] Haubrock J, Harttig U, Souverein O, Boeing H. An improved statistical tool for estimating usual intake distributions: The multiple source method (MSM). Arch Public Health 2010;68:S15–6.

[23] Harttig U, Haubrock J, Knüppel S, Consortium EFCOVAL. The MSM program: Web-based statistics package for estimating usual dietary intake using the Multiple Source Method. European J Clin Nutr 2011;65:S87–91.

[24] Lioret S, Volatier JL, Lafay L, Touvier M, Maire B. Is food portion size a risk factor of childhood overweight? Eur J Clin Nutr 2009;63:382–91.

[25] Pereira J, Mendes A, Crispim S, Marchioni DM, Fisberg RM. Association of overweight with food portion size among adults of São Paulo−Brazil. PloS One 2016;11:e0164127.

[26] Ireland J, van Erp-Baart A, Charrondière U, Møller A, Smithers G, Trichopoulou A, et al. Selection of a food classification system and a food composition database for future food consumption surveys. Eur J Clin Nutr 2002;56. S33−45.

[27] Diethelm K, Huybrechts I, Moreno L, De Henauw S, Manios Y, Beghin L, et al. Nutrient intake of European adolescents: Results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. Public Health Nutr 2014;17:486–97.

[28] Lyons J, Walton J, Flynn A. Larger food portion sizes are associated with both positive and negative markers of dietary quality in Irish adults. Nutrients 2018;10:1929.

[29] Joyce T, Wallace A, McCarthy S, Gibney MJ. Intakes of total fat, saturated, monounsaturated and polyunsaturated fatty acids in Irish children, teenagers and adults. Public Health Nutr 2009;12:156–65.

[30] Knowledge for Policy. References to food-based dietary guidelines in Europe. Available at: https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/references-food-based-dietary-guidelines-europe_en. Accessed May 22, 2021.

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

Table S1. Mean daily nutrient intakes by tertiles of food groups PS for adolescents aged 12.5–17.5 years (n = 1631).

a) Macronutrients (carbohydrate, protein, fat, total sugars, fibres)

Food Groups (g) **Mean value (whole group)**	**Carbohydrate (%TE)** **278.7**			**P-value**	**Protein (%TE)** **97.7**			**P-value**	**Fat (%TE)** **94.5**			**P-value**	**Total sugar (%TE)** **244.7**			**P-value**	**Fibre (g/10MJ)** **31.8**			**P-value**
	T1	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**	
Bread and rolls	440.7	438.7	423.5	0.025	77.9	77.5	77.4	0.944	31.5	32.6	39.7	0.056	71	79.2	73.5	0.573	30.9	38	36.3	**<0.001**
Breakfast cereals	462.2	465.3	442.3	0.013	65.1	65.6	66.1	0.961	27.3	25.6	35.7	0.009	183.9	123.8	146.8	0.678	58.5	52.9	54.1	0.684
Rice and other grains	415.8	463.7	455.7	**<0.001**	73.5	56.7	57.9	0.062	44.9	30.6	33.6	**0.003**	88.5	62.1	80.8	0.397	16.3	14.6	15.9	0.516
Starch roots, potatoes	380.4	394.7	398.4	0.181	71.7	61.4	55.9	**<0.001**	58.1	55.9	56.8	0.877	102.6	155.9	155.2	0.105	55.7	55.7	53.6	0.671
Pasta	408.5	424.2	405.4	0.103	91.9	86.3	90.7	0.007	40.3	35.8	42.4	0.203	109.5	114.9	98.8	0.831	29.3	28.7	28.6	0.850
Fruits	498.1	515.3	514.3	0.025	29.4	26.1	28.3	**<0.001**	14.7	13.1	11.8	**0.001**	543.3	527.6	507.6	0.755	77.2	79.2	75.9	0.287
Vegetables	284.7	307.5	303.2	0.006	128.4	125.0	125.9	0.702	73.9	64.9	66.9	0.020	32.7	57.1	31.0	0.432	111.8	125.9	128.6	**0.046**
Milk, yoghurt, and milk beverages	228.3	251.8	251.9	0.010	153.9	144.8	159.6	0.047	91.6	85.3	78.6	**0.003**	332.6	292.3	208.8	0.153	13.4	23.4	18.3	**<0.001**
Desserts and puddings milk based	179.3	252.6	268.1	**<0.001**	93.3	92.5	71.1	0.169	144.1	110.7	113.7	0.017	71.0	81.9	77.3	0.892	5.8	4.8	4.2	0.712
Cheese	115.9	82.6	82.0	0.045	158.8	159.9	156.3	0.710	142.1	155.9	158.1	**<0.001**	68.4	68.8	67.5	0.994	8.9	14.6	11.1	0.215
Meat and poultry	90.6	80.1	73.5	0.098	199.9	210.7	216.6	0.045	136.4	136.3	136.5	0.013	82.7	87.7	67.5	0.251	6.7	6.6	6.3	0.789
Fish	39.3	59.5	27.1	0.014	322.4	337.5	419.7	**<0.001**	104.3	87.9	64.9	**<0.001**	52.2	35.0	80.9	0.064	2.2	3.9	2.3	0.038
Eggs	108.7	115.9	31.9	**<0.001**	152.5	155.4	167.2	0.027	149.7	155.1	178.8	**<0.001**	39.8	74.9	94.9	0.057	5.7	6.4	1.0	**<0.001**

Meat substitutes, nuts, pulses	157.9	169.7	230.8	**0.001**	63.7	104.9	150.3	**<0.001**	163.3	142.2	94.5	**<0.001**	57.7	50.9	109.5	0.044	42.9	59.3	80.0	**<0.001**
Margarines and vegetable oils	66.8	61.1	104.9	0.008	31.7	19.7	34.1	**<0.001**	224.7	232.9	206.1	0.364	42.1	30.2	34.9	0.277	5.4	4.2	12.1	**<0.001**
Butter and animal fats	126.3	44.9	24.3	**<0.001**	43.3	16.8	7.1	**<0.001**	191.8	241.7	255.7	**0.001**	46.5	40.8	31.6	0.456	9.5	3.3	2.7	**0.001**
Cakes, pies, biscuits	379.6	307.3	307.1	0.086	33.8	46.9	48.6	**<0.001**	77.9	105.6	105.7	**0.002**	83.1	105.1	80.9	0.642	15.1	21.2	20.9	0.008
Savoury snacks	300.9	270.2	252.2	0.157	66.2	61.2	59.9	0.493	100.8	117.1	126.1	0.069	67.8	62.6	90.1	0.547	23.9	23.7	22.1	0.793
Sugar, honey, jams, chocolate	413.0	376.1	397.3	0.021	27.2	29.0	28.5	0.507	93.9	81.1	74.1	**<0.001**	61.8	78.0	72.7	0.180	19.4	17.7	16.3	0.365
Sauces and creams	195.7	197.2	176.5	0.097	69.5	74.2	84.1	**0.001**	138.1	141.0	147.9	0.264	345.7	263.7	225.1	0.373	23.7	22.6	24.3	0.765
Carbonated soft/isotonic drinks	432.4	435.3	464.9	**0.002**	85.5	72.5	67.7	0.032	11.5	10.2	9.1	0.694	756.4	312.3	306.2	0.154	91.4	60.7	52.7	0.156
Fruit and vegetables juices	435.5	410.6	476.9	**<0.001**	76.8	88.0	45.5	**<0.001**	26.9	32.6	20.5	**0.003**	558.7	577.1	728.9	**0.001**	44.2	34.2	31.3	0.180

b) Vitamins (A, D, E, C, and B12)

Food Groups (g)	**Vitamin A (mg/10MJ) 1.5**			**P-value**	**Vitamin D (µg/10MJ) 5.6**			**P-value**	**Vitamin E (mg/10MJ) 28.8**			**P-value**	**Vitamin C (mg/10MJ) 185.5**			**P-value**	**Vitamin B12 (mg/10MJ) 6.8**			**P-value**
Mean value (whole group)	**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**	
Bread and rolls	0.6	0.7	0.8	0.465	0.3	0.4	0.9	**<0.001**	8.4	10.7	11.5	0.009	2.0	5.4	4.9	0.383	1.1	1.2	1.3	0.401
Breakfast cereals	0.2	1.2	1.6	0.200	0.5	0.4	0.1	0.748	40.8	27.2	33.1	0.204	30.4	18.2	14.7	0.269	0.1	0.1	0.2	0.052
Rice and other grains	0.2	0.9	0.8	0.013	0.7	1.0	0.5	0.067	12.3	9.2	9.6	0.642	58.8	18.1	9.1	0.247	2.1	0.8	0.8	0.012

Starch roots, potatoes	0.2	0.1	0.4	0.133	0.6	0.9	0.9	0.034	20.8	19.6	22.1	0.021	34.5	33.2	32.9	0.243	1.9	1.0	0.4	**<0.001**
Pasta	2.7	1.9	3.4	0.014	0.7	0.8	0.9	0.296	5.5	6.1	6.4	0.642	4.8	3.2	8.9	0.048	2.4	1.4	3.3	0.009
Fruits	8.7	6.7	7.4	0.070	0.1	0.02	0.0	0.070	28.3	31.6	29.1	0.052	104	84	90	0.010	0.1	0.01	0.01	0.052
Vegetables	9.3	10.0	9.9	0.479	2.7	3.9	1.9	0.330	88.5	92.3	10.1	0.852	129.3	145.4	146.3	0.487	3.7	2.7	1.8	**0.001**
Milk, yoghurt, and milk beverages	7.1	8.6	7.8	0.558	10.6	12.9	14.9	0.130	15.8	16.2	13.1	0.009	119.7	203.5	154.9	0.172	20.4	19.7	22.8	0.192
Desserts and puddings milk based	5.1	2.8	2.9	0.009	5.4	7.1	8.0	0.088	23.9	11.6	11.3	**<0.001**	31.1	15.6	12.7	**<0.001**	12.6	11.9	7.6	0.286
Cheese	4.6	4.9	5.1	0.404	2.7	3.5	3.6	**<0.001**	13.3	15.5	15.4	0.017	25.8	55.5	44.3	0.203	10.9	11.3	11.4	0.565
Meat and poultry	1.5	2.1	2.4	**0.002**	0.6	0.7	0.6	0.292	10.9	14.3	15.2	**0.004**	38.1	41.1	43.7	0.536	13.4	15.7	14.5	0.010
Fish	1.5	1.8	1.6	0.680	0.8	0.9	1.1	0.376	98.9	46.7	41.7	**0.003**	24.6	32.7	35.9	0.536	45.2	42.5	48.3	0.758
Eggs	5.3	5.5	5.6	0.686	21.0	21.3	23.2	0.409	44.7	37.6	37.6	0.019	7.2	14.7	3.7	0.016	18.7	19.4	23.3	**<0.001**
Meat substitutes, nuts, pulses	3.3	5.1	2.8	0.052	0.3	0.9	0.2	0.010	63.3	59.3	38.9	0.017	27.5	51.1	39.1	0.064	1.1	1.1	0.8	0.032
Margarines and vegetable oils	7.5	3.4	4.1	0.112	4.8	4.0	4.5	0.144	51.2	54.9	50.9	0.284	11.1	7.1	27.1	**0.002**	2.4	1.3	1.4	**0.001**
Butter and animal fats	4.8	6.1	5.9	**<0.001**	4.9	5.9	5.5	0.068	19.1	25.1	22.7	0.009	28.1	10.6	2.2	**<0.001**	3.1	1.4	0.6	**0.002**
Cakes, pies, biscuits	4.3	5.5	3.0	0.484	2.1	3.4	2.2	0.034	23.3	24.1	21.3	0.432	22.2	31.6	18.2	0.387	0.6	1.1	1.4	**0.001**
Savoury snacks	1.9	2.1	1.8	0.786	1.7	1.1	1.4	0.477	34.8	40.6	42.7	0.218	67.1	62.6	83.7	0.447	2.8	2.6	2.7	0.954
Sugar, honey, jams, chocolate	0.4	0.7	0.4	0.164	0.2	0.6	0.5	**<0.001**	11.2	12.1	8.5	0.181	8.8	42.9	13.9	0.478	0.9	1.3	1.2	0.014
Sauces and creams	6.8	1.3	1.7	**<0.001**	1.2	1.8	2.0	**0.002**	59.0	43.6	49.5	**0.003**	13.9	13.7	15.9	0.641	4.8	4.7	5.7	0.145
Carbonated soft/isotonic drinks	2.3	3.8	2.1	0.147	0.1	0.1	0.1	0.552	11.8	15.5	9.7	0.307	10.5	23.7	13.9	0.189	0.9	0.8	0.6	0.749
Fruit and vegetables juices	1.1	7.9	6.9	0.049	0.0	0.0	0.0	0.235	39.6	32.8	25.7	**<0.001**	403.9	391.9	332.7	0.073	3.4	2.8	1.2	0.008

c) Minerals (Calcium, iron, sodium, potassium, and zinc)

Food Groups (g)	**Calcium (mg/10MJ) 875.1**			**P-value**	**Iron (mg/10MJ) 17.5**			**P-value**	**Sodium (mg/10MJ) 2765.4**			**P-value**	**Potassium (mg/10MJ) 3763.9**			**P-value**	**Zinc (mg/10MJ) 12.0**			**P-value**
Mean value (whole group)	**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**		**T1**	**T2**	**T3**	
Bread and rolls	309.7	310.9	334.8	0.431	13.6	15.5	14.9	<**0.001**	4182	4179	3934	**0.001**	1287	1566	1524	<**0.001**	10.6	12.3	12.3	<**0.001**
Breakfast cereals	587.1	463.9	525.4	0.603	19.1	20.6	21.4	0.316	3302	3083	2346	0.010	2864	2916	3069	0.935	10.3	10.6	12.0	0.148
Rice and other grains	271.3	242.5	259.2	0.582	12.8	12.5	12.6	0.935	1918	1399	1339	0.045	1656	1101	1056	**0.001**	11.2	9.4	9.2	0.009
Starch roots, potatoes	425.9	336.3	343.2	0.014	18.7	15.0	13.7	0.009	2912	2454	2502	0.029	9526	9122	9061	0.174	12.2	10.0	8.9	<**0.001**
Pasta	317.5	275.4	342.1	0.124	11.1	10.1	10.8	0.023	1429	949	1275	0.082	1167	1020	1151	0.013	12.2	11.1	12.1	0.125
Fruits	749.7	609.1	698.3	<**0.001**	18.9	18.3	17.5	0.119	92.3	96.1	92.5	0.278	8042	7511	7798	**0.001**	5.9	5.7	5.4	0.036
Vegetables	248.0	214.4	205.5	0.137	60.3	59.7	60.8	0.951	3958	3914	3943	0.993	14448	14328	13972	0.858	26.8	23.9	22.9	**0.001**
Milk, yoghurt, and milk beverages	3423	3040	7041	0.489	11.1	14.2	12.2	0.051	2355	1855	1777	<**0.001**	6089	6610	6958	0.142	16.9	16.4	16.7	0.416
Desserts and puddings milk based	1265	1327	1288	0.194	7.7	7.9	6.6	0.335	2042	1028	944	<**0.001**	2329	2547	2082	0.176	9.9	8.9	8.3	0.108
Cheese	4243	4513	4189	0.025	7.7	7.4	6.5	0.206	5548	6149	5306	0.024	1441	1425	1311	0.648	20.3	21.5	19.7	0.021
Meat and poultry	408.1	291.8	288.8	<**0.001**	14.6	16.9	17.9	**0.001**	6651	5445	3900	<**0.001**	2677	3043	3158	<**0.001**	21.2	23.3	21.8	0.036
Fish	702.8	655.6	796.8	0.015	21.3	18.9	19.8	0.679	6446	4832	3713	0.114	4789	5354	6620	<**0.001**	22.7	16.1	18.3	0.028
Eggs	831.3	779.4	820.8	0.572	17.8	20.5	23.8	<**0.001**	2152	2463	3132	<**0.001**	1439	1736	1750	<**0.001**	16.6	16.9	16.9	0.817
Meat substitutes, nuts, pulses	889.0	751.1	778.7	0.052	20.3	26.8	37.6	<**0.001**	7266	5371	1860	<**0.001**	2972	3867	5278	<**0.001**	10.7	14.5	19.2	<**0.001**
Margarines and vegetable oils	170.5	140.8	292.6	0.016	4.9	3.0	6.7	<**0.001**	1314	831	1338	<**0.001**	662	393	948	<**0.001**	4.6	2.4	4.5	0.042
Butter and animal fats	405.4	204.9	103.5	<**0.001**	5.8	2.1	1.2	<**0.001**	1532	928	470	<**0.001**	1152	461	233	<**0.001**	5.4	2.3	1.5	<**0.001**
Cakes, pies, biscuits	345.8	535.4	498.3	0.015	10.2	12.2	10.9	0.346	1424	1370	1219	0.787	1120	1390	1305	0.188	4.4	5.9	6.1	**0.002**

Savoury snacks	611.7	598.8	523.5	0.572	8.3	8.0	9.0	0.103	3375	3403	2866	0.248	2981	3172	3948	0.051	9.1	8.8	8.6	0.863
Sugar, honey, jams, chocolate	377.0	479.1	460.9	**0.001**	10.1	9.7	9.0	0.403	2059	1156	535	0.65	1680	1736	1625	0.628	6.3	5.9	6.1	0.672
Sauces and creams	699.1	761.2	914.6	**0.001**	14.5	18.5	20.8	0.034	8664	8296	6974	0.115	4658	5060	5454	0.190	10.0	11.9	13.3	**<0.001**
Carbonated soft/isotonic drinks	156.9	142.6	143.0	0.815	29.8	27.7	26.1	0.748	1225	1152	975	0.624	3201	2767	1846	0.050	9.0	8.3	8.3	0.891
Fruit and vegetables juices	995.1	946.9	851.1	0.223	43.1	35.1	34.1	0.043	772	570	533	0.044	1287	1566	1524	**<0.001**	10.6	12.3	12.3	**<0.001**

T1, T2 and T3 describe mean values of the dietary quality indicator being examined for each of PS tertiles; ANCOVA was used to calculated differences across tertiles with a Tukey post-hoc test for normal data or Kruskal–Wallis with a post hoc Mann–Whitney U Test for non-normal data; Significance accepted after applied Holm–Bonferroni adjustment method.

nutrients

MDPI

Article

The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study †

Sondos M. Flieh [1], María L. Miguel-Berges [1,2], Esther M. González-Gil [1,2,3,4,*], Frédéric Gottrand [5], Laura Censi [6], Kurt Widhalm [7,8], Yannis Manios [9,10], Anthony Kafatos [11], Dénes Molnár [12], Jean Dallongeville [13], Peter Stehle [14], Marcela Gonzalez-Gross [15,16], Ascensión Marcos [17], Stefaan De Henauw [18], Cristina Molina-Hidalgo [19], Inge Huybrechts [20,21] and Luis A. Moreno [1,2,3,15]

[1] Growth, Exercise, Nutrition and Development (GENUD) Research Group, Faculty of Health Sciences, University of Zaragoza, 50009 Zaragoza, Spain; sondosnserat991@gmail.com (S.M.F.); mlmiguel@unizar.es (M.L.M.-B.); lmoreno@unizar.es (L.A.M.)
[2] Instituto Agroalimentario de Aragón (IA2), 50013 Zaragoza, Spain
[3] Instituto de Investigación Sanitaria Aragón (IIS Aragón), 50009 Zaragoza, Spain
[4] Center of Biomedical Research (CIBM), Department of Biochemistry and Molecular Biology II, Instituto de Nutrición y Tecnología de los Alimentos, University of Granada, 18071 Granada, Spain
[5] CHU Lille, University Lille, INSERM U1286 Infinite, F-59000 Lille, France; Frederic.GOTTRAND@chru-lille.fr
[6] Council for Agricultural Research and Economics, Research Centre for Food and Nutrition, 00178 Roma, Italy; laura.censi@crea.gov.it
[7] Department of Gastroenterology and Hepatology, Medical University of Vienna, 1090 Vienna, Austria; kurt.widhalm@meduniwien.ac.at
[8] Austrian Academic Institute for Clinical Nutrition, A-3100 Vienna, Austria
[9] Department of Nutrition and Dietetics, School of Health Science and Education, Harokopio University, 17671 Athens, Greece; manios@hua.gr
[10] Institute of Agri-Food and Life Sciences, Hellenic Mediterranean University Research Centre, 71410 Heraklion, Greece
[11] Faculty of Medicine, University of Crete, GR-71003 Crete, Greece; kafatos@med.uoc.gr
[12] Department of Pediatrics, Medical School, University of Pécs, H-7624 Pécs, Hungary; molnar.denes@pte.hu
[13] Department of Epidemiology and Public Health, Institut Pasteur de Lille, 59000 Lille, France; Jean.Dallongeville@pasteur-lille.fr
[14] Department of Nutrition and Food Sciences, University of Bonn, D-53115 Bonn, Germany; pstehle@uni-bonn.de
[15] CIBER Fisiopatología de la Obesidad y Nutrición (CIBEROBN), Instituto de Salud Carlos III, 28029 Madrid, Spain; marcela.gonzalez.gross@upm.es
[16] ImFINE Research Group, Department of Health and Human Performance, Faculty of Physical Activity and Sport-INEF, Universidad Politécnica de Madrid, 28040 Madrid, Spain
[17] Inmunonutrition Research Group, Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), 28040 Madrid, Spain; amarcos@ictan.csic.es
[18] Department of Public Health and Primary Care, Faculty of Medicine and Health Sciences, Ghent University, 9000 Ghent, Belgium; Stefaan.DeHenauw@UGent.be
[19] EFFECTS 262 Department of Medical Physiology, School of Medicine, University of Granada, 18071 Granada, Spain; criismh@correo.ugr.es
[20] International Agency for Research on Cancer (IARC), 69372 Lyon, France; huybrechtsi@iarc.fr
[21] Department of Public Health, Ghent University, 9000 Ghent, Belgium
* Correspondence: esthergg@ugr.es
† HELENA Study group in Acknowledgments part.

check for updates

Citation: Flieh, S.M.; Miguel-Berges, M.L.; González-Gil, E.M.; Gottrand, F.; Censi, L.; Widhalm, K.; Manios, Y.; Kafatos, A.; Molnár, D.; Dallongeville, J.; et al. The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study . *Nutrients* **2021**, *13*, 954. https://doi.org/ 0.3390/nu13030954

Academic Editor: Tilman Kühn

Received: 5 February 2021
Accepted: 12 March 2021
Published: 16 March 2021

Abstract: Obesity prevalence has been simultaneously increasing with high consumption of large food portion sizes (PS). However, there is scarce information on PS of energy-dense (ED) foods as a potential risk factor of obesity in adolescents. In the present study, we investigate the association between the PS of the most ED foods and body composition. A sample of 1889 adolescents (54.4% females) from the Healthy Lifestyle in Europe by Nutrition in Adolescence cross-sectional multicenter study (HELENA–CSS) study were included. Most ED foods (e.g., cheese) were selected according to higher fat and/or sugar content and low fiber and water. Linear and ordinal logistic regression models were adjusted for age, physical activity, total energy intake (TEI), and socioeconomic status (SES). Analysis was performed both in those adolescents reporting plausible energy intake according to the approach of Goldberg et al. and in the whole sample. In male plausible reporters, PS from "breakfast cereals" showed a significant and positive association with BMI (β = 0.012; 0.048). PS from "carbonated soft drinks" in males (OR = 1.001; 95% CI 1.000; 1.002) and "bread and rolls" in females (OR = 1.002; 95% CI 1.000; 1.004) were associated with higher probability of having obesity, while "sweet bakery products" were associated with lower probability of having obesity (OR = 0.996; 95% CI 0.991; 0.999) in females. The present study suggests association between PS of ED foods and obesity in European adolescents. Prospective studies are needed to examine the effect of prolonged exposure to large PS and obesity development.

Keywords: energy dense food; food portion size; body mass index; fat mass index; obesity; adolescent; Europe

1. Introduction

According to WHO reports, overweight and obesity prevalence in children and adolescents aged between 5 and 19 years continuously rose from just 4% in 1975 to over 18% in 2016, corresponding with over 340 million affected persons worldwide [1]. Youth obesity is classified as chronic, noncommunicable disease that could lead to acute as well as long-lasting health problems at a younger age [2], cardiovascular diseases [3], insulin resistance [4] and type 2 diabetes [5] and, since obesity tracks from youth to adulthood, a greater risk of early morbidity and premature mortality [6,7]. Adolescence is a critical period in which dietary habits are in transition into adulthood. Several studies suggested that adolescents with obesity tend to eat more ED foods compared with normal-weight adolescents [8].

Overall, weight gain is the result from an imbalance between daily nutritive energy intake and energy expenditure as a sum of resting energy expenditure and physical exercise [9]. Apart from increasing sports activities, there are several components of the food environment supporting energy overnutrition [9], food portion sizes (PS) being probably one of the most relevant factors [10]. A portion is described as the amount of food that we choose to eat for a meal or snack or the amount of a food that we decide to eat or serve to an individual at a single eating occasion [11]. Previous studies found that the PS of some prepacked foods, as well as menu sizes consumed in restaurants, have increased dramatically over the last 30 years, concurred with the recent increase in obesity prevalence [12,13]. Specifically, increased PS of foods commonly served in restaurants and market is considered as a major component of the food environment that contributes to the excess of energy consumption and the development of obesity in all age groups [10,14]. Even though PS have been increasing over time, its association with weight would be predictable. In children and adolescents, several short-term controlled feeding trials found that serving PS and the amount of energy consumed per meal were associated significantly with a higher body mass index (BMI) percentile in school-aged males and adolescents of both genders but not in the youngest children (3 to 5 years) [15–17].

Energy density (ED) refers to the energy amount in each weight of food and/or beverage (kcal/g) [18] and mainly depends on the fat and water content of the food [19]. The World Cancer Research Fund has classified food containing 60–150 kcal/100 g as low-ED foods, characterized by high water and fiber content. Medium-ED foods contain 100–225 kcal/100 g, and high-ED foods contain more than 225–275 kcal/100 g [20]. This classification is one of the most commonly used by several studies [11,21] to group specific food items by its energy content.

Previous epidemiologic studies in European adults found only a limited relationship between PS from ED foods and with the actual BMI [22]. An intervention study focusing on the effect of large PS on body weight by a midday meal manipulation in adults noticed that the weight changes were not significant over time or between test periods [23]. On other hand, studies in young children found that PS and ED increased the energy intake at meals [24,25]. However, a cross-sectional study found that PS of milk, bread, cereal, juice, and peanut butter were associated with higher contribution to daily energy intake in children; moreover, they found that the PS z-scores were positively linked with both energy intake and body weight [26]. In the same vein, another study in children found that, when large portion of snack foods were consumed in the absence of hunger in females aged 5 and 7 years old, they had 4.6 times more probability of being overweight at both ages [27]. Finally, in British adolescents, PS of high ED foods from cream, high-fiber breakfast cereals, and soda were positively associated with a higher BMI [11].

Given the scarce previous literature, more information on the relationship between consumption of large food PS, specially of high-ED foods, and body composition are needed. Therefore, the aim of this study is to investigate the association between PS from most frequently consumed high-ED foods and obesity in a sample of European adolescents.

2. Materials and Methods

2.1. Study Design

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) cross-sectional multicenter study (CSS) took place in 2006–2007 and aimed to evaluate the nutritional status of adolescent in Europe. The age of adolescents was between 12.5 and 17.5 years and were recruited from ten European cities: Heraklion and Athens (Greece), Ghent (Belgium), Dortmund (Germany), Rome (Italy), Pécs (Hungary), Stockholm (Sweden), Lille (France), Vienna (Austria), and Zaragoza (Spain) [28]. The HELENA–CSS basic objective was to obtain comparable and reliable data from selected European adolescent groups (n = 3528, 52.3% girls) using widely relevant health and nutrition-related parameters, including mensuration for anthropometric, physical activity, dietary information, choice and preferences of food, metabolism of lipid and glucose, vitamin and mineral serum status, physical fitness, and genetic indicator [29]. The inclusion norms for the main study were participants who were not involve concurrently in other clinical experiments, aged greater than 12.5 years and not exceeding 17.5, and finally, have not suffered from any acute illness less than 1 week before the inclusion procedure [30]. More detailed information about sampling and recruitment procedure were described elsewhere [30].

The Research Ethics Committees in each participant city approved this study, followed by the ethical guidelines of the Declaration of Helsinki 1964: revision of Edinburgh 2000 [31]; moreover, a written consent form was obtained from all participating adolescents and their parents [31].

2.2. Study Sample

From the total sample of the HELENA–CSS, about 1889 adolescents (54.4% females) were included in our study. The inclusion benchmarks were participants who have full two measurements of the 24-h recall and complete data for weight and height and represented (53.5%) of from the whole sample. In total, 140 adolescents were excluded, as they were classified as underweight, because there were too few in this category to provide adequate power. In this study, nutritional intake data from 8 European countries were included; however, data from Pecs (Hungary) and Heraklion (Greece) were not included, because only one 24-hr recall was available. The approach of Goldberg et al. [32] was used to classify adolescents to under-reporters (ratio of energy intake to basal metabolic rate <0.96) and over-reporters (ratio of energy intake to basal metabolic rate >2.40). However, the reason of using this approach is that it is considered to be the most practical method and individualized method of assessing plausibility of self-reported energy intake [33]. Moreover, it has been found that taking into consideration the reporting group and inclusion of a propensity score for misreporting was a useful tool to counteract attenuation of effect estimates [34]. According to this method, about 24.8% of the adolescents were considered as under-reporters and were included in the present study [33]. In addition, adolescents who were considered as over-reporters, 173 (4.9%), were excluded. According to the Goldberg et al. method [32], participants classified as underweight were excluded from analyses, as there were too few in this category to provide comparable information. Finally, 128 participants were also excluded due to missing data on confounders, such as moderate-to-vigorous physical activity level (MVPA).

2.3. Anthropometric Measurements

All anthropometric mensuration were collected using standard methodology [35]. Telescopic height-measuring instrument (model 225; SECA, Hamburg, Germany) was used to measure height to the nearest 0.1 cm, barefoot with the head oriented in the Frankfurt plan. Body weight was measured in underwear and without shoes by electronic scale (model 871; SECA, Hamburg, Germany) to the nearest 0.1 kg. The BMI was calculated by dividing body weight in kilograms by squared body height in meters. International Obesity Task Force criteria was used to classify the obesity status [36]. Children were classified into the normal weight, overweight, and obesity categories, based on pooled international data for BMI, and linked to the widely used adult obesity cut off point of 25 and 30 kg/m^2 [36]. Additionally, skinfold thicknesses were measured in triplicate with a Holtain Caliper (Crymych, Wales, UK) from six body sites (triceps, subscapular, right side at biceps, suprailiac, thigh, and medial calf) to the nearest 0.2 mm, and the average of the three measures was used [37]. To obtain total body fat, the six skinfold thicknesses were summed. Body fat percentage was estimated from skinfold measurements, using the formula of Slaughter et al. [37]. The fat mass index (FMI) was calculated by dividing body fat mass in (kg) by the square of height in (m) [38]. Waist (WC) and hip (HC) circumference were also measured in triplicate to the nearest 0.1 cm with an anthropometric tape (SECA 200, Hamburg, Germany), and the average of the three measures was used. WC was measured at the midpoint between the lowest rib and the iliac crest [39] and considered a marker of abdominal fat. HC was measured at a level parallel to the floor, at the largest circumference of the buttocks.

2.4. Physical Activity Measurement

Accelerometers (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) were used to obtain an objective measurement of physical activity. The devices were placed on the lower back of the participants under the clothes using an elastic belt for seven sequent days. Instructions were given to participants when they wake up to wear the instrument and remove it for water-based activities and sleeping [40]. Data were downloaded to the computer using manufacturer software and analyzed later by software based on Visual Basic. Time spent in moderate and vigorous PA (MVPA) was determined using the cutoff point of 2000 cpm, to generate the various indices the number of days per week were multiplied by minutes per day to produce minutes per week for each activity [41]. More detailed information has been reported elsewhere [40].

2.5. Socioeconomic Status

A general questionnaire with socioeconomic status (SES), health outcomes, and nutritional status was fulfilled by the participants. Family affluence scale (FAS) was used as indicator of the adolescents' material affluence; a recategorization into three levels included low, from 0 to 2; medium, from 3 to 5; and high, from 6 to 8 categories. In this study, FAS is considered a marker of SES. More detailed description about SES has been reported elsewhere [42].

2.6. Dietary Assessment

In order to determine the adolescent's dietary intake, the HELENA Dietary Assessment Tool (HELENA–DIAT) was used. It is a self-administered computerized 24-h recall software, and it was developed and validated originally in Flemish adolescents and then in the HELENA–CSS [43]. HELENA–DIAT comprised the consumption from six meal occasions: breakfast, morning snack, lunch, afternoon snack, evening meal, and evening snack. It included two nonconsecutive 24 h recalls based on a weekday, with one week apart. A well-trained dietitian assessed the adolescents and helped them to complete the 24-h recall.

In total, about 800 photographs were available in the program. The participants could select visually from photographs the consumption amount and indicate the one more accurate with their actual intake. Furthermore, they could type in a textbox their intake amount from each food item. However, the participants can remove or modify the selected items at any time. In addition, for foods that could be sized by household measurements, like cups, several portions appeared on the screen, and the participants chose their consumption amount by clicking directly on the portion. In case the foods were eaten in combination with other food items, such as "French fries and mayonnaise" a box was shown on the screen to remind them to include this additional food item [44]. To calculate energy and nutrient intakes, data from HELENA–DIAT were linked to the German Food Code and Nutrient Database (Bundeslebensmittelschlüssel, version II.3.1) [45]. Taking into account occasionally consumed foods, the usual dietary intake of food and nutrients were estimated by multiple source method (MSM) [46]. The MSM first calculated the individual's dietary intake and then built the population distribution based on the data. When the MSM method was applied, the dietary data were analyzed for average energy intake in kilocalories, kilojoules, and macronutrients (carbohydrates, proteins, and fat) in grams.

2.7. Food Grouping and Portion Size Calculation

Based on European food groups classification system, about 4179 foods and beverages, in the form of recipes or as individual food, were aggregated into 29 food groups [43,47]. As part of the general HELENA analysis, and based on the nutritional composition of food groups, some of them were further reaggregated for PS analysis, according to their nutritional value; for example, milk products and cheese were split to different food groups, due to the difference in their fat content. However, four food groups were excluded from the analysis: "products for special nutrition use," "soya beverages," "miscellaneous," and "meat substitutes," due to very low consumption (more than the 85% of the sample did not report consumption).

PS was established by the total intake of items in grams included in food group and consumed in the 24 h-recall divided by the number of eating occasions of these consumed items. In this study, the average amount was calculated from the two days included in the 24 h-recall by each meal occasion. For example, if an individual consumed 200 g of meat for lunch in the first day and 200 g in the lunch of the second day, then his/her PS at lunch from this food item was 200 g, and if individual consumed 200 g of meat only in lunch and did not consume meat in the lunch of second day, his/her PS was 200 g. Various studies have adapted the same methodology, such as the study of food PS effect on overweight in children and adults [48,49]. Thus, these data represent per-consumer averages, not per capita averages and are aimed to show the average change on the PS for those who consume a certain item. Thus, only participants who consumed a specific food group were included in the analysis.

2.8. Energy Dense Food Selection Criteria

PS were estimated for the 20% most frequently consumed food groups per eating occasion, and then we selected the food items that had been identified as high-ED foods, according to World Cancer Research Fund (containing 225–275 kcal/100 g) [20], and identified in previous research as the foods with the greatest contribution to energy intake, with positive associations to BMI in Europe and the rest of countries [11,48]. Eleven food groups were selected in this analysis and include 1—"breakfast cereals"; 2—"bread and rolls"; 3—"sweet bakery products"; 4—"confectionary nonchocolate"; 5—"chocolate";

6—"sugar, honey, and jam"; 7—"cheese"; 8—"meat"; 9—"meat and poultry products"; 10—"vegetable oils"; and 11—"carbonated soft and isotonic drinks."

2.9. Statistical Analysis

Normality was tested using the Kolmogorov–Smirnov method. Descriptive analyses of mean intakes (g) and standard deviation (SD) for general characteristics, energy, and macronutrients intake were presented. Student's t- and chi-square (for categorial variables) tests were used to compare means of continuous variables by gender. Males and females develop different dietary patterns during the adolescent period, and males increase energy intake in order to increase satiety [50]. Another reason for splitting the analyses by gender is that changes in body composition are different, as males increase lean mass and females increase fat mass during their pubertal development. A stratified analysis was also carried out by splitting the sample into two groups, plausible reporters and under-reporters, to measure any potential differences of under-reporting on the associations under examination. In children, it was observed that consideration of the reporting group for misreporting turned out to be the most useful tool to counteract attenuation of effect estimates [34]. Student's t-tests were performed to describe food PS for plausible reporters and under-reporters, and adolescents were stratified by weight status and between gender. To assess the relation between BMI, fat mass index (FMI), and food PS from each ED food group, multivariable linear regression analysis was carried out, using BMI and FMI as the dependent variables and food PS as the independent variable in both genders. Ordinal logistic regression models were carried out to determine the association between BMI categories (normal weight vs. overweight and obesity, combined) as dependent variable and PS from ED food groups between gender. Finally, a sensitivity analysis was carried out for all samples in order to detect any potential differences in the results after adjustment for misreporting. All regression analyses were adjusted for age, total energy intake (TEI), physical activity, and SES, because it was considered as important predictors of the outcome. Analyses were carried out using IBM–SPSS (v25, SPSS Inc., Chicago, IL, USA), and Stata (v13.0, College Station, TX: StataCorp LP, USA) was used for the multilevel logistic regression. P-values of 0.05 were used as representing statistical significance for all tests.

3. Results

3.1. General Characteristics of Study Participants

Sample descriptive characteristics by gender are presented in Table 1. A total of 1889 adolescents aged between 12.5 and 17.5 years old were included in this study. The plausible reporters number was n = 1421, and the under-reporters' was n = 486. The majority (54.4%) of the participants were females. Generally, in all splitting groups, males had significantly higher waist circumference ($p < 0.001$), higher percentage of overweight (19.8%), and obesity (7.9%) ($p < 0.001$), and higher physical activity level ($p < 0.001$) than females. In contrast, females had significantly higher hip circumference ($p = 0.002$) and higher FMI, compared to males ($p < 0.001$). Furthermore, the results indicated that males had a significantly higher mean of TEI and higher mean intake from macronutrients (carbohydrate, protein, fat, and total sugar) than females ($p < 0.001$).

Table 1. Characteristics of all participants, plausible reporters, and under-reporters in study sample and mean daily intake of energy and macronutrient. Differences of mean values by gender were considered using Student's *t*-test analysis.

	All Participants (n = 1889)			**Plausible Reporters (n = 1421)**			**Under-Reporters (n = 468)**		
General Characteristics	**Males (n = 862)**	**Females (n = 1027)**	***p*-Value**	**Males (n = 659)**	**Females (n = 761)**	***p*-Value**	**Males (n = 202)**	**Females (n = 266)**	***p*-Value**
	M (SD)	**M (SD)**		**M (SD)**	**M (SD)**		**M (SD)**	**M (SD)**	
Age	14.8 (1.3)	14.7 (1.2)	0.181	14.7 (1.3)	14.7 (1.2)	0.408	14.8 (1.3)	14.8 (1.2)	0.199
Weight (kg)	63.6 (14.4)	57.2 (9.8)	**<0.001**	61.2 (12.9)	55.9 (9.1)	**<0.001**	71.2 (16.2)	60.8 (10.6)	**<0.001**
Height (cm)	170.2 (9.3)	162.3 (6.7)	**<0.001**	170.0 (9.3)	162.2 (6.9)	**<0.001**	170.8 (9.4)	162.8 (6.1)	**<0.001**
WC (cm)	75.1 (9.3)	71.1 (7.6)	**<0.001**	73.6 (8.4)	70.4 (7.0)	**0.001**	80.0 (10.4)	73.1 (8.8)	**0.004**
HC (cm)	91.3 (8.7)	93.7 (7.7)	**0.002**	89.9 (8.0)	92.8 (7.5)	**0.040**	95.9 (9.1)	96.2 (7.5)	**0.003**
BMI (kg/m^2)	21.8 (3.8)	21.7 (3.3)	**0.001**	21.0 (3.3)	21.2 (3.1)	0.068	24.2 (4.3)	22.9 (3.5)	**0.014**
BMI Categories (n, %)			**<0.001**			**<0.001**			**<0.001**
Normal weight	623 (72.3%)	814 (79.3%)		530 (80.4%)	642 (84.4%)		92 (45.6%)	172 (64.7%)	
Overweight	171 (19.8%)	172 (16.7%)		97 (14.7%)	96 (12.6%)		74 (36.6%)	76 (28.5%)	
Obese	68 (7.9%)	41 (4.0%)		32 (4.9%)	23 (3.0%)		36 (17.8%)	18 (6.8%)	
FMI (kg/m^2)	7.8 (6.4)	9.6 (4.2)	**<0.001**	6.9 (5.5)	9.1 (3.9)	**<0.001**	10.8 (8.1)	10.9 (4.5)	**<0.001**
MVPA (min/week)	804.50 (607.26)	642.75 (523.07)	**<0.001**	801.42 (599.30)	618.24 (518.46)	**<0.001**	816.97 (634.58)	712.90 (530.89)	**0.006**
SES categories (n, %)			0.207			0.051			0.221
Low	74 (8.6%)	119 (11.7%)		48 (7.3%)	92 (12.1%)		26 (13.0%)	27 (10.2%)	
Medium	487 (56.8%)	558 (54.5%)		382 (58.2%)	419 (55.2%)		105 (54.5%)	139 (52.6%)	
High	296 (34.6%)	346 (33.8%)		226 (34.5%)	248 (32.7%)		69 (34.5%)	98 (37.2%)	
Total energy intake (kcal)	2348.00 (653.05)	1848.01 (487.20)	**<0.001**	2691.33 (440.93)	2128.10 (301.58)	**<0.001**	1578.39 (312.04)	1267.16 (221.76)	**<0.001**
Carbohydrates (g)	285.58 (89.65)	228.13 (68.43)	**<0.001**	323.85 (71.23)	260.14 (52.36)	**<0.001**	195.25 (49.64)	158.86 (36.33)	**<0.001**
% of energy from carbohydrates	48.79 (7.62)	49.49 (7.47)	0.657	48.06 (6.35)	48.80 (6.15)	0.633	49.45 (7.85)	50.20 (7.68)	0.865
Proteins (g)	92.86 (28.20)	70.99 (20.13)	**<0.001**	103.13 (23.43)	79.78 (15.97)	**<0.001**	69.32 (18.48)	52.92 (13.07)	**<0.001**
% of energy from proteins	16.11 (3.50)	15.61 (3.12)	**0.004**	15.38 (2.79)	15.02 (2.43)	**0.004**	17.69 (3.72)	16.81 (3.41)	**0.616**
Fat (g)	91.79 (32.02)	73.04 (24.14)	**<0.001**	106.11 (24.92)	84.94 (18.16)	**<0.001**	59.23 (17.35)	48.47 (12.29)	**<0.001**
% of energy from fat	34.99 (6.46)	34.99 (6.46)	0.455	35.35 (5.15)	35.84 (5.03)	0.585	33.80 (7.27)	34.41 (6.22)	0.348
Total sugars (g)	136.52 (57.69)	111.24 (45.12)	**<0.001**	152.25 (55.33)	124.99 (43.54)	**<0.001**	93.95 (37.36)	79.59 (28.51)	**<0.001**
% of energy from total sugars	23.42 (7.64)	24.32 (7.87)	0.611	22.62 (7.06)	23.48 (7.28)	0.369	23.76 (7.97)	25.26 (8.04)	0.453

M: mean, SD: standard deviation, BMI: body mass index, WC: waist circumference, HC: hip circumference, MVPA: moderate-to-vigorous physical activity level, FMI: fat mass index, socioeconomic status (SES): socioeconomic status, Boldface values indicate significance, *p*-value < 0.05.

3.2. Portion Size Intake from Food Groups between BMI Categories in Both Genders

Table 2 shows the mean intake of food PS from ED food for plausible reporter and by BMI, normal weight or overweight/obesity in males and females. In males, the results indicate that plausible reporters with overweight/obesity had significantly higher portion mean intake from "cheese" and "carbonated soft drink," compared with normal weight, while females with overweight/obesity had a higher portion mean intake from "bread and rolls," and "confectionary nonchocolate," compared with normal-weight females; In contrast, normal-weight females had a higher portion mean intake from "sweet bakery product," compared with females with overweight or obesity. However, when misreporting was not considered in males, the results indicated that overweight/obesity participants had significantly higher portion mean intake from "cheese," "meat and poultry products," and "carbonated soft drink," compared with normal weight. In females, when misreporting was not considered, normal weight had higher portion mean intake from "bread and rolls" and "sweet bakery products," compared with overweight/obesity; meanwhile, females with overweight/obesity had significantly higher portion mean intake from "meat" and "confectionary nonchocolate," compared with normal weight, when misreporting was not considered. Regarding under-reporters (Supplementary Table S1), males with overweight/obesity had significantly higher portion mean intake from "chocolate," compared with normal weight males, while females with overweight/obesity had higher mean portion intake from "bread and rolls," compared with normal weight.

3.3. Association between BMI and Portion Size of the Most Energy-Dense Foods

A positive association was observed between PS and BMI for some ED foods (Table 3). Consumption of higher PS from "breakfast cereals" was significantly associated (β = 0.012; 0.048) with BMI for males who were plausible reporters. When dietary misreporting was not considered, PS from "carbonated soft drink" was positively related with BMI (β = 0.002; p = 0.012), while PS from "sweet bakery products" were inversely associated with BMI (β = −0.04; p = 0.028). In females who were reported as plausible reporters dietary intake, PS from "sweet bakery product" were inversely associated with BMI (β = −0.004; p = 0.014). However, when dietary misreporting was not considered, PS from "sweet bakery product" and "chocolate" were inversely associated with BMI (β = −0.005; p = 0.002), (β = −0.007; p = 0.035), respectively. In under-reporters (Supplementary Table S2), higher PS of "bread and rolls" (β = 0.006; $p \leq 0.001$), "chocolate" (β = 0.029; p = 0.028) and "sugar, honey, and jam" (β = 0.007; p = 0.012) were significantly associated with BMI in males. However, the results did not change when sensitivity analysis was carried out for all participants and with adjusting for misreporting.

3.4. Association between FMI and Portion Size of the Most Energy-Dense Foods

Table 4 shows the associations between FMI and PS of ED food groups by gender. In females who were plausible reporters and when misreporting was not considered, only PS from "sweet bakery product" ($p < 0.050$) were inversely related with FMI, while, in males and when misreporting was not considered, PS from "bread and rolls" (β = −0.006; p = 0.005) and "sweet bakery product" (β = −0.009; p = 0.002) showed an inversely significant relation to FMI. Regarding under-reporters (Supplementary Table S3), adolescent males showed a significant association between PS of "chocolate" and FMI (β = 0.061; p = 0.031). Meanwhile, in females, PS from "meat and poultry product" showed an inversely significant relation to FMI (β = −0.013; p = 0.023). When sensitivity analysis was carried out for all participants and with adjusting for misreporting, the results did not change.

Table 2. Mean portion size of energy-dense (ED) foods by BMI status in both genders, for consumers of different food categories, using *t*-test.

	Plausible Reporters (*n* = 1421)										**All Participants (*n* = 1889)**									
Body Mass Index Categories	**Males**				***p*-Value**	**Females**				***p*-Value**	**Males**				***p*-Value**	**Females**				***p*-Value**
	Normal Weight (*n* = 530)		**Overweight/Obesity (*n* = 129)**			**Normal Weight (*n* = 642)**		**Overweigh/Obesity (*n* = 119)**			**Normal Weight (*n* = 623)**		**Overweight/Obesity (*n* = 236)**			**Normal Weight (*n* = 814)**		**Overweight/Obesity (*n* = 213)**		
Food Groups (g)	**n**	**M (SD)**	**n**	**M (SD)**		**n**	**M (SD)**	**n**	**M (SD)**		**n**	**M (SD)**	**n**	**M (SD)**		**n**	**M (SD)**	**n**	**M (SD)**	
Breakfast cereals	151	53.99 (36.23)	24	54.42 (29.93)	0.680	175	42.81 (24.92)	20	38.30 (30.28)	0.275	167	51.93 (35.36)	40	61.63 (85.94)	0.066	198	42.11 (24.37)	41	37.71 (26.28)	0.442
Bread and rolls	487	170.18 (111.77)	114	176.80 (103.42)	0.709	611	142.45 (100.58)	111	162.07 (119.61)	**0.003**	562	162.48 (109.22)	209	150.69 (99.91)	0.435	756	132.59 (95.47)	195	131.99 (107.56)	**0.003**
Sweet bakery product	265	129.66 (101.86)	50	107.017 (80.82)	0.075	384	108.18 (91.15)	68	79.64 (58.45)	**0.022**	298	123.75 (98.42)	79	90.82 (72.35)	**0.006**	444	103.58 (87.94)	97	75.38 (57.15)	**0.005**
Confectionary nonchocolate	77	34.45 (42.66)	12	40.12 (54.70)	0.879	181	24.76 (27.29)	29	34.52 (55.37)	**0.001**	90	33.36 (41.19)	20	39.42 (51.27)	0.240	209	24.94 (26.68)	49	31.24 (45.99)	**0.033**
Chocolate	161	63.46 (75.91)	33	58.899 (71.18)	0.745	216	47.40 (51.21)	29	41.65 (48.99)	0.387	178	60.91 (73.02)	45	61.58 (67.68)	0.922	251	45.91 (49.62)	49	35.02 (41.58)	0.132
Sugar, honey, and jam	98	30.03 (23.67)	25	28.06 (19.70)	0.911	135	23.77 (24.22)	30	15.46 (12.80)	0.226	110	29.10 (22.98)	36	34.10 (32.07)	0.260	156	23.38 (23.32)	41	16.36 (13.39)	0.251
Cheese	208	49.10 (61.41)	41	53.22 (38.63)	**0.007**	217	36.06 (29.94)	38	35.73 (28.25)	0.990	230	48.27 (59.54)	72	75.72 (57.11)	**0.024**	265	34.14 (28.47)	60	31.80 (25.18)	0.761
Meat	289	168.05 (172.14)	46	185.94 (229.92)	0.280	289	120.30 (126.28)	44	142.53 (150.17)	0.178	323	169.07 (173.77)	102	169.07 (173.77)	0.850	363	112.46 (121.32)	83	130.22 (169.36)	**0.049**
Meat and poultry product	395	125.88 (123.40)	93	149.26 (125.03)	0.158	452	92.43 (85.89)	83	83.96 (71.46)	0.461	445	122.29 (121.60)	167	185.44 (153.84)	**0.017**	545	88.36 (83.06)	134	78.71 (71.81)	0.236
Vegetable oils	111	21.96 (18.04)	43	20.56 (18.14)	0.891	149	17.10 (12.86)	34	19.21 (17.71)	0.159	123	21.48 (17.78)	58	19.63 (16.97)	0.858	188	16.55 (13.22)	65	18.57 (15.13)	0.316
Carbonated soft and isotonic drink	229	442.40 (271.99)	49	525.41 (389.77)	**0.009**	250	392.24 (310.88)	27	400.51 (244.72)	0.570	253	452.19 (284.26)	82	557.73 (439.49)	**0.001**	284	384.25 (299.28)	50	419.51 (282.55)	0.912

n: number of consumers, M: mean, SD: standard deviation, Boldface values indicate significance, *p*-value < 0.05.

Table 3. The association between BMI and portion sizes (PS) of most ED food using multiple linear regression model.

Body Mass Index *	**Plausible Reporters (*n* = 1421)**								**All Participants (*n* = 1889)**							
	Males				**Females**				**Males**				**Females**			
Food Groups (g)	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**
		Upper	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**	
Breakfast cereals	0.012	0.000	0.023	**0.048**	−0.001	−0.016	0.014	0.892	0.006	−0.002	0.017	0.154	−0.003	−0.019	0.013	0.698
Bread and rolls	0.001	−0.001	0.004	0.223	0.002	0.000	0.004	0.069	0.000	−0.002	0.003	0.880	−0.001	−0.003	0.001	0.978
Sweet bakery product	−0.001	−0.004	0.002	0.548	−0.004	−0.008	−0.001	**0.014**	−0.004	−0.008	0.000	**0.028**	−0.005	−0.008	−0.002	**0.002**
Confectionary nonchocolate	0.004	−0.001	0.018	0.613	0.006	−0.006	0.017	0.318	0.001	−0.014	0.015	0.923	0.003	−0.009	0.015	0.597
Chocolate	−0.001	−0.007	0.005	0.819	−0.003	−0.009	0.003	0.291	0.003	−0.006	0.006	0.990	−0.007	−0.014	0.000	**0.035**
Sugar, honey, and jam	−0.001	−0.031	0.028	0.922	−0.013	−0.034	0.008	0.218	0.026	0.000	0.052	0.051	−0.014	−0.034	0.007	0.186
Cheese	0.004	−0.003	0.011	0.246	0.001	−0.011	0.013	0.905	0.001	−0.002	0.005	0.357	−0.004	−0.016	0.008	0.550
Meat	0.001	−0.001	0.003	0.300	0.001	−0.002	0.003	0.663	0.000	−0.002	0.002	0.874	0.000	−0.005	0.002	0.366
Meat and poultry product	0.001	−0.001	0.004	0.213	−0.001	−0.004	0.002	0.493	0.000	0.000	0.001	0.390	−0.001	−0.004	0.001	0.327
Vegetable oils	0.004	−0.031	0.039	0.812	−0.007	−0.044	0.030	0.692	−0.004	−0.038	0.030	0.825	−0.002	−0.034	0.030	0.914
Carbonated soft and isotonic drink	0.001	0.000	0.002	0.067	0.001	0.000	0.002	0.241	0.002	0.000	0.003	**0.012**	0.001	0.000	0.002	0.122

β: regression coefficient. CI: confidence interval, BMI: body mass index. * Adjusting for confounders: age, Moderate-to-vigorous physical activity (MVPA), and total energy intake (TEI) and SES. Boldface values indicate significance, *p*-value < 0.05.

Table 4. The association between FMI and portion size of most ED food between gender using multiple linear regression model.

Fat Mass Index *	**Plausible Reporters (n = 1421)**								**All Participants (n = 1889)**							
	Males				**Females**				**Males**				**Females**			
Food Groups (g)	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**
		Upper	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**	
Breakfast cereals	0.011	−0.080	0.029	0.246	−0.008	−0.026	0.009	0.345	0.006	−0.008	0.019	0.417	−0.014	−0.033	0.005	0.156
Bread and rolls	−0.003	−0.007	0.001	0.165	0.000	−0.002	0.003	0.817	−0.006	−0.010	−0.002	**0.005**	−0.002	−0.005	0.001	0.122
Sweet bakery product	−0.005	−0.011	0.000	0.064	−0.006	−0.010	−0.002	**0.005**	−0.009	−0.015	−0.003	**0.002**	−0.007	−0.011	−0.003	**0.001**
Confectionary nonchocolate	0.013	−0.010	0.036	0.281	0.009	−0.005	0.024	0.194	0.014	−0.010	0.038	0.240	0.008	−0.006	0.023	0.257
Chocolate	−0.004	−0.014	0.006	0.408	−0.002	−0.010	0.005	0.554	−0.002	−0.012	0.008	0.756	−0.004	−0.013	0.004	0.328
Sugar, honey, and jam	−0.007	−0.046	0.032	0.730	−0.020	−0.045	0.006	0.124	−0.013	−0.048	0.022	0.471	−0.018	−0.044	0.008	0.173
Cheese	0.001	−0.011	0.013	0.883	0.004	−0.012	0.021	0.605	0.003	−0.002	0.008	0.305	−0.001	−0.017	0.015	0.900
Meat	0.002	−0.001	0.005	0.144	0.002	−0.001	0.005	0.176	0.001	−0.002	0.004	0.518	0.002	−0.001	0.005	0.225
Meat and poultry product	−0.001	−0.005	0.003	0.695	0.000	−0.004	0.005	0.820	0.000	−0.001	0.001	0.587	−0.003	−0.007	0.001	0.196
Vegetable oils	0.007	−0.059	0.073	0.836	0.006	−0.041	0.053	0.815	−0.006	−0.069	0.057	0.847	0.019	−0.023	0.062	0.372
Carbonated soft and isotonic drink	0.001	−0.001	0.003	0.167	0.001	−0.001	0.002	0.296	0.001	−0.001	0.002	0.585	0.001	−0.001	0.002	0.427

β: regression coefficient. CI: confidence interval, FMI: fat mass index. * Adjusting for confounders: age, physical activity (MVPA), TEI, and SES. Boldface values indicate significance, p-value < 0.05.

3.5. Association between BMI Categories and Portion Size of the Most Energy-Dense Foods

Table 5 illustrates the results of ordinal logistic regression model by gender, using BMI categories (normal weight vs. overweight and obesity) as a dependent variable and PS of the most ED foods as independent variables. The model was adjusted for age, physical activity, TEI, and SES. Consumption of higher PS from "carbonated soft drinks" is associated with higher probability of having obesity in males who were plausible reporters (OR = 1.001; 95% CI 1.000; 1.002) and when misreporting was not considered (OR = 1.000; 95% CI 1.000; 1.001). Moreover, "sweet bakery products" is associated with lower probability of having obesity in males (OR = 0.996; 95% CI 0.993; 1.000) when misreporting was not considered. Consumption of higher PS from "bread and rolls" is associated with higher probability of having obesity in females who were plausible reporters (OR = 1.002; 95% CI 1.000; 1.004) and when misreporting was not considered (OR = 1.002; 95% CI 1.000; 1.003), while "sweet bakery products" is associated with lower probability of having obesity in females who were plausible reporters (OR = 0.996; 95% CI 0.991; 0.999) and when misreporting was not considered (OR = 0.996; 95% CI 0.992; 1.000). For under-reporting males (Supplementary Table S4), dietary intake of higher PS of "breakfast cereals" is associated with higher probability of having obesity (OR = 1.012; 95% CI 1.002; 1.024). However, the results did not change when sensitivity analysis was carried out for all participants and with adjusting for misreporting.

Table 5. Ordinal logistic regression model, the association between BMI categories and ED food portion groups between gender.

BMI Categories *	**Plausible Reporters (*n* = 1421)**								**All Participants (*n* = 1889)**							
	Males				**Females**				**Males**				**Females**			
Food Groups (g)	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**	**β**	**95% CI**		***p*-Value**
		Upper	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**			**Upper**	**Lower**	
Breakfast cereals	1.002	0.989	1.015	0.751	0.999	0.978	1.020	0.912	1.004	0.998	1.010	0.152	0.998	0.981	1.015	0.802
Bread and rolls	1.000	0.999	1.002	0.608	1.002	1.000	1.004	**0.012**	1.001	0.999	1.002	0.358	1.002	1.000	1.003	**0.047**
Sweet bakery product	0.997	0.994	1.000	0.150	0.996	0.991	0.999	**0.046**	0.996	0.993	1.000	**0.049**	0.996	0.992	1.000	**0.032**
Confectionary nonchocolate	1.004	0.992	1.017	0.506	1.008	0.999	1.018	0.123	1.006	0.995	1.016	0.305	1.006	0.997	1.015	0.174
Chocolate	0.999	0.993	1.004	0.666	0.999	0.990	1.008	0.854	1.000	0.996	1.006	0.782	0.997	0.989	1.006	0.488
Sugar, honey, and jam	0.993	0.972	1.014	0.514	0.975	0.941	1.010	0.161	1.009	0.995	1.023	0.233	0.981	0.955	1.008	0.165
Cheese	1.001	0.996	1.006	0.665	1.003	0.991	1.015	0.659	1.000	0.999	1.002	0.238	1.001	0.990	1.012	0.886
Meat	1.000	0.999	1.002	0.613	1.001	0.999	1.002	0.525	1.000	0.999	1.002	0.535	1.001	0.999	1.003	0.284
Meat and poultry product	1.001	0.999	1.003	0.102	0.999	0.996	1.002	0.531	1.000	0.999	1.000	0.292	0.999	0.996	1.002	0.440
Vegetable oils	0.995	0.974	1.016	0.651	1.006	0.982	1.031	0.636	0.995	0.975	1.015	0.603	1.012	0.993	1.032	0.221
Carbonated soft and isotonic drink	1.001	1.000	1.002	**0.032**	1.000	0.999	1.002	0.636	1.000	1.000	1.001	**0.035**	1.000	0.999	1.002	0.262

OR: odd ratio. CI: confident interval. * Adjusting for confounders: age, moderate-to-vigorous physical activity (MVPA), and TEI and SES. Boldface values indicate significance, *p*-value < 0.05.

4. Discussion

The main results suggested that there is an association between PS of specific ED foods and BMI in adolescence. Specifically, in plausible reporters, "carbonated soft drinks" in males and "bread and rolls" in females are associated with a high probability of having obesity. Meanwhile, PS from "sweet bakery products" were associated with lower probability of having obesity in females, considering potential confounders, like physical activity level, TEI, and SES. This study also provides useful descriptive information on PS from ED food groups between gender and BMI categories in European adolescents.

Our results indicate that plausible reporters males with overweight or obesity had significantly higher portion mean intake from "cheese" and "carbonated soft drink," compared with normal weight males. Plausible reporters' females with obesity had higher mean portion intake from "bread and rolls" and "confectionary nonchocolate," compared with normal weight females. Contrarily, a previous study based on adolescents showed that average PS of chocolate confectionery; cheese; and buns, cakes, and pastries were higher among normal weight than among adolescents with overweight or obesity [11]. Moreover, one study in adolescents noticed that energy intake from candy, packed goods, and ice cream was significantly greater in normal weight than in participants with obesity [51]. A study of adults from two national surveys found that mean PS of cakes, reported by French individuals with overweight/obesity, were 44% larger than normal-weight individuals; in contrast, adults with overweight/obesity reported smaller food PS from biscuit, crisps, and chocolate subgroups than normal-weight French adults [22]. However, food PS of biscuits reported by UK adults with overweight/obesity were 30% larger than those reported by normal-weight ones [22]. The possible reason of these results is that lean active subjects tend to select high energy and sugar diets, while subjects with overweight seem to prefer diets high in fat and restrict dietary sugars [52,53].

In this study, we adjusted for SES in all analyses. It is noteworthy that SES is considered as one of the strongest predictors of obesity development in all age groups and of living in a deprived area with oversized portions of unhealthy food [54]. In this context, a study in children reported larger food PS consumption of meat when the annual household income was higher [55]. Moreover, in adults, there has been found a small reliable relation between lower SES and consumption of large portions of unhealthy foods [54]. However, in our study, the observed associations were independent of SES, suggesting a strong association between PS from ED and BMI. It is also noteworthy that lower SES families are less likely to realize that their child is overweight and may believe that they should not impede the eating and activity behaviors of their child [56].

In this study, a positive association was observed between PS and BMI for some ED foods, and there were differences between plausible reporters and under-reporters. In another cross-sectional study in children, it was showed that overweight was positively correlated with the PS of sweetened pastries and biscuits [48]. Similarly, a positive correlation was found for PS of cakes, biscuits, and cheese and BMI in plausible reporter adolescents but not in the under-reporters. Meanwhile, the PS of high-fiber breakfast cereals was positively associated with BMI in under-reporters and among all adolescents [11]. The possible explanation of the positive association between breakfast cereals and BMI may be that some types of breakfast cereals contain nuts, sugars, honey, and fruit, which make the food more ED. In addition, we found that large PS from "bread and rolls," "chocolate," and "sugar, honey, and jam" groups were associated with higher BMI in under-reporter males. However, it was noticed that under-reporter children and adolescents were more likely to have overweight or obesity than normal reporters [57]. In addition, subjects with obesity tend to underreport their consumption to provide sociable desirable answers, even in adolescence [58]. It is noteworthy that several studies in children and adolescents found that one of the main reasons of dietary assessment errors was misreporting, mainly because of underreporting [59,60], which happens frequently in adolescents [61,62]. In this age, under-reporters generally provide lower intakes of ED foods and snacks than plausible reporters, because they tend to give socio-desirable answers [63], easily forget what they consumed, or/and they tend to have lower ability to report their own dietary intake [64]. In addition, adolescents tend to omit their food consumption by following a dietary restriction as a step to reduce their weight [64]. Moreover, it has been noticed that the exclusion of under-reporters or introducing them as covariates can strongly enhance the associations between dietary factors, including ED food and obesity [34].

In this study, we found that in females who were under-reporters on large PS from "meat and poultry product" showed an inverse significant relation with FMI. In a Korean study in children and adolescents, it was found that a high level of meat consumption was associated with lower BMI [65]. Contrarily, the possible explanation of an inverse relation between PS of "sweet bakery products" and BMI and FMI in plausible reporters females and "meat and poultry product" with BMI in under-reporter females is that adolescents with obesity tend to restrict their intake from sugars and fat foods as a primary step to reduce weight [66]. A hallmark of PS from these food groups is that they belong to the category of "convenience foods" or fast-food chains, which are sometimes packaged for single-serving consumption, and whose PS have been reported to be increasing, such as chocolate, bread, soda, and burgers [67]. In addition, researchers have noticed inverse or no associations with overweight and obesity, when the data were analyzed without adjustment for the ratio of (energy intake: estimated energy requirement), in both children and adolescents [68]. However, more studies are needed to give insights about our finding.

Regarding PS from "carbonated soft drinks," we found in our study that large PS from this food group is associated with higher probability of having obesity in males. Clearly, in the last decades, PS of some foods, especially those consumed in restaurants, such as burgers and soda, have increased dramatically and concurrently with obesity prevalence [69]. Varied scientific reviews have confirmed the hypothesis that increased weight is linked with increased intake from carbonated soft drink in cross-sectional studies [70–72]. Moreover, it has been suggested from observational analysis that the odds of becoming obese over 5 years increased to 60% with each additional 12 ounces (340.19 g) of soda consumed per day by children [73], which means that the main contributor to the obesity epidemic is the elevating consumption of sweetened drinks [74]. The possible explanation of these results is that liquid carbohydrates, such as soda or solid jelly, cause less satiety, compared with solid carbohydrates sources; thus, increased consumption of energy-yielding fluids may enhance the positive energy balance [75,76]. However, in children, the trial studies that aim to reduce the effect of sugar-sweetened beverage intake on obesity are inconsistent; this may be due to failure to control confounders and some methodological limitations [77,78]. Although the effect sizes in our study are small, further studies are needed to confirm the association between food PS from ED food and obesity development.

In our study, a sensitivity analysis was carried out in order to detect any potential differences in the results after adjusting for misreporting, and the results did not change.

This study has some limitations. Firstly, although studies performed some years ago are not useful to describe the current situation, they are useful for assessing the associations between different types of variables. The information from holidays or from Fridays and Saturdays were not included, as the 24-h recalls were completed during school days. Secondly, the cross-sectional nature of HELENA study does not allow us to assess the behavior over a period of time and did not provide information in determining the cause-and-effect association. The self-reported questionnaires were used for collecting the food consumption data, and therefore, a social bias must be considered. However, a good agreement between the self-reports and the interviews was found [43]. Moreover, a high percentage of under- and over-reporters were detected. Additionally, the ED was not calculated from the food groups, so the main selected criteria for analysis were based on those foods identified in other studies as high sources of energy. However, there are several strengths in this study that need to be mentioned. To our best of knowledge, the present study is the first to investigate the association between the portion size of ED foods and body composition among European adolescents. Although residual confounding should be considered when interpreting the results, potential confounders such as age, total EI, physical activity, and SES were taken into account. Moreover, sample size had been selected from a wide geographical spread, including eight European cities, with large cultural dietary diversity. In order to increase the accuracy, highly standardized and validated procedures were used to collect the sample and assess anthropometric measurements.

5. Conclusions

In conclusion, large PS of "sweet bakery products" were found to be associated with a lower body composition among plausible females reporters, while increase PS from "breakfast cereals" groups were correlated with higher BMI in males. This was significant after adjustment for age, physical activity, TEI, and SES. Moreover, in subjects who were considered as plausible reporters, the results showed that large PS from "carbonated soft and isotonic drinks" in males and "bread and rolls" in females were associated with higher probability of having obesity, while large PS of "sweet bakery products" is associated with lower probability of having obesity in females. Further studies are needed to examine the prolonged exposure to large PS from several ED food sources and their effect on obesity development. If results are confirmed, this should be followed by nutritional health promotion programs directed to European adolescents to enhance their PS food selection.

Supplementary Materials: The following are available online at https://www.mdpi.com/2072-6643/13/3/954/s1, Table S1: Mean intake of food PS from ED food for plausible reporter and by BMI, normal weight or overweight/obesity in males and females. Table S2: The association between BMI and PS of most ED food in under-reporters, using multiple linear regression model. Table S3: The association between FMI and portion size of most ED food between gender in under-reporters, using multiple linear regression model. Table S4: Ordinal logistic regression model, the association between BMI categories and ED food portion groups in under-reporters and between gender.

Author Contributions: The HELENA study was designed and contributed to get the funding by L.A.M., M.G.-G., S.D.H., A.M., D.M., P.S., F.G., K.W., L.C., A.K., J.D., E.M.G.-G. and C.M.-H. The supervision procedure and acquisition of data were done by L.A.M., M.G.-G. and S.D.H. Field work contribution and data analysis were conducted by Y.M., I.H. and the rest of authors. D.M. was responsible for the body composition work package. S.M.F. analyzed the data and wrote the manuscript. E.M.G.-G., M.L.M.-B. and L.A.M. critically revised the manuscript, provided essential comments, and supervised all procedures. P.S., F.G., J.D., Y.M., L.C., Y.M., A.K., I.H. and the rest of the coauthors revised the manuscript and provided their essential comments. All authors have read and agreed to the published version of the manuscript.

Funding: HELENA study received funding from the European Community Sixth RTD Framework Program (Contract FOODCT-2005-007034). E.M.G.-G. holds a Juan de la Cierva-Formación grant from the Spanish Government (FJCI-2017-34967).

Institutional Review Board Statement: The ethics committees in all countries approved the HELENA study. All countries involved in the study provided good clinical practices and ethical guidelines of the Declaration of Helsinki 1964 (revision of 2000) and the legislation about clinical research in humans. The ethical approval code from the coordinator center was 03/2006; date of approval: February 2006, obtained from the Ethical Committee of clinical research in Aragon (CEICA).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available for further scientific analysis on request from the coordinator of the HELENA study to the following e-mail: lmoreno@unizar.es.

Acknowledgments: We are grateful for the support provided by school boards, headmasters, teachers, school staff, and communities and the effort of all study nurses and our data managers.

HELENA Study Group: Coordinator: Luis A. Moreno.Core Group members: Luis A. Moreno, Fréderic Gottrand, Stefaan De Henauw, Marcela González-Gross, Chantal Gilbert.Steering Committee: Anthony Kafatos (President), Luis A. Moreno, Christian Libersa, Stefaan De Henauw, Sara Castelló, Fréderic Gottrand, Mathilde Kersting, Michael Sjöstrom, Dénes Molnár, Marcela González-Gross, Jean Dallongeville, Chantal Gilbert, Gunnar Hall, Lea Maes, Luca Scalfi.Project Manager: Pilar Meléndez.

1. Universidad de Zaragoza (Spain): Luis A. Moreno, José A. Casajús, Jesús Fleta, Gerardo Rodríguez, Concepción Tomás, María I. Mesana, Germán Vicente-Rodríguez, Adoración Villarroya, Carlos M. Gil, Ignacio Ara, Juan Fernández Alvira, Gloria Bueno, Olga Bueno, Juan F. León, Jesús Mª Garagorri, Idoia Labayen, Iris Iglesia, Silvia Bel, Luis A. Gracia Marco, Theodora Mouratidou, Alba Santaliestra-Pasías, Iris Iglesia, Esther González-Gil, Pilar De Miguel-Etayo, Mary Miguel-Berges, Isabel Iguacel, Azahara Rupérez.
2. Consejo Superior de Investigaciones Científicas (Spain): Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez, Ligia Esperanza Díaz, Javier Romeo, Ana Veses, Belén Zapatera, Tamara Pozo, David Martínez.
3. Université de Lille 2 (France): Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, Juliana Von Berlepsch.
4. Research Institute of Child Nutrition Dortmund, Rheinische Friedrich–Wilhelms–Universität Bonn (Germany): Mathilde Kersting, Wolfgang Sichert-Hellert, Ellen Koeppen.
5. Pécsi Tudományegyetem (University of Pécs) (Hungary): Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs. Angster, Enikö Nagy, Orsolya Kovács, Judit Répasi.
6. University of Crete School of Medicine (Greece): Anthony Kafatos, Caroline Codrington, María Plada, Angeliki Papadaki, Katerina Sarri, Anna Viskadourou, Christos Hatzis, Michael Kiriakakis, George Tsibinos, Constantine Vardavas, Manolis Sbokos, Eva Protoyeraki, Maria Fasoulaki.
7. Institut für Ernährungs- und Lebensmittelwissenschaften–Ernährungphysiologie. Rheinische Friedrich Wilhelms Universität (Germany): Peter Stehle, Klaus Pietrzik, Marcela González-Gross, Christina Breidenassel, Andre Spinneker, Jasmin Al-Tahan, Miriam Segoviano, Anke Berchtold, Christine Bierschbach, Erika Blatzheim, Adelheid Schuch, Petra Pickert.
8. University of Granada (Spain): Manuel J. Castillo, Ángel Gutiérrez, Francisco B Ortega, Jonatan R Ruiz, Enrique G Artero, Vanesa España, David Jiménez-Pavón, Palma Chillón, Cristóbal Sánchez-Muñoz, Magdalena Cuenca.
9. Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione (Italy): Davide Arcella, Elena Azzini, Emma Barrison, Noemi Bevilacqua, Pasquale Buonocore, Giovina Catasta, Laura Censi, Donatella Ciarapica, Paola D'Acapito, Marika Ferrari, Myriam Galfo, Cinzia Le Donne, Catherine Leclercq, Giuseppe Maiani, Beatrice Mauro, Lorenza Mistura, Antonella Pasquali, Raffaela Piccinelli, Angela Polito, Romana Roccaldo, Raffaella Spada, Stefania Sette, Maria Zaccaria.
10. University of Napoli "Federico II" Dept of Food Science (Italy): Luca Scalfi, Paola Vitaglione, Concetta Montagnese.
11. Ghent University (Belgium): Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere, Inge Huybrechts.
12. Medical University of Vienna (Austria): Kurt Widhalm, Katharina Phillipp, Sabine Dietrich, Birgit Kubelka, Marion Boriss-Riedl.
13. Harokopio University (Greece): Yannis Manios, Eva Grammatikaki, Zoi Bouloubasi, Tina Louisa Cook, Sofia Eleutheriou, Orsalia Consta, George Moschonis, Ioanna Katsaroli, George Kraniou, Stalo Papoutsou, Despoina Keke, Ioanna Petraki, Elena Bellou, Sofia Tanagra, Kostalenia Kallianoti, Dionysia Argyropoulou, Stamatoula Tsikrika, Christos Karaiskos.
14. Institut Pasteur de Lille (France): Jean Dallongeville, Aline Meirhaeghe.
15. Karolinska Institutet (Sweden): Michael Sjöstrom, Jonatan R Ruiz, Francisco B. Ortega, María Hagströmer, Anita Hurtig Wennlöf, Lena Hallström, Emma Patterson, Lydia Kwak, Julia Wärnberg, Nico Rizzo.
16. Asociación de Investigación de la Industria Agroalimentaria (Spain): Jackie Sánchez-Molero, Sara Castelló, Elena Picó, Maite Navarro, Blanca Viadel, José Enrique Carreres, Gema Merino, Rosa Sanjuán, María Lorente, María José Sánchez.
17. Campden BRI (United Kingdom): Chantal Gilbert, Sarah Thomas, Elaine Allchurch, Peter Burgess.

18. SIK—Institutet foer Livsmedel och Bioteknik (Sweden): Gunnar Hall, Annika Astrom, Anna Sverkén, Agneta Broberg.
19. Meurice Recherche & Development asbl (Belgium): Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, Laurence Fontaine.
20. Campden & Chorleywood Food Development Institute (Hungary): Andras Sebok, Tunde Kuti, Adrienn Hegyi.
21. Productos Aditivos SA (Spain): Cristina Maldonado, Ana Llorente.
22. Cárnicas Serrano SL (Spain): Emilio García.
23. Cederroth International AB (Sweden): Holger von Fircks, Marianne Lilja Hallberg, Maria Messerer.
24. Lantmännen Food R&D (Sweden): Mats Larsson, Helena Fredriksson, Viola Adamsson, Ingmar Börjesson.
25. European Food Information Council (Belgium): Laura Fernández, Laura Smillie, Josephine Wills.
26. Universidad Politécnica de Madrid (Spain): Marcela González-Gross, Raquel Pedrero-Chamizo, Agustín Meléndez, Jara Valtueña, David Jiménez-Pavón, Ulrike Albers, Pedro J. Benito, Juan José Gómez Lorente, David Cañada, Alejandro Urzanqui, Rosa María Torres, Paloma Navarro.

Conflicts of Interest: The authors declare no conflict of interest.

IARC Disclaimer: Where authors are identified as personnel of the International Agency for Research on Cancer/World Health Organization, the authors alone are responsible for the views expressed in this article and they do not necessarily represent the decisions, policy or views of the International Agency for Research on Cancer/World Health Organization.

References

1. World Health Organization (2014). *European Food and Nutrition Action Plan 2015–2020*; WHO: Geneva, Switzerland, 2018; Available online: https://www.euro.who.int/en/publications/abstracts/european-food-and-nutrition-action-plan-20152020-2014 (accessed on 1 April 2020).
2. Sahoo, K.; Sahoo, B.; Choudhury, A.; Sofi, N.; Kumar, R.; Bhadoria, A. Childhood obesity: Causes and consequences. *J. Fam. Med. Prim. Care* **2015**, *4*. [CrossRef]
3. Rumińska, M.; Majcher, A.; Pyrzak, B.; Czerwonogrodzka-Senczyna, A.; Brzewski, M.; Demkow, U. Cardiovascular Risk Factors in Obese Children and Adolescents. *Adv. Exp. Med. Biol.* **2016**, *878*. [CrossRef]
4. Sese, M.; Moreno, L.; Censi, L.; Bresidenassel, C.; González-Gross, M.; Sjöström, M.; Manios, Y.; Dénes, M.; Dallongeville, J.; Widhalm, K.; et al. Association of body composition indices with insulin resistance in European adolescents: The HELENA study. *Nutr. Hosp.* **2016**, *33*. [CrossRef]
5. Pulgaron, E.; Delamater, A. Obesity and type 2 diabetes in children: Epidemiology and treatment. *Curr. Diabetes Rep.* **2014**, *14*, 508. [CrossRef] [PubMed]
6. Adami, F.; Vasconcelos, F.A. Childhood and adolescent obesity and adult mortality: A systematic review of cohort studies. *Cad. Saude Publica* **2008**, *24* (Suppl. 4). [CrossRef]
7. Evensen, E.; Wilsgaard, T.; Furberg, A.; Skeie, G. Tracking of overweight and obesity from early childhood to adolescence in a population-based cohort—The Tromsø Study, Fit Futures. *BMC Pediatr.* **2016**, *16*, 64. [CrossRef]
8. Moreno, L.; Rodríguez, G. Dietary Risk Factors for Development of Childhood Obesity. *Curr. Opin. Clin. Nutr. Metab. Care* **2007**, *10*. [CrossRef]
9. Agostoni, C.; Braegger, C.; Decsi, T.; Kolacek, S.; Koletzko, B.; Mihatsch, W.; Moreno, L.; Puntis, J.; Shamir, R.; Szajewska, H.; et al. Role of dietary factors and food habits in the development of childhood obesity: A commentary by the ESPGHAN Committee on Nutrition. *J. Pediatr. Gastroenterol. Nutr.* **2011**, *52*. [CrossRef]
10. Flieh, S.; González Gil, E.; Miguel-Berges, M.; Moreno, A.L.A. Food portion sizes, obesity, and related metabolic complications in children and adolescents. *Nutr. Hosp.* **2020**. [CrossRef]
11. Albar, S.A.; Alwan, N.A.; Evans, C.E.; Cade, J.E. Is there an association between food portion size and BMI among British adolescents? *Br. J. Nutr.* **2014**, *112*, 841–851. [CrossRef]
12. O'Brien, S.A.; Livingstone, M.B.; McNulty, B.A.; Lyons, J.; Walton, J.; Flynn, A.; Segurado, R.; Dean, M.; Spence, M.; McCaffrey, T.A.; et al. Secular trends in reported portion size of food and beverages consumed by Irish adults. *Br. J. Nutr.* **2015**, *113*, 1148–1157. [CrossRef] [PubMed]
13. Ledikwe, J.H.; Ello-Martin, J.A.; Rolls, B.J. Portion sizes and the obesity epidemic. *J. Nutr.* **2005**, *135*, 905–909. [CrossRef]
14. Prentice, A.M.; Jebb, S.A. Fast foods, energy density and obesity: A possible mechanistic link. *Obes. Rev.* **2003**, *4*, 187–194. [CrossRef]
15. Huang, T.T.; Howarth, N.C.; Lin, B.H.; Roberts, S.B.; McCrory, M.A. Energy intake and meal portions: Associations with BMI percentile in U.S. children. *Obes. Res.* **2004**, *12*, 1875–1885. [CrossRef]

16. Rolls, B.J.; Engell, D.; Birch, L.L. Serving portion size influences 5-year-old but not 3-year-old children's food intakes. *J. Am. Diet. Assoc.* **2000**, *100*, 232–234. [CrossRef]
17. Torbahn, G.; Gellhaus, I.; Koch, B.; von Kries, R.; Obermeier, V.; Holl, R.; Fink, K.; van Egmond-Fröhlich, A. Reduction of Portion Size and Eating Rate Is Associated with BMI-SDS Reduction in Overweight and Obese Children and Adolescents: Results on Eating and Nutrition Behaviour from the Observational KgAS Study. *Obes. Facts* **2017**, *10*. [CrossRef] [PubMed]
18. Westerterp-Plantenga, M. Analysis of energy density of food in relation to energy intake regulation in human subjects. *Br. J. Nutr.* **2001**, *85*. [CrossRef]
19. Rolls, B.; Roe, L.; Beach, A.; Kris-Etherton, P. Provision of Foods Differing in Energy Density Affects Long-Term Weight Loss. *Obes. Res.* **2005**, *13*. [CrossRef] [PubMed]
20. World Cancer Research Fund (WCRFUK). Energy Density: Finding the Balance for Cancer Prevention. Available online: http://www.wcrf-uk.org/PDFs/EnergyDensity.pdf (accessed on 13 September 2020).
21. Bechthold, A. Food Energy Density and Body Weight. *Sci. Statement DGE. Ernahr. Umsch.* **2014**, *61*, 2–11. [CrossRef]
22. Rippin, H.L.; Hutchinson, J.; Jewell, J.; Breda, J.J.; Cade, J.E. Portion Size of Energy-Dense Foods among French and UK Adults by BMI Status. *Nutrients* **2018**, *11*, 12. [CrossRef]
23. Jeffery, R.W.; Rydell, S.; Dunn, C.L.; Harnack, L.J.; Levine, A.S.; Pentel, P.R.; Baxter, J.E.; Walsh, E.M. Effects of portion size on chronic energy intake. *Int. J. Behav. Nutr. Phys. Act.* **2007**, *4*, 27. [CrossRef] [PubMed]
24. Fisher, J.O.; Liu, Y.; Birch, L.L.; Rolls, B.J. Effects of portion size and energy density on young children's intake at a meal. *Am. J. Clin. Nutr.* **2007**, *86*, 174–179. [CrossRef] [PubMed]
25. Orlet Fisher, J.; Rolls, B.J.; Birch, L.L. Children's bite size and intake of an entree are greater with large portions than with age-appropriate or self-selected portions. *Am. J. Clin. Nutr.* **2003**, *77*, 1164–1170. [CrossRef] [PubMed]
26. McConahy, K.L.; Smiciklas-Wright, H.; Birch, L.L.; Mitchell, D.C.; Picciano, M.F. Food portions are positively related to energy intake and body weight in early childhood. *J. Pediatr.* **2002**, *140*, 340–347. [CrossRef]
27. Fisher, J.O.; Birch, L.L. Eating in the absence of hunger and overweight in girls from 5 to 7 y of age. *Am. J. Clin. Nutr.* **2002**, *76*, 226–231. [CrossRef] [PubMed]
28. Moreno, L.; González-Gross, M.; Kersting, M.; Molnár, D.; de Henauw, S.; Beghin, L.; Sjöström, M.; Hagströmer, M.; Manios, Y.; Gilbert, C.; et al. Assessing, Understanding and Modifying Nutritional Status, Eating Habits and Physical Activity in European Adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public Health Nutr.* **2008**, *11*. [CrossRef] [PubMed]
29. Henauw, S.D.; Gottrand, F.; Bourdeaudhuij, I.D.; Gonzalez-Gross, M.; Leclercq, C.; Kafatos, A.; Molnar, D.; Marcos, A.; Castillo, M.; Dallongeville, J.; et al. Nutritional status and lifestyles of adolescents from a public health perspective. The HELENA Project—Healthy Lifestyle in Europe by Nutrition in Adolescence. *J. Public Health* **2007**, *15*, 187–197. [CrossRef]
30. Moreno, L.; De Henauw, S.; González-Gross, M.; Kersting, M.; Molnár, D.; Gottrand, F.; Barrios, L.; Sjöström, M.; Manios, Y.; Gilbert, C.; et al. Design and Implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int. J. Obes.* **2008**, *32* (Suppl. 5). [CrossRef]
31. Beghin, L.; Castera, M.; Manios, Y.; Gilbert, C.C.; Kersting, M.; De Henauw, S.; Kafatos, A.; Gottrand, F.; Molnar, D.; Sjostrom, M.; et al. Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. *Int. J. Obes.* **2008**, *32*, S12–S18. [CrossRef]
32. Goldberg, G.; Black, A.; Jebb, S.; Cole, T.; Murgatroyd, P.; Coward, W.; Prentice, A. Critical Evaluation of Energy Intake Data Using Fundamental Principles of Energy Physiology: 1. Derivation of Cut-Off Limits to Identify Under-Recording. *Eur. J. Clin. Nutr.* **1991**, *45*, 569–581. [PubMed]
33. Banna, J.; McCrory, M.; Fialkowski, M.; Boushey, C. Examining Plausibility of Self-Reported Energy Intake Data: Considerations for Method Selection. *Front. Nutr.* **2017**, *4*. [CrossRef]
34. Börnhorst, C.; Huybrechts, I.; Hebestreit, A.; Vanaelst, B.; Molnár, D.; Bel-Serrat, S.; Mouratidou, T.; Moreno, L.; Pala, V.; Eha, M.; et al. Diet-obesity associations in children: Approaches to counteract attenuation caused by misreporting. *Public Health Nutr.* **2013**, *16*. [CrossRef]
35. Nagy, E.; Vicente-Rodriguez, G.; Manios, Y.; Béghin, L.; Iliescu, C.; Censi, L.; Dietrich, S.; Ortega, F.; De Vriendt, T.; Plada, M.; et al. Harmonization Process and Reliability Assessment of Anthropometric Measurements in a Multicenter Study in Adolescents. *Int. J. Obes.* **2008**, *32* (Suppl. 5). [CrossRef]
36. Cole, T.; Lobstein, T. Extended International (IOTF) Body Mass Index Cut-Offs for Thinness, Overweight and Obesity. *Pediatr. Obes.* **2012**, *7*. [CrossRef]
37. Slaughter, M.; Lohman, T.; Boileau, R.; Horswill, C.; Stillman, R.; Van Loan, M.; Bemben, D. Skinfold Equations for Estimation of Body Fatness in Children and Youth. *Hum. Biol.* **1988**, *60*, 709–723. [PubMed]
38. Kyle, U.; Schutz, Y.; Dupertuis, Y.; Pichard, C. Body composition interpretation. Contributions of the fat-free mass index and the body fat mass index. *Nutrition* **2003**, *19*, 597–604. [CrossRef] [PubMed]
39. Lohman, T.G.; Roche, A.F.; Martorell, R. *Anthropometric Standardization Reference Manual*; Human Kinetics Books: Champaign, IL, USA, 1988.
40. Hagströmer, M.; Bergman, P.; De Bourdeaudhuij, I.; Ortega, F.; Ruiz, J.; Manios, Y.; Rey-López, J.; Phillipp, K.; von Berlepsch, J.; Sjöström, M. Concurrent Validity of a Modified Version of the International Physical Activity Questionnaire (IPAQ-A) in European Adolescents: The HELENA Study. *Int. J. Obes.* **2008**, *32* (Suppl. 5). [CrossRef] [PubMed]

41. Ainsworth, B.; Haskell, W.; Whitt, M.; Irwin, M.; Swartz, A.; Strath, S.; O'Brien, W.; Bassett, D.; Schmitz, K.; Emplaincourt, P.; et al. Compendium of physical activities: An update of activity codes and MET intensities. *Med. Sci. Sports A Exerc.* **2000**, *32*. [CrossRef] [PubMed]
42. Béghin, L.; Dauchet, L.; De Vriendt, T.; Cuenca-García, M.; Manios, Y.; Toti, E.; Plada, M.; Widhalm, K.; Repasy, J.; Huybrechts, I.; et al. Influence of Parental Socio-Economic Status on Diet Quality of European Adolescents: Results From the HELENA Study. *Br. J. Nutr.* **2014**, *111*. [CrossRef]
43. Vereecken, C.; Covents, M.; Sichert-Hellert, W.; Alvira, J.; Le Donne, C.; De Henauw, S.; De Vriendt, T.; Phillipp, M.; Béghin, L.; Manios, Y.; et al. Development and Evaluation of a Self-Administered Computerized 24-h Dietary Recall Method for Adolescents in Europe. *Int. J. Obes.* **2008**, *32* (Suppl. 5). [CrossRef]
44. Vereecken, C.; Covents, M.; Matthys, C.; Maes, L. Young adolescents' nutrition assessment on computer (YANA-C). *Eur. J. Clin. Nutr.* **2005**, *59*. [CrossRef] [PubMed]
45. Julián-Almárcegui, C.; Bel-Serrat, S.; Kersting, M.; Vicente-Rodriguez, G.; Nicolas, G.; Vyncke, K.; Vereecken, C.; De Keyzer, W.; Beghin, L.; Sette, S.; et al. Comparison of Different Approaches to Calculate Nutrient Intakes Based Upon 24-h Recall Data Derived from a Multicenter Study in European Adolescents. *Eur. J. Nutr.* **2016**, *55*, 537–545. [CrossRef] [PubMed]
46. Harttig, U.; Haubrock, J.; Knüppel, S.; Boeing, H. The MSM program: Web-based statistics package for estimating usual dietary intake using the Multiple Source Method. *Eur. J. Clin. Nutr.* **2011**, *65* (Suppl. 1). [CrossRef] [PubMed]
47. Ireland, J.; van Erp-Baart, A.; Charrondière, U.; Møller, A.; Smithers, G.; Trichopoulou, A. Selection of a food classification system and a food composition database for future food consumption surveys. *Eur. J. Clin. Nutr.* **2002**, *56* (Suppl. 2). [CrossRef]
48. Lioret, S.; Volatier, J.L.; Lafay, L.; Touvier, M.; Maire, B. Is food portion size a risk factor of childhood overweight? *Eur. J. Clin. Nutr.* **2009**, *63*, 382–391. [CrossRef]
49. Pereira, J.; Mendes, A.; Crispim, S.; Marchioni, D.; Fisberg, R. Association of Overweight with Food Portion Size Among Adults of São Paulo-Brazil. *PLoS ONE* **2016**, *11*. [CrossRef] [PubMed]
50. Askovic, B.; Kirchengast, S. Gender differences in nutritional behavior and weight status during early and late adolescence. *Anthropol. Anz.* **2012**, *69*. [CrossRef]
51. Bandini, L.; Vu, D.; Must, A.; Cyr, H.; Goldberg, A.; Dietz, W. Comparison of high-calorie, low-nutrient-dense food consumption among obese and non-obese adolescents. *Obes. Res.* **1999**, *7*. [CrossRef] [PubMed]
52. Gibson, S. Are High-Fat, High-Sugar Foods and Diets Conducive to Obesity? *Int. J. Food Sci. Nutr.* **1996**, *47*. [CrossRef]
53. Flieh, S.; Moreno, L.; Miguel-Berges, M.; Stehle, P.; Marcos, A.; Molnár, D.; Widhalm, K.; Béghin, L.; De Henauw, S.; Kafatos, A.; et al. Free Sugar Consumption and Obesity in European Adolescents: The HELENA Study. *Nutrients* **2020**, *12*. [CrossRef]
54. Best, M.; Papies, E. Lower socioeconomic status is associated with higher intended consumption from oversized portions of unhealthy food. *Appetite* **2019**, *140*. [CrossRef] [PubMed]
55. Colapinto, C.; Fitzgerald, A.; Taper, L.; Veugelers, P. Children's preference for large portions: Prevalence, determinants, and consequences. *J. Am. Diet. Assoc.* **2007**, *107*. [CrossRef] [PubMed]
56. Hansen, A.; Duncan, D.; Tarasenko, Y.; Yan, F.; Zhang, J. Generational shift in parental perceptions of overweight among school-aged children. *Pediatrics* **2014**, *134*. [CrossRef] [PubMed]
57. Livingstone, M.; Robson, P.; Wallace, J. Issues in dietary intake assessment of children and adolescents. *Br. J. Nutr.* **2004**, *92* (Suppl. 2). [CrossRef]
58. Gomes, D.; Luque, V.; Xhonneux, A.; Verduci, E.; Socha, P.; Koletzko, B.; Berger, U.; Grote, V. A simple method for identification of misreporting of energy intake from infancy to school age: Results from a longitudinal study. *Clin. Nutr.* **2018**, *37*. [CrossRef] [PubMed]
59. Van Sluijs, E.; Sharp, S.; Ambrosini, G.; Cassidy, A.; Griffin, S.; Ekelund, U. The independent prospective associations of activity intensity and dietary energy density with adiposity in young adolescents. *Br. J. Nutr.* **2016**, *115*. [CrossRef] [PubMed]
60. Butte, N.; Cai, G.; Cole, S.; Wilson, T.; Fisher, J.; Zakeri, I.; Ellis, K.; Comuzzie, A. Metabolic and behavioral predictors of weight gain in Hispanic children: The Viva la Familia Study. *Am. J. Clin. Nutr.* **2007**, *85*. [CrossRef] [PubMed]
61. Collins, C.; Watson, J.; Burrows, T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. *Int. J. Obes.* **2010**, *34*. [CrossRef] [PubMed]
62. Forrestal, S. Energy intake misreporting among children and adolescents: A literature review. *Matern. Child Nutr.* **2011**, *7*. [CrossRef]
63. Börnhorst, C.; Huybrechts, I.; Ahrens, W.; Eiben, G.; Michels, N.; Pala, V.; Molnár, D.; Russo, P.; Barba, G.; Bel-Serrat, S.; et al. Prevalence and determinants of misreporting among European children in proxy-reported 24 h dietary recalls. *Br. J. Nutr.* **2013**, *109*. [CrossRef]
64. Bel-Serrat, S.; Julián-Almárcegui, C.; González-Gross, M.; Mouratidou, T.; Börnhorst, C.; Grammatikaki, E.; Kersting, M.; Cuenca-García, M.; Gottrand, F.; Molnár, D.; et al. Correlates of dietary energy misreporting among European adolescents: The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study. *Br. J. Nutr.* **2016**, *115*. [CrossRef] [PubMed]
65. Kim, G.; Shin, S.; Lee, J.; Hwang, J.; Park, S.; Moon, J.; Kim, H.; Ahn, H. Red meat and chicken consumption and its association with high blood pressure and obesity in South Korean children and adolescents: A cross-sectional analysis of KSHES, 2011–2015. *Nutr. J.* **2017**, *16*, 31. [CrossRef] [PubMed]

66. Parnell, W.; Wilson, N.; Alexander, D.; Wohlers, M.; Williden, M.; Mann, J.; Gray, A. Exploring the Relationship Between Sugars and Obesity. *Public Health Nutr.* **2008**, *11*. [CrossRef] [PubMed]
67. Young, L.; Nestle, M. Expanding portion sizes in the US marketplace: Implications for nutrition counseling. *J. Am. Diet. Assoc.* **2003**, *103*. [CrossRef] [PubMed]
68. Murakami, K.; Livingstone, M. Associations between meal and snack frequency and overweight and abdominal obesity in US children and adolescents from National Health and Nutrition Examination Survey (NHANES) 2003–2012. *Br. J. Nutr.* **2016**, *115*. [CrossRef]
69. Benton, D. Portion size: What we know and what we need to know. *Crit. Rev. Food Sci. Nutr.* **2015**, *55*, 988–1004. [CrossRef]
70. Berkey, C.; Rockett, H.; Field, A.; Gillman, M.; Colditz, G. Sugar-added beverages and adolescent weight change. *Obesity Res.* **2004**, *12*. [CrossRef]
71. Gillis, L.; Bar-Or, O. Food away from home, sugar-sweetened drink consumption and juvenile obesity. *J. Am. Coll. Nutr.* **2003**, *22*. [CrossRef]
72. Mrdjenovic, G.; Levitsky, D. Nutritional and energetic consequences of sweetened drink consumption in 6- to 13-year-old children. *J. Pediatr.* **2003**, *142*. [CrossRef]
73. Ludwig, D.; Peterson, K.; Gortmaker, S. Relation between consumption of sugar-sweetened drinks and childhood obesity: A prospective, observational analysis. *Lancet* **2001**, *357*, S0140–S6736. [CrossRef]
74. Glickman, D.; Parker, L.; Sim, L.; Del Valle Cook, H.; Miller, E. *Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation*; National Academies Press: Washington, DC, USA, 2012. [CrossRef]
75. Pan, A.; Hu, F. Effects of carbohydrates on satiety: Differences between liquid and solid food. *Curr. Opin. Clin. Nutr. Metab. Care* **2011**, *14*. [CrossRef] [PubMed]
76. DiMeglio, D.; Mattes, R. Liquid versus solid carbohydrate: Effects on food intake and body weight. *Int. J. Obes. Relat. Metab. Disord.* **2000**, *24*, 794–800. [CrossRef] [PubMed]
77. Bachman, C.; Baranowski, T.; Nicklas, T. Is there an association between sweetened beverages and adiposity? *Nutr. Rev.* **2006**, *64*. [CrossRef] [PubMed]
78. Malik, V.; Schulze, M.; Hu, F. Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review. *Am. J. Clin. Nutr.* **2006**, *84*. [CrossRef]

Table S1: Mean intake of food PS from ED food for under-reporters and by BMI, normal weight or overweight/obesity in males and females.

	Under-reporters									
Body Mass Index categories *	Males				*p-value*	Females				*p-value*
	Normal weight (*n*=92)		**Overweight/ Obesity (*n*=110)**			**Normal weight (*n*=172)**		**Overweight/ Obesity (*n*=94)**		
Food groups (g)	*n*	M (SD)	*n*	M (SD)		*n*	M (SD)	*n*	M (SD)	
Breakfast cereals	16	32.47 (16.19)	16	72.44 (132.74)	0.068	23	36.80 (19.28)	21	37.14 (22.56)	0.520
Bread and rolls	75	112.50 (73.94)	95	119.35 (86.09)	0.070	145	91.02 (52.61)	84	92.25 (72.62)	**0.001**
Sweet bakery product	33	76.35 (41.20)	29	62.90 (43.29)	0.400	60	74.16 (55.76)	29	65.40 (53.63)	0.296
Confectionary non chocolate	13	26.87 (31.74)	8	38.38 (49.29)	0.206	28	26.07 (22.79)	20	26.49 (28.03)	0.845
Chocolate	17	36.82 (26.31)	12	68.96 (59.18)	**0.018**	35	36.70 (37.65)	20	25.41 (25.79)	0.418
Sugar, honey, and Jam	12	21.50 (14.99)	11	47.82 (48.69)	0.160	21	20.87 (16.59)	11	18.83 (17.09)	0.943
Cheese	22	40.39 (37.63)	31	105.48 (390.96)	0.166	48	25.44 (18.39)	22	24.99 (17.28)	0.898
Meat	34	177.74 (189.62)	56	155.63 (162.08)	0.656	74	81.83 (94.22)	39	116.34 (189.75)	0.072
Meat and poultry product	49	94.83 (81.89)	74	230.91 (278.42)	0.182	93	68.57 (64.45)	51	70.15 (72.25)	0.718
Vegetable oils	12	17.06 (15.11)	15	16.95 (13.26)	0.729	39	14.45 (14.48)	31	17.87 (11.95)	0.989
Carbonated soft and isotonic drink	24	545.57 (376.74)	33	605.72 (507.02)	0.215	34	325.51 (186.62)	23	441.82 (325.69)	0.066

n: number of consumers, M: mean, SD: standard deviation, Boldface values indicate significance, *p*-value <0.05.

Table S2: The association between BMI and PS of most ED food in under-reporters, using multiple linear regression model.

Body Mass Index*	**Under-reporters**							
	Males				**Females**			
Food groups (g)	β	95% CI		*p-value*	β	95% CI		*p-value*
		Upper	Lower			Upper	Lower	
Breakfast cereals	0.002	-0.011	0.015	0.751	0.011	-0.045	0.066	0.705
Bread and rolls	0.014	0.006	0.022	**<0.001**	0.001	-0.005	0.005	0.805
Sweet bakery product	-0.016	-0.039	0.008	0.181	-0.008	-0.020	0.005	0.238
Confectionary non chocolate	-0.011	-0.057	0.035	0.614	-0.018	-0.057	0.022	0.366
Chocolate	0.029	0.003	0.054	**0.028**	-0.023	-0.052	0.006	0.119
Sugar, honey, and Jam	0.007	0.018	0.135	**0.012**	-0.010	-0.085	0.064	0.778
Cheese	0.003	-0.010	0.028	0.525	-0.005	-0.049	0.038	0.815
Meat	-0.002	-0.008	0.003	0.465	0.001	-0.004	0.005	0.774
Meat and poultry product	0.001	-0.001	0.001	0.847	0.004	-0.005	0.012	0.417
Vegetable oils	-0.031	-0.152	0.090	0.604	0.032	-0.040	0.104	0.380
Carbonated soft and isotonic drink	0.001	-0.003	0.004	0.735	0.003	-0.001	0.006	0.108

β: regression coefficient. CI: confidence interval, BMI: body mass index. *Adjusting for confounders: age, Moderate-to-vigorous physical activity (MVPA), and TEI and SES. Boldface values indicate significance, *p*-value <0.05.

Table S3: The association between FMI and portion size of most ED food between gender in under-reporters using multiple linear regression model.

Fat Mass Index*	**Under-reporters**							
	Males				**Females**			
Food groups (g)	β	95% CI		*p-value*	β	95% CI		*p-value*
		Upper	Lower			Upper	Lower	
Breakfast cereals	0.002	-0.022	0.026	0.874	-0.014	-0.080	0.052	0.668
Bread and rolls	0.001	-0.013	0.014	0.935	-0.005	-0.015	0.004	0.272
Sweet bakery product	-0.024	-0.068	0.020	0.282	-0.012	-0.029	0.005	0.173
Confectionary non chocolate	0.028	-0.062	0.118	0.519	0.000	-0.049	0.049	0.991
Chocolate	0.061	0.006	0.117	**0.031**	-0.006	-0.048	0.036	0.776
Sugar, honey, and Jam	-0.030	-0.125	0.064	0.510	0.017	-0.088	0.122	0.746
Cheese	0.002	-0.005	0.008	0.584	0.004	-0.052	0.059	0.890
Meat	-0.002	-0.012	0.007	0.633	0.003	-0.003	0.010	0.280
Meat and poultry product	0.000	-0.001	0.002	0.769	-0.013	-0.025	-0.002	**0.023**
Vegetable oils	-0.036	-0.250	0.178	0.731	0.066	-0.029	0.162	0.172
Carbonated soft and isotonic drink	-0.003	-0.008	0.002	0.197	0.004	-0.005	0.003	0.984

β: regression coefficient. CI: confidence interval, FMI: fat mass index. *Adjusting for confounders: age, physical activity (MVPA), TEI, and SES. Boldface values indicate significance, *p*-value <0.05.

Table S4: Ordinal logistic regression model, the association between BMI categories and ED food portion groups in under-reporters and between gender.

Body Mass Index categories*	**Under-reporters**							
	Males				**Females**			
Food groups (g)	OR	95% CI		*p-value*	OR	95% CI		*p-value*
		Upper	Lower			Upper	Lower	
Breakfast cereals	1.012	1.002	1.024	**0.023**	0.987	0.957	1.018	0.411
Bread and rolls	1.002	0.998	1.006	0.260	0.999	0.995	1.004	0.702
Sweet bakery product	0.991	0.979	1.003	0.147	0.996	0.987	1.006	0.460
Confectionary non chocolate	0.997	0.970	1.025	0.822	1.000	0.976	1.025	0.963
Chocolate	1.012	0.991	1.033	0.256	0.985	0.961	1.010	0.251
Sugar, honey, and Jam	1.037	0.982	1.096	0.189	0.988	0.942	1.036	0.611
Cheese	1.000	0.999	1.002	0.683	0.985	0.953	1.018	0.366
Meat	0.999	0.996	1.001	0.282	1.001	0.999	1.004	0.346
Meat and poultry product	1.000	0.999	1.000	0.822	0.998	0.993	1.004	0.545
Vegetable oils	0.996	0.941	1.055	0.902	1.032	0.993	1.073	0.113
Carbonated soft and isotonic drink	1.000	0.999	1.001	0.687	1.000	0.999	1.003	0.483

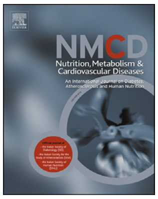
OR: odd ratio. CI: confident interval. *Adjusting for confounders: age, moderate-to-vigorous physical activity (MVPA), and TEI and SES. Boldface values indicate significance, *p*-value <0.05.

Nutrition, Metabolism & Cardiovascular Diseases (2022) **32**, 2061–2073

Available online at www.sciencedirect.com

Nutrition, Metabolism & Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd



Associations between food portion sizes, insulin resistance, VO2 max and metabolic syndrome in European adolescents: The HELENA study

S.M. Flieh [a], M.L. Miguel-Berges [a,b,*], I. Huybrechts [c,d], M.J. Castillo [e], M. Gonzalez-Gross [f,g], A. Marcos [h], F. Gottrand [i], C. Le Donne [j], K. Widhalm [k,l], D. Molnár [m], P. Stehle [n], A. Kafatos [o], J. Dallongeville [p], E. Gesteiro [f], S. Abbeddou [d], L.A. Moreno [a,b,g,q], E.M. González-Gil [a,g,q], HELENA Study Group[1]

[a] Growth, Exercise, Nutrition and Development (GENUD) Research Group, Faculty of Health Sciences, University of Zaragoza, 50009, Zaragoza, Spain
[b] Instituto Agroalimentario de Aragón (IA2), 50013, Zaragoza, Spain
[c] International Agency for Research on Cancer (IARC), 69372, Lyon, France
[d] Department of Public Health and Primary Care, Ghent University, 9000, Ghent, Belgium
[e] Department of Medical Physiology, School of Medicine, University of Granada, Granada, 18071, Spain
[f] ImFine Research Group, Departamento de Salud y Rendimiento Humano, Facultad de Ciencias de la Actividad Física y del Deporte-INEF, Universidad Politécnica de Madrid, 28040, Madrid, Spain
[g] CIBER Fisiopatología de la Obesidad y Nutrición, Instituto de Salud Carlos III, 28029, Madrid, Spain
[h] Inmunonutrition Research Group, Department of Metabolism and Nutrition, Instituto del Frío, Institute of Food Science and Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), 28040, Madrid, Spain
[i] Univ. Lille, CHU Lille, INSERM U1286 Infinite, F-59000, Lille, France
[j] Council for Agricultural Research and Economics, Research Centre for Food and Nutrition, Via Ardeatina 546, 00178, Rome, Italy
[k] Department of Gastroenterology and Hepatology, Medical University of Vienna, 1090, Vienna, Austria
[l] Austrian Academic Institute for Clinical Nutrition, A-3100, Vienna, Austria
[m] Department of Pediatrics, Medical School, University of Pécs, H-7624, Pécs, Hungary
[n] Department of Nutrition and Food Sciences, University of Bonn, D-53115, Bonn, Germany
[o] Faculty of Medicine, University of Crete, GR-71003, Crete, Greece
[p] Department of Epidemiology and Public Health, Institut Pasteur de Lille, 59000, Lille, France
[q] Instituto de Investigación Sanitaria Aragón (IIS Aragón), 50009, Zaragoza, Spain

Received 4 February 2022; received in revised form 6 May 2022; accepted 23 May 2022
Handling Editor: A. Siani
Available online 31 May 2022

KEYWORDS
Food portion size (PS);
VO2 max;
Insulin resistance (IR);
Metabolic syndrome

Abstract *Background and aims:* This study aims to examine the associations of food portion size (PS) with markers of insulin resistance (IR) and clustered of metabolic risk score in European adolescents.
Methods: A total of 495 adolescents (53.5% females) from the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study were included. The association between PS from food groups and homeostasis model assessment of insulin resistance (HOMA-IR) index, VO2 max, and metabolic risk score was assessed by multilinear regression analysis adjusting for several confounders. Analysis of covariance (ANCOVA) was used to determine the mean differences of food

---

Abbreviations: ANCOVA, Analysis of covariance; BMI, Body mass index; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; HOMA-IR index, Homeostasis model assessment of insulin resistance; Metabolic Syndrome, MS; PA, Physical activity; PS, Portion size; VO2 max, Maximal oxygen uptake.

[*] Corresponding author. Growth, Exercise, Nutrition and Development (GENUD) Research Group, Department of health and sport sciences, University of Zaragoza, Zaragoza, Spain.

E-mail addresses: sondosnserat991@gmail.com (S.M. Flieh), mlmiguel@unizar.es (M.L. Miguel-Berges), huybrechtsi@iarc.fr (I. Huybrechts), mcgarzon@ugr.es (M.J. Castillo), marcela.gonzalez.gross@upm.es (M. Gonzalez-Gross), amarcos@ictan.csic.es (A. Marcos), Frederic.GOTTRAND@chru-lille.fr (F. Gottrand), cinzia.ledonne@crea.gov.it (C. Le Donne), kurt.widhalm@meduniwien.ac.at (K. Widhalm), molnar.denes@pte.hu (D. Molnár), p.stehle@uni-bonn.de (P. Stehle), kafatos@med.uoc.gr (A. Kafatos), Jean.Dallongeville@pasteur-lille.fr (J. Dallongeville), eva.gesteiro@upm.es (E. Gesteiro), Souheila.Abbeddou@ugent.be (S. Abbeddou), lmoreno@unizar.es (L.A. Moreno), esthergg@unizar.es (E.M. González-Gil).

[1] The members of HELENA Study Group are listed in Acknowledgments section.

https://doi.org/10.1016/j.numecd.2022.05.017

(MS);
Adolescents

PS from food groups by HOMA-IR cutoff categories by using maternal education as a covariable.
Results: Larger PS from vegetables in both gender and milk, yoghurt, and milk beverages in males were associated with higher VO2 max, while larger PS from margarines and vegetable oils were associated with lower VO2 max ($p < 0.05$). Males who consumed larger PS from fish and fish products; meat substitutes, nuts, and pulses; cakes, pies, and biscuits; and sugar, honey, jams, and chocolate have a higher metabolic risk score ($p < 0.05$). Males with lower HOMA-IR cutoff values consumed larger PS from vegetables, milk, yoghurt, and milk beverages ($p < 0.05$). Females with lower HOMA-IR cutoff values consumed larger PS from breakfast cereals, while those with higher HOMA-IR cutoff values consumed larger PS from butter and animal fats ($p = 0.018$).
Conclusion: The results show that larger PS from dairy products, cereals, and high energy dense foods are a significant determinant of IR and VO2 max, and larger PS from food with higher content of sugar were associated with higher metabolic risk score.

1. Introduction

During the past decades, increasing prevalence of type 2 diabetes mellitus and prediabetic stages such as insulin resistance (IR) or impaired fasting glucose has been reported in children and adolescents [1]. This increase seems to parallel the increase in the prevalence of obesity in these age groups [2]. Dietary factors are environmental determinants of both adiposity, IR, and the components of metabolic syndrome (MS) [3].

IRs improve after weight loss [4] and in the presence of high levels of physical activity (PA) [5]. Diet composition, in particular, carbohydrate type and amount and fat intake may also influence IR [6]. In children, it has been found that total energy, fat, saturated fat, and protein intakes were significant predictors of fasting insulin and quantitative insulin sensitivity check index (QUICKI), independent of body mass index (BMI), and age [7]. Several dietary factors could promote a positive energy balance [8] and thereby increase the risk for obesity and diabetes, including the following: excessive portion size (PS), with single large meals often approaching or exceeding individual daily energy requirements; palatability, emphasizing primordial taste preferences for sugar, salt, and fat; high energy density; and high glycemic load [9]. PS of many foods have been increasing in countries with a well-established industrialized food supply [10].

Increased consumption of margarine, sweets (candies, lollipops, jellies, and traditional fruit in heavy syrup), and savory snacks (chips, cheese puffs, and not home-made popcorn) was associated with high homeostasis model assessment of IR (HOMA-IR) index value in children and adolescents [11,12]. Additionally, it was shown previously that sugar intake in the form of sugar-sweetened beverages was associated with IR in adolescents [13]. Data from children indicated that short absorption time that follows the consumption of sugar may impair blood glucose control and may result in hyperinsulinemia and peripheral IR [14]. Frequent intake of obesogenic foods such as crackers, chips, and cooked ham was observed in adolescents with MS [15]. Moreover, a ‘Western’ dietary pattern was associated with a greater risk for MS, among female adolescents [16].

The relationship between food PS and IR and the development of MS in children and adolescents have not been previously examined. Therefore, this study investigates the potential effect of food PS on IR and a quantitative score of metabolic risk in European adolescents.

2. Methods

2.1. Study design

A European multicentre cross-sectional study was performed (2006–2007) in adolescents aged 12.5–17.5 years from 10 cities to assess a Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) [17]. The main objective of the HELENA-Cross sectional was to obtain reliable and comparable data from randomly selected European adolescents (n = 3528, 52.3% females) by using wide relevant health and nutrition-related parameters that included the following: dietary intake, food choices and preferences, serum vitamin and mineral status, lipid and glucose metabolism, anthropometric measurements, PA and fitness, and genetic markers [18]. The inclusion criteria were participants who were free from any acute infection lasting less than 1 week before the inclusion process and were not concurrently involved in another clinical trial [19]. The exclusion criteria were participants not having information on age, gender, height, and weight; participants who were concurrently involved in another clinical trial, age more than 17.5 years or less than 12.5 years and having any acute infection lasting more than 1 week before the inclusion process [19]. More details about recruitment and sampling process are described elsewhere [19].

2.2. Study sample

Blood samples were obtained from around one-third of patients, following the same randomization criteria as those for the whole sample. Out of 3528 adolescents included in the HELENA study, blood samples were obtained from one-third (1089) of the adolescents as was foreseen in the protocol. A total of 1188 adolescents (33.7%) did not have information for the 24-hr. Also, 1198 adolescents who were considered over-reporters (173) and under-reporters (526), according to the approach of Goldberg et al. [20], were excluded. Out of those with valid dietary data, 647 participants were excluded, as they had no data on glucose, insulin, and HOMA-IR index, skinfold thickness, systolic blood pressure, triglycerides, maximal oxygen uptake (VO2 max), maternal education, or PA. Finally, 495 (265 females) adolescents were included in the present analysis.

The study was performed following the ethical guidelines of the Declaration of Helsinki 1964 (revision of Edinburgh, 2000), the Good Clinical Practice, and the legislation about clinical research in humans in each of the participating countries. The protocol was approved by the Human Research Review Committees of the involved centres [21]. Moreover, a written informed consent was obtained from participating adolescents and their parents [22].

2.3. Questionnaires

The education level of the adolescent's mothers was adapted from the International Standard Classification of Education (ISCED) [23] and reported as primary education, lower secondary education, higher secondary education, and higher education/university degree. In this study, the two lowest levels have been merged into one group called lower level of education, in addition to higher level of education. More details have been reported elsewhere [24].

2.4. Physical examination

Measurements were taken 3 times by trained researchers in each city. A training session was conducted by the coordinator of HELENA, with the 10 field workers who planned to perform anthropometric measurements. The aim of the training was to familiarize researchers with the exact protocol to be used and to perform the 1st approach to assess the intra-observer technical error. Then, a workshop was organized that aims to assess the intra-observer (2nd time) and inter-observer (1st time) technical error of measurements (TEMs<1) and the reliability (>90%) of anthropometry and BIA measurements. All the anthropometric variables were measured in order, and the same measurements were then repeated two more times [25].

Weight was measured with an electronic scale (model 871; SECA, Hamburg, Germany) to the nearest 0.05 kg, and height was measured with a telescopic height measuring instrument (model 225; SECA, Hamburg, Germany) to the nearest 0.1 cm. All measurements were performed in underwear and barefoot [25]. BMI was calculated as body weight (kg) divided by the height (m) squared (kg/m^2). The obesity status was classified using the International Obesity Task Force scale [26]. Skinfold thickness was measured to the nearest 0.2 mm in triplicate in the right side at biceps, triceps, subscapular, suprailiac, thigh, and medial calf with a Holtain Caliper (Crymmych, Wales, UK). The sum of six skinfold thickness was used as an indicator of total body fat [27].

2.5. Physical activity measurement

Accelerometers (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) were used to obtain an objective measurement of PA. The devices were placed on the lower back of the participants under the clothes using an elastic belt for seven sequent days. Instructions were given to participants when they wake up to wear the instrument and remove it for water-based activities and sleeping [28]. Data were downloaded to the computer using manufacturer software and analyzed later by software based on Visual Basic. Time spent in moderate and vigorous physical activity (MVPA) was determined using the cutoff point of 2000 cpm to generate the various indices; the number of days per week was multiplied by minutes per day, to calculate minutes per week for each activity [29]. More detailed information has been reported elsewhere [28].

2.6. Blood samples

Briefly, fasting blood samples were collected by venepuncture at school between 8:00 and 10:00 after a 10-h overnight fast. Whole blood samples for the hemogram were sent directly to the local laboratory of each country to be analyzed. Concentrations of triglycerides, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), and glucose were measured in fresh serum enzymatically on the Siemens Dimension RxL Max Integrated Chemistry System (Dade Behring, Schwalbach, Germany) using the manufacturer's reagents and instructions at the University Hospital in Bonn (Germany). TC/HDL-c ratio was calculated. Insulin was measured by a solid-phase two-site chemiluminescent immunometric assay with an Immulite 2000 analyzer (DPC Biermann GmbH, Bad Nauheim, Germany). More details about blood handling procedures have been described elsewhere [30]. The intra-assay coefficients of variation were <3.3%, and the inter-assay coefficients were <3.9% for all parameters.

2.7. Cardiorespiratory fitness

Cardiorespiratory fitness was measured by the progressive 20-m shuttle run test [31]. This test required participants to run back and forth between two lines set 20 m apart following a running pace determined by audio signals and with an initial speed of 8.5 km h^{-1} increasing by 0.5 km h-1 every minute (1 min equals 1 stage). The test is finished when the adolescent failed to reach the end lines concurrent with the audio signals on two consecutive occasions, and the final score was computed as the number of stages completed (precision of 0.5 stages). Maximal oxygen uptake (VO2 max) was estimated using the formula described by Léger et al. (1984).

2.8. Metabolic risk score

The HOMA-IR index was calculated as fasting insulin [(pmol/l)/6.945] * fasting glucose [(mmol/l)/22.5] [32]. The cutoff value for HOMA-IR was based on the 90th percentile. A QUICKI was calculated as QUICKI = 1/log insulin (lIU/mL) + log glucose (mg/dl) [32]. Systolic blood pressure was measured with an automatic oscillometric device (M6, HEM-7001-E, Omron). A continuous score of clustering metabolic risk factors was computed using the following variables: systolic blood pressure, triglycerides, TC/HDL-c ratio, HOMA-IR index, the sum of six skinfolds, and VO2 max. Z-scores were calculated for each risk factor variable by age and gender, and then all individual Z-scores were summed to create a clustered risk score based on the one by Andersen et al. [33], that has been used in the previous HELENA study [12].

2.9. Dietary assessment

The HELENA Dietary Assessment Tool (HELENA-DIAT) was used to assess adolescents dietary consumption; this software was used as self-administered, computerized 24-h recall, developed and validated originally in Flemish adolescents, and then in the HELENA-CSS [34]. HELENA-DIAT is based on previous day assessments of the intake from six meal occasions (breakfast, morning snack, lunch, afternoon snack, evening meal, and evening snack). The two nonconsecutive 24-h recalls performed on one convenient weekday and one weekend day. A well-trained dietitian was present to assess the adolescent in case they need any help to complete the diet 24-hr recall.

A total of 800 photographs were available in the HELENA-DIAT program. The participants were able to select one of the amounts that appeared in a photograph or indicate that they consume less or more than the amount appeared on the computer. In addition, they were able to type the consumed amount for each food item in a text box. Moreover, the participants were able to remove or modify the selected items at any time. Moreover, foods that can be measured with household tools like cups, several portions appeared on the screen, so that the participants can select the consumption amount by clicking directly on the portion. In case some foods usually eaten in combination with other items such as french fries and mayonnaise, a box was shown on the screen to remind them to include this item [34].

2.10. Selection of food groups

Based on the European food groups classification system, about 4179 foods and beverages, in the form of recipes or as individual food, were aggregated into food groups [34]. In our study, we excluded the foods that were very infrequently consumed from the analysis: products for special nutrition use, soya beverages, and miscellaneous due to their very low consumption (reported by less than 15% of the participants). Furthermore, the daily diet was divided into 11 food groups based on their nutritional composition: (1) water, (2) bread and cereal, (3) grains and potatoes, (4) fruit, (5) vegetables, (6) milk, milk desserts, and yogurt, (7) cheese, (8) meat/fish/eggs/vegetarian substitutes, (9) spread and cooking fat (10) low-nutrient, energy-dense foods (e.g., chocolate, sugar products, biscuits, pies, savoury snacks, creams, and confectionery), and (11) low-nutrient, energy-dense drinks (e.g., carbonated soft drinks, juices, and alcoholic drinks). Milk products and cheese were allocated to different food groups because of the important difference in fat content.

2.11. Portion size calculation

PS was calculated by dividing the intake in grams (g) of the items included in the group and reported to be consumed during the 24 h-recall, by the number of eating occasions of these consumed items. In this study, the average amount of PS was calculated from the two days included in the 24 h-recall by each eating occasion. For instance, if an individual consumed 100 g of meat for lunch in the first day and 100 g in the lunch for the second day, then his/her PS at lunch from this food item was 100 g, and if the individual consumed 100 g of meat only in lunch and did not consume meat in any other meal, his/her PS was 100 g. Several studies of food PS effect on overweight in children and adults have used the same methodology [35,36]. Thus, these data represent per consumer averages, not per capita averages, and it is used to show the average change on the PS for those who consume a certain item. Therefore, to analyze a specific food group only participants who consumed this food group were included in the analysis.

2.12. Statistical analysis

Descriptive analysis of mean and standard deviation for general characteristics were presented with Student's t-test for continuous variables. Chi-square test was used to assess the difference of categorical variables between genders. To achieve normality Johnson transformation has been performed for VO2 max, HOMA-IR index, and metabolic risk score. Sensitivity analysis was carried out in order to consider age or pubertal stage in adjustment. Interaction products of gender and markers of body fat in the association between PS from food groups with markers of IR were calculated. Since an interaction effect was observed for gender, all the analyses were performed separately for females and males. Analysis of covariance

(ANCOVA) was also used to determine the mean differences and standard deviations of food PS from the studied food groups by HOMA-IR cutoff categories and metabolic risk score median cutoff categories between gender by using maternal education as covariable for all participants.

The association between PS from food groups as independent variables and HOMA-IR, systolic blood pressure, triglycerides, TC/HDL-c ratio, the sum of six skinfolds and VO2 max, and the metabolic risk score as dependent variables was assessed by multilinear regression analysis. All regression models were adjusted for age, maternal education, PA, total energy intake, BMI, and city as dummy variable. To avoid multiple testing, all analysis were performed individually. The analyses were conducted using IBM-SPSS (v25, SPSS Inc., Chicago, IL, USA), and the level of significance was set to 0.05.

3. Results

3.1. General characteristics of study participants

Sample descriptive characteristics by gender are presented in Table 1. A total of 495 adolescents aged between 12.5 and 17.5 years old were included in this study. More than half (53.5%) of the participants were females. Males had significantly higher mean glucose (p = 0.047), QUICKI (p = 0.010), and VO2 max (p = 0.002), than females.

Table 1 Descriptive characteristics of the study sample.

General characteristics	All participants (n = 495)		p-value
	Males (n = 230)	Females (n = 265)	
	Mean (SD)	Mean (SD)	
Age	14.7 (1.3)	14.7 (1.2)	0.314
Maternal education (n, %)[a]			0.914
Low	69 (30.0%)	90 (33.9%)	
High	161 (70.0%)	175 (66.1%)	
BMI (kg/m^2)	20.6 (3.4)	20.8 (3.3)	0.789
BMI categories (n,%)			0.090
Normal weight	189 (82.2%)	229 (86.4%)	
Overweight	30 (13.0%)	26 (9.8%)	
Obesity	11 (4.8%)	10 (3.8%)	
Glucose (mg/dL)	91.9 (7.2)	88.3 (6.2)	**0.047**
Triglycerides (mg/dL)	65.4 (31.9)	70.8 (30.7)	0.730
Total cholesterol (mg/dL)	152.4 (25.4)	166.2 (27.1)	0.198
Insulin (μIU/mL)	8.9 (6.9)	10.0 (6.8)	0.899
HOMA-IR index[b]	2.1 (1.7)	2.2 (1.7)	0.811
QUICKI	0.4 (0.03)	0.3 (0.03)	**0.010**
SBP (mm Hg)	119.2 (13.0)	112.2 (11.5)	0.102
VO2max (ml/kg/min)	53.2 (7.9)	36.5 (6.4)	**0.002**
Sum of skinfold thickness (mm)	22.4 (11.3)	30.2 (11.8)	0.216
Waist circumference (cm)[b]	72.9 (8.3)	69.9 (7.2)	0.164
Metabolic risk score[c]	−0.81 (3.4)	0.75 (2.7)	0.060
TC/HDL ratio	2.9 (0.6)	2.9 (0.6)	0.680

All values are mean ± standard deviation, or [a] percentage. BMI: body mass index; HOMA-IR index: homeostasis model assessment for insulin resistance; SBP: systolic blood pressure; TC/HDL-c: total cholesterol/high-density lipoprotein cholesterol; VO2max: maximal oxygen uptake. Non transformed data are presented in this table, but analyzes were performed with [b] and [c] Johnson transformation. Level of significance was set to 0.05.

3.2. Association between PS from various food groups and HOMA-IR index and metabolic risk score components (systolic blood pressure, triglycerides, TC/HDL-c ratio, sum of six skinfolds, and VO2 max) by gender

The results are showing no significant association between food PS and HOMA-IR index (Table 2), and all of metabolic risk score components except VO2 max in both genders (Supplementary Tables S1–S4) after adjustment for age, maternal education, PA, total energy intake, BMI, and city.

3.3. Association between PS from various food groups and VO2 max stratified by gender

The result from Table 3 shown that in males, larger PS from vegetables (β = 0.001; p = 0.048), milk, yoghurt, and milk beverages (β = 0.002; p = 0.026) were associated with higher VO2 max; while larger PS from margarines and vegetable oils (β = -0.004; p = 0.025) were associated with lower VO2 max. In females, larger PS from vegetables (β = 0.001; p = 0.007) were associated with higher VO2 max, taking in consideration the adjustment for age, maternal education, PA, total energy intake, BMI, and city.

3.4. Association between PS from various food groups and metabolic risk score

Table 4 illustrates the results of multilinear regression model by gender using metabolic risk score categories as a dependent variable and PS of food as independent variables. The model was adjusted for age, maternal education, PA, total energy intake, BMI, and city. The results indicates that males with larger PS consumption from fish and fish products (β = 0.007; p = 0.015); meat substitutes, nuts, and pulses (β = 0.018; p = 0.032); cakes, pies, and biscuits (β = 0.005; p = 0.010); sugar, honey, jams, and chocolate (β = 0.005; p = 0.009) have higher metabolic risk score. Females with only larger PS from cakes, pies, and biscuits (β = 0.005; p = 0.030) have higher metabolic risk score.

3.5. Relationship between PS mean intake from food groups and HOMA-IR cutoff categories by gender

PS mean intake characteristics were obtained from the different food groups and HOMA-IR cutoff categories using mother's education as covariable (ANCOVA) for all participants (Table 5). The results indicate that males with lower HOMA-IR cutoff consumed higher mean PS from vegetables (p = 0.036) and milk, yoghurt, and milk beverages (p = 0.040). In the same line, females with lower HOMA-

Table 2 The association between food PS and HOMA-IR index in a selected sample of European adolescents, by gender.

Food Groups (g/day)	HOMA-IR index							
	Males (n = 230)				Females (n = 265)			
	β	95% CI		P-value	β	95% CI		P-value
		Lower	Upper			Lower	Upper	
Bread and Cereals								
Bread and rolls	0.011	−0.002	0.003	0.589	−0.003	−0.007	0.001	0.102
Breakfast cereals	−0.010	−0.022	0.003	0.212	−0.007	−0.014	0.001	0.051
Grains and potato								
Rice and other grains	0.050	−0.004	0.009	0.500	−0.012	−0.002	0.005	0.847
Starch roots, potatoes	−0.001	−0.003	0.002	0.512	−0.001	−0.002	0.001	0.561
Pasta	0.004	−0.001	0.003	0.589	0.002	0.000	0.004	0.087
Fruits	0.051	−0.010	0.006	0.052	0.007	−0.005	0.003	0.507
Vegetables	0.002	0.001	0.003	0.066	0.002	−0.001	0.002	0.654
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	0.001	−0.005	0.001	0.065	0.002	−0.001	0.002	0.160
Desserts and puddings milk based	−0.007	−0.012	0.003	0.067	−0.004	−0.004	0.003	0.164
Cheese	0.001	−0.002	0.005	0.792	−0.025	−0.008	0.002	0.614
Meat/poultry/fish/eggs								
Meat and poultry	0.002	−0.003	0.002	0.546	0.003	−0.002	0.005	0.253
Fish and fish products	0.013	−0.004	0.001	0.298	0.005	−0.001	0.009	0.845
Eggs	−0.015	−0.008	0.007	0.771	0.002	−0.003	0.002	0.524
Meat substitutes, nuts, pulses	−0.045	−0.055	0.096	0.105	−0.010	−0.009	0.018	0.096
Spread and cooking fats								
Margarines and vegetable oils	0.011	−0.008	0.008	0.912	0.006	−0.009	0.016	0.395
Butter and animal fats	0.023	−0.005	0.007	0.136	0.019	−0.019	0.005	0.950
Low nutrient energy- dense food								
Cakes, pies, biscuits	0.012	−0.010	0.009	0.104	0.001	−0.002	0.002	0.600
Savoury snacks	−0.003	−0.004	0.004	0.507	0.006	−0.002	0.012	0.213
Sugar, honey, jams, chocolate	−0.005	−0.002	0.006	0.460	−0.004	−0.001	0.006	0.105
Sauces and creams	0.003	−0.008	0.005	0.136	0.019	−0.020	0.000	0.248
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	0.001	−0.003	0.003	0.391	0.006	0.002	0.009	0.125
Fruit and vegetables juices	0.008	−0.004	0.009	0.235	0.003	−0.002	0.011	0.161

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, PA, total energy intake, BMI and city. Level of significance was set to 0.05.

IR cutoff consumed higher mean PS from breakfast cereals ($p = 0.010$). Contrary, females with higher HOMA-IR cutoff, consumed higher mean PS from butter and animal fats ($p = 0.018$).

3.6. Relationship between PS mean intake from food groups and metabolic risk score median cutoff categories by gender

The results indicate that no significant relationship between food PS and metabolic risk score median cutoff categories (**Supplementary Table S5**).

4. Discussion

The main results suggest that there is an association between PS of some food groups and a metabolic risk score in adolescence. Specifically, we identified that larger PS from cakes, pies, biscuits in males and females were associated with higher metabolic risk score. Meanwhile, PS from fish; meat substitutes, nuts, and pulses; and sugar, honey, jams, and chocolate were associated with a higher metabolic risk score in males, considering potential confounders, such as PA, total energy intake, BMI, city, and maternal education.

4.1. Portion size of specific food groups and metabolic risk score components

Out of the components of the metabolic risk score, significant results were found only for VO2 max, a marker of cardiorespiratory fitness. We found that larger PS from vegetables in both genders and milk, yoghurt, and milk beverages were associated with higher VO2 max in males, while larger PS from margarines and vegetable oils were associated with lower VO2 max in males. In general, fruit and vegetables are one of the most abundant source of natural flavonoids Quercetin [37]. Noteworthy, these compounds play an important role as antioxidant and anti-inflammatory activity, in addition to the most prominent role which is the ability to increase mitochondrial biogenesis in both muscle and brain in mice [38]. In adults, low doses of the naturally occurring dietary flavonoid quercetin were associated with a modestly higher VO2 max [39]. Similarly, in young adult, it has been observed a significantly higher levels of VO2 max in the vegetarian compared with omnivores [40]. Moreover, it has been found that adolescents with the highest cardiorespiratory fitness are the most active and tend to consume higher fruits and vegetables [41].

Table 3 The association between food PS and VO2 max in a selected sample of European adolescents, by gender.

Food Groups (g/day)	VO2 Max							
	Males (n = 230)				Females (n = 265)			
	β	95% CI		P-value	β	95% CI		P-value
		Lower	Upper			Lower	Upper	
Bread and Cereals								
Bread and rolls	0.006	−0.005	0.004	0.605	−0.002	−0.022	−0.001	0.990
Breakfast cereals	0.002	−0.002	0.002	0.150	0.003	−0.003	0.010	0.110
Grains and potato								
Rice and other grains	0.006	−0.001	0.003	0.104	0.000	−0.002	0.001	0.376
Starch roots, potatoes	0.022	−0.008	0.004	0.467	0.005	−0.005	0.015	0.293
Pasta	0.031	−0.023	0.014	0.450	0.021	−0.013	0.011	0.219
Fruits	0.001	−0.002	0.005	0.232	0.002	−0.001	0.004	0.154
Vegetables	0.033	−0.002	0.015	**0.038**	0.026	−0.007	0.009	**0.012**
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	0.009	−0.001	0.008	**0.006**	0.000	0.000	0.001	0.559
Desserts and puddings milk based	0.004	−0.010	0.000	0.079	0.005	−0.004	0.003	0.374
Cheese	0.001	−0.009	0.002	0.090	0.002	−0.005	0.003	0.754
Meat/poultry/fish/eggs								
Meat and poultry	0.009	−0.006	0.002	0.150	0.030	−0.015	0.009	0.059
Fish and fish products	0.005	−0.013	0.003	0.420	0.003	−0.005	0.009	0.400
Eggs	0.001	−0.006	0.008	0.772	0.001	−0.001	0.003	0.445
Meat substitutes, nuts, pulses	0.002	−0.003	0.007	0.205	−0.001	−0.003	0.004	0.306
Spread and cooking fats								
Margarines and vegetable oils	−0.008	−0.012	0.009	**0.015**	0.003	−0.003	0.010	0.267
Butter and animal fats	0.004	−0.001	0.012	0.508	0.002	−0.032	0.005	0.508
Low nutrient energy- dense food								
Cakes, pies, biscuits	0.000	−0.001	0.002	0.692	−0.002	−0.004	0.000	0.067
Savoury snacks	0.004	−0.003	0.010	0.288	−0.007	−0.014	0.001	0.077
Sugar, honey, jams, chocolate	−0.001	−0.003	0.002	0.512	−0.001	−0.002	0.001	0.561
Sauces and creams	0.000	−0.003	0.002	0.687	−0.009	−0.003	0.002	0.937
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	0.000	−0.003	0.002	0.686	0.002	0.000	0.004	0.087
Fruit and vegetables juices	0.000	−0.001	0.001	0.701	0.000	−0.001	0.001	0.617

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, PA, total energy intake, BMI and city. Level of significance was set to 0.05

4.2. Portion size of specific food groups and metabolic risk score

Regarding metabolic risk score, we found that larger PS from cakes, pies, biscuits in males and females were associated with higher metabolic risk score. PS from fish and fish products; meat substitutes; nuts, pulses, and sugar; and honey, jams, and chocolate were associated with higher metabolic risk score in males. In a previous study in adolescents, significant differences were found, in the consumption of pretzels, chips, ham, and burgers between the group with MS and those who did not have the syndrome [15].

In adult men, it has been noticed that seafood consumption was significantly associated with elevated high-sensitivity C-reactive protein levels, after adjustment for age, PA, and BMI [42]. However, contrary to our results, a study found that low-fat meats and fish and fish products consumption was negatively associated with the inflammatory response in adults [43]. In this study, higher intake of fish and fish products was associated with higher metabolic risk score. The benefits of increased fish and fish products consumption on health have been associated to its content of omega 3 and PUFA, but fish consumption contributes with considerable amounts of other nutrients that may have an effect on the metabolic score [44]. The possible explanation of our results is that processed fish such as fish cakes, fish balls, fish pudding, and fish fingers are made from lean fish filet mixed with other ingredients like: milk and flour; moreover, it has been found that these products contain free or added sugars and saturated and trans-fats that makes them high energy dense food, these fish products represent nearly 40% of the total fish consumption [45]. The lack of health benefits from processed fish may partly be explained by a reduction of some of the nutrients present during the processing such as deep-fried, fried, boiled, or minced, and therefore, they contain a higher amount of total fat. Additionally, these products previously contained trans-fatty acids that are known to be associated with lowered HDL-level [46].

Moreover, an increased frequency of consumption of fruits and vegetables, and dairy products decreased the probability of having MS in adolescents [47], while the probability of having MS increased along with the consumption of solid hydrogenated fat, and bread made with white flour in both genders [47]. Similarly, a systematic review focusing on European dietary patterns and MS from various age groups concluded that higher intake of meat or meat products, desserts, and sugar-sweetened beverages, which are considered as a good source of

Table 4 The association between food PS and a metabolic risk score in a selected sample of European adolescents, by gender.

Food Groups (g/day)	Metabolic risk score							
	Males (n = 230)				Females (n = 265)			
	B	95% CI		P-value	β	95% CI		P-value
		Lower	Upper			Lower	Upper	
Bread and Cereals								
Bread and rolls	0.000	−0.002	0.001	0.435	0.003	−0.002	0.001	0.695
Breakfast cereals	−0.003	−0.002	0.007	0.209	0.005	−0.003	0.012	0.210
Grains and potato								
Rice and other grains	−0.001	−0.002	0.001	0.380	0.001	−0.001	0.003	0.461
Starch roots, potatoes	−0.001	−0.001	0.003	0.215	0.000	−0.002	0.001	0.522
Pasta	−0.006	−0.002	0.001	0.758	0.000	−0.002	0.001	0.666
Fruits	0.003	−0.001	0.001	0.936	0.000	−0.001	0.000	0.428
Vegetables	0.011	−0.012	0.002	0.058	0.001	−0.008	0.002	0.097
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	−0.002	0.000	0.001	0.056	0.002	−0.010	0.001	0.559
Desserts and puddings milk based	−0.001	−0.002	0.003	0.456	−0.002	−0.005	0.000	0.077
Cheese	0.002	−0.001	0.004	0.298	0.001	−0.003	0.004	0.285
Meat/poultry/fish/eggs								
Meat and poultry	0.000	−0.001	0.000	0.157	−0.002	−0.001	0.001	0.959
Fish and fish products	0.005	−0.012	0.020	**0.007**	0.001	−0.003	0.002	0.593
Eggs	0.001	−0.006	0.008	0.772	0.001	−0.001	0.003	0.445
Meat substitutes, nuts, pulses	0.031	0.006	0.050	**0.001**	0.004	−0.004	0.014	0.307
Spread and cooking fats								
Margarines and vegetable oils	0.013	−0.005	0.002	0.050	0.001	−0.003	0.010	0.267
Butter and animal fats	0.000	−0.009	0.008	0.848	−0.002	−0.012	0.008	0.698
Low nutrient energy-dense food								
Cakes, pies, biscuits	0.004	0.001	0.023	**0.036**	0.004	−0.012	0.003	**0.020**
Savoury snacks	0.015	−0.004	0.019	0.147	0.025	−0.002	0.012	0.184
Sugar, honey, jams, chocolate	0.023	0.009	0.028	**0.009**	−0.001	−0.007	0.006	0.728
Sauces and creams	−0.003	−0.002	0.002	0.974	−0.006	−0.002	0.002	0.945
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	0.005	−0.001	0.009	0.763	0.003	−0.004	0.001	0.254
Fruit and vegetables juices	−0.000	−0.001	0.012	0.101	0.002	−0.002	0.000	0.243

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, PA, total energy intake, BMI and city. Level of significance was set to 0.05.

saturated fatty acids, salts, and added sugars, have been associated with higher risk of MS [48]. In contrast, higher intake from vegetables, fruits, whole cereals, and fish and fish products were associated with a reduced risk of MS [48].

Interestingly, the associations between PS of sugar-rich products such as cakes, pies, and biscuits and sugar, honey, jams, and chocolate were associated with a higher metabolic risk score. It has been confirmed that sucrose and mainly fructose induce MS [49]. For example, in young men, serum triacylglycerol increased when receiving a diet supplemented with 200 g sucrose/day; moreover, one-third of these patients developed hyperinsulinemia [49]. In addition, consumption of sugar-sweetened beverages has the same result on MS development, which may be explained by less satiety-inducing effects and a high-glycemic-index, which raises the postprandial glucose levels [50]. The mechanism was associated to the inability of sugar to acutely stimulate insulin and leptin and to inhibit ghrelin that are known to affect the satiety center in the central nervous system [51]. Moreover, the sweetness of fructose or sucrose often makes food more palatable, which may stimulate an increase in food intake [52].

4.3. Portion size of specific food groups and HOMA-IR cutoff

Our results indicated that males with lower HOMA-IR cutoff were consuming higher mean PS from vegetables, milk, yoghurt, and milk beverages. In the same manner, females with lower HOMA-IR cutoff were consuming higher mean PS from breakfast cereals. In contrast, females with higher HOMA-IR cutoff were consuming higher mean PS from butter and animal fats. These results are in line with other studies which observed that consumption of vegetables, low-fat dairy, cruciferous vegetables, tomato, chicken, and beans and low consumption of butter, red meat, and cereals was associated with low levels of HOMA-IR in adults [53]. On the contrary, they found that consumption of processed meats, mayonnaise, and solid fats was associated with a higher level of fasting blood glucose, fasting insulin, 2-h insulin, and HOMA-IR index [53]. A previous HELENA study also found that frequently consumption of nuts, chocolates, burgers, and meat stick in females and frequently consumption of burgers and pizzas in males were directly associated with HOMA-IR index [12]. Moreover, a marked preference for sweet and low fruit consumption and IR were observed in other

Table 5 Mean PS from the main contributing food groups by HOMA-IR cut off categories, in both gender (ANCOVA).

Food groups PS (g/day)	Males (n = 230)					Females (n = 265)				
	[a]HOMA-IR cut off≤2.5		HOMA-IR cut off >2.5		p-value	HOMA-IR cut off≤2.5		HOMA-IR cut off >2.5		p-value
	N	Mean (SD)	N	Mean (SD)		N	Mean (SD)	N	Mean (SD)	
Bread and rolls	146	134.1 (82.5)	42	144.2 (74.9)	0.228	166	111.3 (70.7)	67	93.1 (49.3)	0.493
Breakfast cereals	48	54.6 (30.5)	21	70.7 (50.3)	0.479	63	49.9 (28.6)	19	28.5 (10.8)	**0.010**
Rice and other grains	57	192.1 (135.9)	15	225.2 (117.5)	0.817	55	156.2 (95.7)	21	128.0 (75.1)	0.976
Starch roots, potatoes	76	159.2 (89.1)	16	158.4 (62.4)	0.993	103	142.4 (87.7)	45	123.8 (74.3)	0.244
Pasta	64	217.9 (109.9)	14	218.7 (105.7)	0.698	73	178.1 (73.5)	26	215.0 (113.5)	0.149
Fruits	98	244.1 (153.3)	26	239.8 (153.9)	0.778	121	206.2 (125.5)	43	194.1 (130.2)	0.954
Vegetables	127	193.4 (122.6)	37	136.4 (115.7)	**0.036**	149	133.6 (112.3)	63	128.2 (99.7)	0.784
Milk, yoghurt, and milk beverages	120	434.1 (354.6)	34	348.9 (217.7)	**0.040**	137	317.1 (212.9)	51	279.5 (168.4)	0.188
Desserts and puddings milk based	29	105.6 (74.1)	6	52.3 (24.8)	0.060	55	89.2 (68.9)	15	76.3 (45.7)	0.693
Cheese	119	57.4 (42.9)	31	77.9 (48.36)	0.314	123	44.3 (34.2)	52	43.6 (29.9)	0.989
Meat and poultry	147	237.1 (200.6)	37	260.6 (225.3)	0.265	144	161.6 (133.5)	66	178.5 (134.6)	0.331
Fish and fish products	30	208.5 (172.1)	5	108.6 (54.3)	0.251	30	156.3 (132.9)	13	145.9 (118.9)	0.439
Eggs	28	53.5 (41.5)	9	55.8 (34.1)	0.512	52	51.5 (42.6)	15	62.4 (50.1)	0.715
Meat substitutes, nuts, pulses	29	61.5 (57.0)	10	27.9 (10.9)	0.120	40	82.5 (76.1)	12	75.9 (56.4)	0.962
Margarines and vegetable oils	102	27.1 (13.4)	26	37.4 (30.1)	0.188	97	18.9 (16.4)	43	19.9 (17.1)	0.515
Butter and animal fats	57	28.8 (23.5)	14	22.9 (13.6)	0.496	58	18.9 (13.6)	25	27.3 (24.9)	**0.018**
Cakes, pies, biscuits	109	115.9 (84.8)	26	106.7 (78.2)	0.798	132	98.5 (78.8)	50	104.3 (101.1)	0.377
Savoury snacks	38	62.8 (51.3)	6	55.8 (42.9)	0.671	43	38.2 (25.2)	14	32.9 (15.5)	0.457
Sugar, honey, jams, chocolate	106	74.4 (62.4)	26	68.7 (55.4)	0.920	133	63.2 (50.8)	57	42.6 (36.5)	0.138
Sauces and creams	107	67.0 (52.8)	22	77.9 (49.1)	0.494	113	64.2 (54.1)	44	73.9 (56.3)	0.343
Carbonated soft/isotonic drinks	99	529.9 (325.2)	26	529.9 (416.1)	0.824	102	462.3 (309.4)	32	419.2 (262.6)	0.869
Fruit and vegetables juices	103	408.6 (319.7)	30	351.3 (209.3)	0.162	105	332.2 (241.5)	51	352.9 (180.1)	0.437

[a] HOMA-IR cut off categorized based on the 90th percentile. SD: Standard deviation. Level of significance was set to 0.05.

study in adolescents [15]. However, to the best of our knowledge, there are no studies addressing the relationship between food PS and HOMA-IR index.

The possible explanation of these results is that vegetables, fruits, and cereals are a good source of antioxidants mainly polyphenols and fibers, in addition to the significant amount of magnesium, calcium, potassium and having a limited amount of sodium, which play an important role in IR in all age groups [54]. For instance, individuals with low levels of serum magnesium have impaired blood sugar levels [55]; it has been found that the lack of magnesium can result in disordered transfer of the cellular glucose, which influencing in insulin signaling pathways or even reducing the pancreatic secretion of insulin [56]. Furthermore, a high amount of sodium intake has been associated with IR and MS development in adults [57].

Moreover, the type and quality of fats in the diet play an important role in homeostasis and insulin sensitivity [58]. It seems that the fatty acid combination or fat type can affect independently on insulin function and lead to change the cells sensitivity to insulin [59]. However, in adolescents with obesity, a positive effect when consumption of omega-3 fatty acids on insulin sensitivity has been identified [60]. Consumption of milk and yogurt is another factor that has been examined on IR syndrome; it has been shown that the daily consumption of dairy and calcium cause a reduction of the IR syndrome, cardiovascular disease, blood pressure, and stroke in young adults [53].

In this study, no significant relationship between food PS and continuous HOMA-IR index was found, which may be associated with the very restrictive model with various confounders. However, some relevant results when analyzing the results considering the HOMA-IR cutoff values were observed, as it was discussed previously.

Several studies have attempted to explain the association of dietary indexes on the development of IR and MS, but most of them do not focus on PS of food items. Although the effect sizes in our study were small, further studies are needed to confirm the association between food PS and the metabolic markers.

The main limitation of this study is the relatively small sample size. Further studies with larger population samples and longitudinal observation are needed. Moreover, the HELENA study was performed some years ago, and it is not useful to describe the current situation. Additionally, the cross-sectional nature of the HELENA study does not allow us to assess the behavior over a period of time and did not provide information in determining the cause—and—effect association. The self-reported questionnaires were used for collecting the food consumption data, and therefore, a social bias should be considered. Moreover, the food groups did not differentiate between type of chocolate (black, with milk, etc) and artificially sweetened products from sugar-sweetened products. However, there are several strengths in this study that need to be mentioned. To our best of knowledge, the present study is the first to investigate the association between the PS of different food groups and both IR and metabolic risk among European adolescents, taking into account potential confounders such as age, total energy intake, BMI, PA, city, and maternal education. To increase the accuracy, highly standardized and validated procedures were used to collect the sample and assess anthropometric measurements. Despite the limitation, these results may suggest useful information to promote proper selection of healthy foods for early prevention of MS and other health concerns.

Conclusion

Larger PS from cakes, pies, and biscuits were associated with a higher metabolic risk score, and PS from fish and fish products; meat substitutes; nuts, pulses, and sugar; and honey, jams, and chocolate were associated with a higher metabolic risk score in males. Noteworthy, these results suggests that there are associations between PS of sugar-based foods and metabolic risk already in adolescence. Larger PS from vegetables, cereals, and dairy products enhance the VO2 max and might reduce developing IR. Overall, these findings suggest that intervention studies should focus on the food PS and not only on the potential effect of food habits and energy density in order to prevent IR and metabolic risk in youth.

Author contributions

The HELENA study was designed and contributed to get the funding by Moreno. L, Gonzalez-Gross. M, Castillo. M, Molnár.D, Stehle. P, Widhalm. K, Kafatos. A, and Dallongeville.J. The supervision procedure and acquisition of data were done by Moreno. L, and Gonzalez-Gross.M. Field work contribution and data analysis were conducted by Castillo. M, Marcos. A, Gottrand. F, Huybrechts. I and the rest of authors. Molnár.D was responsible for the body composition work package. Flieh. S analyzed the data and wrote the manuscript Miguel-Berges. M, González-Gil. EM and Moreno. L critically revised the manuscript, provided essential comments, and supervised all procedures. All coauthor revised the manuscript and provided their essential comments. All authors have read and agreed to the published version of the manuscript.

Funding

HELENA study received funding from the European Community Sixth RTD Framework Program (Contract FOODCT-2005-007034). E.M.G.-G. holds a Juan de la Cierva-Formación grant from the Spanish Government (FJCI-2017-34,967).

Institutional review board statement

The HELENA study was approved by the ethics committees in all countries, and followed good clinical practice, ethical guidelines of the Declaration of Helsinki 1964 (revision of 2000), and the legislation about clinical research in humans in each one of the countries involved in the study. The ethical approval code from the coordinator centre was 03/2006; date of approval: February 2006, obtained from the Ethical Committee of clinical research in Aragon (CEICA).

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Data availability statement

The data presented in this study are available for further scientific analysis on request from the coordinator of the HELENA study to the following. e-mail: lmoreno@unizar.es.

IARC disclaimer

Where authors are identified as personnel of the International Agency for Research on Cancer/World Health Organization, the authors alone are responsible for the views expressed in this article, and they do not necessarily represent the decisions, policy or views of the International Agency for Research on Cancer/World Health Organization.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

We are grateful for the support provided by school boards, headmasters, teachers, school staff and communities, and the effort of all study nurses, laboratory technicians, and our data managers.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2022.05.017.

HELENA Study Group.

Coordinator: Luis A. Moreno.

Core Group members: Luis A. Moreno, Fréderic Gottrand, Stefaan De Henauw, Marcela González-Gross, Chantal Gilbert.

Steering Committee: Anthony Kafatos (President), Luis A. Moreno, Christian Libersa, Stefaan De Henauw, Sara Castelló, Fréderic Gottrand, Mathilde Kersting, Michael Sjöstrom, Dénes Molnár, Marcela González-Gross, Jean Dallongeville, Chantal Gilbert, Gunnar Hall, Lea Maes, Luca Scalfi.

Project Manager: Pilar Meléndez.

1. Universidad de Zaragoza (Spain):

Luis A. Moreno, José A. Casajús, Jesús Fleta, Gerardo Rodríguez, Concepción Tomás, María I. Mesana, Germán Vicente-Rodríguez, Adoración Villarroya, Carlos M. Gil, Ignacio Ara, Juan Fernández Alvira, Gloria Bueno, Olga Bueno, Juan F. León, Jesús M^a Garagorri, Idoia Labayen, Iris Iglesia, Silvia Bel, Luis A. Gracia Marco, Theodora Mouratidou, Alba Santaliestra-Pasías, Iris Iglesia, Esther González-Gil, Pilar De Miguel-Etayo, Mary Miguel-Berges, Isabel Iguacel, Azahara Rupérez.

2. Consejo Superior de Investigaciones Científicas (Spain):

Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez, Ligia Esperanza Díaz, Javier Romeo, Ana Veses, Belén Zapatera, Tamara Pozo, David Martínez.

3. Université de Lille 2 (France):

Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, Juliana Von Berlepsch.

4. Research Institute of Child Nutrition Dortmund, Rheinische Friedrich—Wilhelms—Universität Bonn (Germany):

Mathilde Kersting, Wolfgang Sichert-Hellert, Ellen Koeppen.

5. Pécsi Tudományegyetem (University of Pécs) (Hungary):

Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs. Angster, Enikö Nagy, Orsolya Kovács, Judit Répasi.

6. University of Crete School of Medicine (Greece):

Anthony Kafatos, Caroline Codrington, María Plada, Angeliki Papadaki, Katerina Sarri, Anna Viskadourou, Christos Hatzis, Michael Kiriakakis, George Tsibinos, Constantine Vardavas, Manolis Sbokos, Eva Protoyeraki, Maria Fasoulaki.

7. Institut für Ernährungs-und Lebensmittelwissenschaften—Ernährungphysiologie. Rheinische Friedrich Wilhelms Universität (Germany):

Peter Stehle, Klaus Pietrzik, Marcela González-Gross, Christina Breidenassel, Andre Spinneker, Jasmin Al-Tahan, Miriam Segoviano, Anke Berchtold, Christine Bierschbach, Erika Blatzheim, Adelheid Schuch, Petra Pickert.

8. University of Granada (Spain):

Manuel J. Castillo, Ángel Gutiérrez, Francisco B Ortega, Jonatan R Ruiz, Enrique G Artero, Vanesa España, David Jiménez-Pavón, Palma Chillón, Cristóbal Sánchez-Muñoz, Magdalena Cuenca.

9. Council for Agricultural Research and Economics, Research Centre for Food and Nutrition (Italy) (former INRAN):

Davide Arcella, Elena Azzini, Emma Barrison, Noemi Bevilacqua, Pasquale Buonocore, Giovina Catasta, Laura Censi, Donatella Ciarapica, Paola D'Acapito, Marika Ferrari, Myriam Galfo, Cinzia Le Donne, Catherine Leclercq, Giuseppe Maiani, Beatrice Mauro, Lorenza Mistura, Antonella Pasquali, Raffaela Piccinelli, Angela Polito, Romana Roccaldo, Raffaella Spada, Stefania Sette, Maria Zaccaria.

10. University of Napoli “Federico II” Dept of Food Science (Italy):

Luca Scalfi, Paola Vitaglione, Concetta Montagnese.

11. Ghent University (Belgium):

Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere, Inge Huybrechts.

12. Medical University of Vienna (Austria):

Kurt Widhalm, Katharina Phillipp, Sabine Dietrich, Birgit Kubelka, Marion Boriss-Riedl.

13. Harokopio University (Greece):

Yannis Manios, Eva Grammatikaki, Zoi Bouloubasi, Tina Louisa Cook, Sofia Eleutheriou, Orsalia Consta, George Moschonis, Ioanna Katsaroli, George Kraniou, Stalo Papoutsou, Despoina Keke, Ioanna Petraki, Elena Bellou, Sofia Tanagra, Kostalenia Kallianoti, Dionysia Argyropoulou, Stamatoula Tsikrika, Christos Karaiskos.

14. Institut Pasteur de Lille (France):

Jean Dallongeville, Aline Meirhaeghe.

15. Karolinska Institutet (Sweden):

Michael Sjöstrom, Jonatan R Ruiz, Francisco B. Ortega, María Hagströmer, Anita Hurtig Wennlöf, Lena Hallström, Emma Patterson, Lydia Kwak, Julia Wärnberg, Nico Rizzo.

16. Asociación de Investigación de la Industria Agroalimentaria (Spain):

Jackie Sánchez-Molero, Sara Castelló, Elena Picó, Maite Navarro, Blanca Viadel, José Enrique Carreres, Gema Merino, Rosa Sanjuán, María Lorente, María José Sánchez.

17. Campden BRI (United Kingdom):

Chantal Gilbert, Sarah THOMA-IRs, Elaine Allchurch, Peter Burgess.

18. SIK - Institutet foer Livsmedel och Bioteknik (Sweden):

Gunnar Hall, Annika Astrom, Anna Sverkén, Agneta Broberg.

19. Meurice Recherche & Development asbl (Belgium):

Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, Laurence Fontaine.

20. Campden & Chorleywood Food Development Institute (Hungary):

Andras Sebok, Tunde Kuti, Adrienn Hegyi.

21. Productos Aditivos SA (Spain):

Cristina Maldonado, Ana Llorente.

22. Cárnicas Serrano SL (Spain):

Emilio García.

23. Cederroth International AB (Sweden):

Holger von Fircks, Marianne Lilja Hallberg, Maria Messerer.

24. Lantmännen Food R&D (Sweden):

Mats Larsson, Helena Fredriksson, Viola Adamsson, Ingmar Börjesson.

25. European Food Information Council (Belgium):

Laura Fernández, Laura Smillie, Josephine Wills.

26. Universidad Politécnica de Madrid (Spain):

Marcela González-Gross, Raquel Pedrero-Chamizo, Agustín Meléndez, Jara Valtueña, David Jiménez-Pavón, Ulrike Albers, Pedro J. Benito, Juan José Gómez Lorente, David Cañada, Alejandro Urzanqui, Rosa María Torres, Paloma Navarro.

References

[1] DeBoer M. Assessing and managing the metabolic syndrome in children and adolescents. Nutrients 2019;11(8). https://doi:10.3390/nu11081788.

[2] Kao K, Sabin M. Type 2 diabetes mellitus in children and adolescents. Aust Fam Physician 2016;45(6).

[3] Zimmermann M, Aeberli I. Dietary determinants of subclinical inflammation, dyslipidemia and components of the metabolic syndrome in overweight children: a review. Int J Obes 2008; 32(Suppl 6) (2005), https://doi:10.1038/ijo.2008.202.

[4] Christensen P, Meinert Larsen T, Westerterp-Plantenga M, Macdonald I, Martinez JA, Handjiev S, et al. Men and women respond differently to rapid weight loss: metabolic outcomes of a multi-centre intervention study after a low-energy diet in 2500 overweight, individuals with pre-diabetes (PREVIEW). Diabetes Obes Metabol 2018;20(12). https://doi:10.1111/dom.13466.

[5] Kim J, Jeon J. Role of exercise on insulin sensitivity and beta-cell function: is exercise sufficient for the prevention of youth-onset type 2 diabetes? Ann Pediat Endocrinol Metabol 2020;25(4). https://doi:10.6065/apem.2040140.070.

[6] Reaven G. Insulin resistance: the link between obesity and cardiovascular disease. Med Clin 2011;95(5). https://doi:10.1016/j.mcna.2011.06.002.

[7] Aeberli I, Spinas G, Lehmann R, l'Allemand D, Molinari L, Zimmermann MB. Diet determines features of the metabolic syndrome in 6- to 14-year-old children. Int J Vitam Nutrit Res Int Zeitsch Vitam Ernahrungsforschung J Int Vitaminol Nutri 2009; 79(1). https://doi:10.1024/0300-9831.79.1.14.

[8] Apovian C. The causes, prevalence, and treatment of obesity revisited in 2009: what have we learned so far? Am J Clin Nutr 2010;91(1). https://doi:10.3945/ajcn.2009.28473A.

[9] Flieh S, Miguel-Berges M, González-Gil E, Gottrand F, Censi L, Widhalm K, et al. The association between portion sizes from high-energy-dense foods and body composition in European adolescents: the HELENA study. Nutrients 2021;13(3). https://doi:10.3390/nu13030954.

[10] Young L, Nestle M. Expanding portion sizes in the US marketplace: implications for nutrition counseling. J Am Diet Assoc 2003; 103(2). https://doi:10.1053/jada.2003.50027.

[11] Karatzi K, Moschonis G, Barouti A, Lionis C, Chrousos GP, Manios Y. Dietary patterns and breakfast consumption in relation to insulin resistance in children. Healthy Growth Study Public Health Nutr 2014;17(12). https://doi:10.1017/S1368980013003327.

[12] Sesé M, Jiménez-Pavón D, Gilbert C, González-Gross M, Gottrand F, de Henauw S, et al. Eating behaviour, insulin resistance and cluster of metabolic risk factors in European adolescents. HELENA study 2012;59(1). Appetite, https://doi:10.1016/j.appet.2012.04.011.

[13] Kynde I, Johnsen N, Wedderkopp N, Bygbjerg IB, Helge JW, Heitmann BL. Intake of total dietary sugar and fibre is associated with insulin resistance among Danish 8-10- and 14-16-year-old girls but not boys. European Youth Heart Studies I and II. Publ Health Nutr 2010;13(10). https://doi:10.1017/S1368980010000285.

[14] Harrington S. The role of sugar-sweetened beverage consumption in adolescent obesity: a review of the literature. J Sch Nurs Offic Publ Nat Assoc School Nurses 2008;24(1). https://doi:10.1177/10598405080240010201.

[15] Pedrozo W, Rascón M, Bonneau G, de Pianesi MI, Olivera CC, de Aragón SJ, et al. Revista panamericana de salud publica = Pan. Am J Publ Health 2008;24(3). https://doi:10.1590/s1020-49892008000900001.

[16] Ambrosini G, Huang R, Mori T, Hands BP, O'Sullivan TA, de Klerk NH, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. Nutrition, metabolism, and cardiovascular diseases. Nutr Metabol Cardiovasc Dis 2010;20(4). https://doi:10.1016/j.numecd.2009.03.024.

[17] Moreno L, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L, et al. Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents: the HELENA (healthy Lifestyle in Europe by nutrition in adolescence) study. Publ Health Nutr 2008;11(3). https://doi:10.1017/S1368980007000535.

[18] Henauw SD, Gottrand F, Bourdeaudhuij ID, Gonzalez-Gross M, Leclercq C, Kafatos A, et al. Nutritional status and lifestyles of adolescents from a public health perspective. The HELENA Project—healthy Lifestyle in Europe by nutrition in adolescence. OriginalPaper. J Public Health 2007;15(3):187—97. https://doi:10.1007/s10389-007-0107-3.

[19] Moreno L, De Henauw S, González-Gross M, Kersting M, Molnár D, Gottrand F, et al. Design and implementation of the healthy Lifestyle in Europe by nutrition in adolescence cross-sectional study. Int J Obes 2008;32(Suppl 5) (2005), https://doi:10.1038/ijo.2008.177.

[20] Goldberg G, Black A, Jebb S, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 1991;45(12).

[21] The world medical association-declaration of Helsinki. Initiated; 2000. 1964:17.C.

[22] Béghin L, Castera M, Manios Y, Gilbert CC, Kersting M, De Henauw S, et al. Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA cross-sectional study. Int J Obes 2008;32(Suppl 5) (2005), https://doi:10.1038/ijo.2008.179.

[23] UNESCO. International Standard Classification of Education. http://www.uis.unesco.org/Education/Documents/isced-2011-en.pdf.

[24] Béghin L, Dauchet L, De Vriendt T, Cuenca-García M, Manios Y, Toti E, et al. Influence of parental socio-economic status on diet quality of European adolescents: results from the HELENA study. Br J Nutr 2014;111(7). https://doi:10.1017/S0007114513003796.

[25] Nagy E, Vicente-Rodriguez G, Manios Y, Béghin L, Iliescu C, Censi L, et al. Harmonization process and reliability assessment of anthropometric measurements in a multicenter study in adolescents. Int J Obes 2008;32(Suppl 5) (2005), https://doi:10.1038/ijo.2008.184.

[26] Cole T, Bellizzi M, Flegal K, Dietz W. Establishing a standard definition for Child overweight and obesity worldwide: international Survey. BMJ (Clinical research ed) 2000;320(7244). https://doi:10.1136/bmj.320.7244.1240.

[27] Slaughter M, Lohman T, Boileau R, Horswill CA, Stillman RJ, Van Loan MD, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol 1988;60(5).

[28] Hagströmer M, Bergman P, De Bourdeaudhuij I, Ortega FB, Ruiz JR, Manios Y, et al. Concurrent validity of a modified version of the international physical activity questionnaire (IPAQ-A) in European adolescents: the HELENA study. Int J Obes 2005;32(Suppl 5). https://doi:10.1038/ijo.2008.182.

[29] Ainsworth B, Haskell W, Whitt M, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sportics Exerc 2000;32(9 Suppl). https://doi:10.1097/00005768-200009001-00009.

[30] González-Gross M, Breidenassel C, Gómez-Martínez S, Ferrari M, Béghin L, Spinneker A, et al. Sampling and processing of fresh blood samples within a European multicenter nutritional study: evaluation of biomarker stability during transport and storage. Int J Obes 2008;32(Suppl 5) (2005), https://doi:10.1038/ijo.2008.185.

[31] Léger L, Lambert J, Goulet A, Rowan C, Dinelle Y. Canadian journal of applied sport sciences. J Can Sci Appl Sport 1984;9(2).

[32] Katz A, Nambi S, Mather K, Baron AD, Follmann DA, Sullivan G, et al. Quantitative insulin sensitivity check index: a simple, accurate method for assessing insulin sensitivity in humans. J Clin Endocrinol Metab 2000;85(7). https://doi:10.1210/jcem.85.7.6661.

[33] Andersen L, Harro M, Sardinha L, Froberg K, Ekelund U, Brage S, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). Lancet (London, England) 2006;368(9532). https://doi:10.1016/S0140-6736(06)69075-2.

[34] Vereecken C, Covents M, Sichert-Hellert W, Alvira JM, Le Donne C, De Henauw S, et al. Development and evaluation of a self-administered computerized 24-h dietary recall method for

adolescents in Europe. Int J Obes 2008;32(Suppl 5) (2005), https://doi:10.1038/ijo.2008.180.

[35] Lioret S, Volatier JL, Lafay L, Touvier M, Maire B. Is food portion size a risk factor of childhood overweight? Eur J Clin Nutr 2009; 63(3):382–91. https://doi:10.1038/sj.ejcn.1602958.

[36] Pereira J, Mendes A, Crispim S, Marchioni DM, Fisberg RM. Association of overweight with food portion size among adults of são Paulo - Brazil. PLoS One 2016;11(10). https://doi:10.1371/journal.pone.0164127.

[37] Harwood M, Danielewska-Nikiel B, Borzelleca J, Flamm GW, Williams GM, Lines TC. Critical review of the data related to the safety of quercetin and lack of evidence of in vivo toxicity, including lack of genotoxic/carcinogenic properties. Food Chem Toxicol Int J Publ Br Ind Biol Res Assoc 2007;45(11). https://doi:10.1016/j.fct.2007.05.015.

[38] Davis J, Murphy E, Carmichael M, Davis B. Quercetin increases brain and muscle mitochondrial biogenesis and exercise tolerance. Am J Physiol Regul Integr Comp Physiol 2009;296(4). https://doi:10.1152/ajpregu.90925.2008.

[39] Davis J, Carlstedt C, Chen S, Carmichael MD, Murphy EA. The dietary flavonoid quercetin increases VO(2max) and endurance capacity. Int J Sport Nutr Exerc Metabol 2010;20(1). https://doi:10.1123/ijsnem.20.1.56.

[40] Boutros G, Landry-Duval M, Garzon M, Karelis AD. Is a vegan diet detrimental to endurance and muscle strength? Eur J Clin Nutr 2020;74(11). https://doi:10.1038/s41430-020-0639-y.

[41] Howe A, Skidmore P, Parnell W, Wong JE, Lubransky AC, Black KE. Cardiorespiratory fitness is positively associated with a healthy dietary pattern in New Zealand adolescents. Publ Health Nutr 2016;19(7). http://doi:10.1017/S1368980015002566.

[42] Nanri H, Nakamura K, Hara M, Higaki Y, Imaizumi T, Taguchi N, et al. Association between dietary pattern and serum C-reactive protein in Japanese men and women. J Epidemiol 2011;21(2). https://doi:10.2188/jea.je20100110.

[43] Yeo R, Yoon S, Kim O. The association between food group consumption patterns and early metabolic syndrome risk in non-diabetic healthy people. Clin Nutr Res 2017;6(3). https://doi:10.7762/cnr.2017.6.3.172.

[44] Carpentier Y, Portois L, Malaisse W. n-3 fatty acids and the metabolic syndrome. Am J Clin Nutr 2006;83(6 Suppl). https://doi:10.1093/ajcn/83.6.1499S.

[45] Christine T, Marianne M, Milada C. Lean fish consumption is associated with beneficial changes in the metabolic syndrome components: a 13-year follow-up study from the Norwegian tromsø study. Nutrients 2017;9(3):247 (in en), https://doi:10.3390/nu9030247.

[46] Yanai H, Katsuyama H, Hamasaki H, Abe S, Tada N, Sako A. Effects of dietary fat intake on HDL metabolism. J Clin Med Res 2015;7(3). https://doi:10.14740/jocmr2030w.

[47] Kelishadi R, Gouya M, Adeli K, Ardalan G, Gheiratmand R, Majdzadeh R, et al. Factors associated with the metabolic syndrome in a national sample of youths: CASPIAN Study. Nutrition, metabolism, and cardiovascular diseases. Nutr Metabol Cardiovasc Dis 2008;18(7). https://doi:10.1016/j.numecd.2007.02.014.

[48] Martínez-González M, Martín-Calvo N. The major European dietary patterns and metabolic syndrome. Rev Endocr Metab Disord 2013;14(3). https://doi:10.1007/s11154-013-9264-6.

[49] Raben A, Vasilaras T, Møller A, Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. Am J Clin Nutr 2002;76(4). http://doi:10.1093/ajcn/76.4.721.

[50] McKeown N, Meigs J, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care 2004;27(2). http://doi:10.2337/diacare.27.2.538.

[51] Teff K, Elliott S, Tschöp M, Kieffer TJ, Rader D, Heiman M, et al. Dietary fructose reduces circulating insulin and leptin, attenuates postprandial suppression of ghrelin, and increases triglycerides in women. J Clin Endocrinol Metab 2004;89(6). http://doi:10.1210/jc.2003-031855.

[52] Yudkin J. Evolutionary and historical changes in dietary carbohydrates. Am J Clin Nutr 1967;20(2). http://doi:10.1093/ajcn/20.2.108.

[53] Ehrampoush E, Nazari N, younfar R, Ghaemi A, Osati S, Tahamtan S, et al. Association between dietary patterns with insulin resistance in an Iranian population, vol. 36. Clinical nutrition ESPEN; 2020. https://doi:10.1016/j.clnesp.2020.02.011.

[54] Guasch-Ferré M, Merino J, Sun Q, Fitó M, Salas-Salvadó J. Dietary polyphenols, Mediterranean diet, prediabetes, and type 2 diabetes: a narrative review of the evidence. Oxidative medicine and cellular longevity. Epub; 2017. https://doi:10.1155/2017/6723931.

[55] Ferguson MA, Gutin B, Owens S, Litaker M, Tracy RP, Allison J. Fat distribution and hemostatic measures in obese children. Am J Clin Nutr 1998;67(6):1136–40. https://doi:10.1093/ajcn/67.6.1136.

[56] Sales C, Pedrosa L, Lima J, Lemos TM, Colli C. Influence of magnesium status and magnesium intake on the blood glucose control in patients with type 2 diabetes. Clin Nutr (Edinb) 2011;30(3). https://doi:10.1016/j.clnu.2010.12.011.

[57] Baudrand R, Campino C, Carvajal C, Olivieri O, Guidi G, Faccini G, et al. High sodium intake is associated with increased glucocorticoid production, insulin resistance and metabolic syndrome. Clin Endocrinol 2014;80(5). https://doi:10.1111/cen.12225.

[58] Sears B, Perry M. The role of fatty acids in insulin resistance. Lipids Health Dis 2015;14. https://doi:10.1186/s12944-015-0123-1.

[59] Silva Figueiredo P, Carla Inada A, Marcelino G, Maiara Lopes Cardozo C, de Cássia Freitas K, de Cássia Avellaneda Guimarães R, et al. Fatty acids consumption: the role metabolic aspects involved in obesity and its associated disorders. Nutrients 2017;9(10). https://doi:10.3390/nu9101158.

[60] Dangardt F, Chen Y, Gronowitz E, Dahlgren J, Friberg P, Strandvik B. High physiological omega-3 Fatty Acid supplementation affects muscle Fatty Acid composition and glucose and insulin homeostasis in obese adolescents. Journal of nutrition and metabolism 2012. https://doi:10.1155/2012/395757.

Table S1**:** Association between food portion size and triglycerides between gender in selected sample of European adolescents.

Food Groups (g/day)	**Triglycerides**							
	Males				**Females**			
	β	**95% CI**		**P-value**	**β**	**95% CI**		**P-value**
		Lower	**Upper**			**Lower**	**Upper**	
Bread and Cereals								
Bread and rolls	0.000	-0.001	0.002	0.692	-0.002	-0.004	0.000	0.067
Breakfast cereals	0.004	-0.003	0.010	0.288	-0.007	-0.014	0.001	0.077
Grains and potato								
Rice and other grains	0.000	-0.003	0.002	0.687	-0.009	-0.003	0.002	0.937
Starch roots, potatoes	-0.001	-0.003	0.002	0.512	-0.001	-0.002	0.001	0.561
Pasta	0.000	-0.003	0.002	0.686	0.002	0.000	0.004	0.087
Fruits	-0.005	-0.010	0.001	0.050	-0.006	-0.001	0.012	0.107
Vegetables	-0.001	-0.009	0.002	0.059	-0.003	-0.001	0.004	0.054
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	0.000	-0.001	0.000	0.064	0.000	-0.001	0.000	0.162
Desserts and puddings milk based	0.005	-0.010	0.000	0.073	-0.002	-0.005	0.001	0.154
Cheese	0.000	-0.003	0.004	0.790	-0.001	-0.005	0.003	0.654
Meat/poultry/fish/eggs								
Meat and poultry	0.000	-0.001	0.001	0.856	0.000	0.000	0.001	0.314
Fish and fish products	0.001	-0.001	0.003	0.398	-0.001	-0.003	0.002	0.995
Eggs	-0.001	-0.009	0.008	0.877	0.000	-0.004	0.005	0.918
Meat substitutes, nuts, pulses	0.002	-0.008	0.004	0.565	0.000	-0.004	0.005	0.886
Spread and cooking fats								
Margarines and vegetable oils	0.002	-0.004	0.007	0.512	-0.002	-0.012	0.007	0.633
Butter and animal fats	-0.003	-0.015	0.008	0.554	0.000	-0.013	0.012	0.948
Low nutrient energy- dense food								
Cakes, pies, biscuits	0.001	-0.001	0.003	0.144	0.000	-0.002	0.001	0.576
Savoury snacks	-0.002	-0.008	0.004	0.467	0.005	-0.005	0.015	0.293
Sugar, honey, jams, chocolate	-0.001	-0.003	0.001	0.490	-0.001	-0.003	0.001	0.203
Sauces and creams	0.001	-0.002	0.005	0.412	0.002	-0.001	0.004	0.254
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	0.000	-0.001	0.000	0.521	0.000	0.000	0.001	0.568
Fruit and vegetables juices	0.000	-0.001	0.000	0.345	0.000	0.000	0.001	0.301

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, physical activity, total energy intake, BMI and city. Level of significance was set to 0.05.

Table S2: Association between food portion size and systolic blood pressure between gender in selected sample of European adolescents.

Food Groups (g/day)	**Systolic blood pressure**							
	Males (n=230)				**Females (n=265)**			
	β	**95% CI**		**P-value**	**β**	**95% CI**		**P-value**
		Lower	**Upper**			**Lower**	**Upper**	
Bread and Cereals								
Bread and rolls	0.000	-0.002	0.001	0.365	0.003	-0.002	0.001	0.095
Breakfast cereals	0.003	-0.002	0.007	0.129	0.005	-0.003	0.012	0.220
Grains and potato								
Rice and other grains	-0.001	-0.002	0.001	0.380	0.001	-0.001	0.003	0.461
Starch roots, potatoes	0.001	-0.001	0.003	0.215	0.000	-0.002	0.001	0.522
Pasta	0.000	-0.002	0.001	0.758	0.000	-0.002	0.001	0.666
Fruits	0.003	-0.001	0.001	0.936	0.000	-0.001	0.000	0.428
Vegetables	-0.001	-0.005	0.002	0.058	-0.009	-0.003	0.005	0.067
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	0.005	0.000	0.003	0.096	0.000	0.000	0.001	0.559
Desserts and puddings milk based	0.001	-0.002	0.003	0.666	-0.002	-0.005	0.000	0.087
Cheese	0.002	-0.001	0.004	0.258	0.001	-0.003	0.004	0.785
Meat/poultry/fish/eggs								
Meat and poultry	0.000	-0.001	0.000	0.157	-0.002	-0.001	0.001	0.959
Fish and fish products	-0.001	-0.002	0.001	0.487	0.001	-0.001	0.002	0.421
Eggs	0.001	-0.006	0.008	0.772	0.001	-0.001	0.003	0.445
Meat substitutes, nuts, pulses	0.002	-0.003	0.007	0.404	-0.001	-0.003	0.004	0.616
Spread and cooking fats								
Margarines and vegetable oils	0.003	-0.008	0.012	0.125	0.003	-0.003	0.010	0.267
Butter and animal fats	0.000	-0.009	0.008	0.848	-0.002	-0.012	0.008	0.698
Low nutrient energy- dense food								
Cakes, pies, biscuits	-0.001	-0.002	0.001	0.408	0.000	-0.001	0.001	0.771
Savoury snacks	0.000	-0.004	0.003	0.847	0.005	-0.002	0.012	0.184
Sugar, honey, jams, chocolate	0.000	-0.001	0.001	0.858	0.004	-0.002	0.001	0.651
Sauces and creams	-0.003	-0.002	0.002	0.974	-0.006	-0.002	0.002	0.945
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	-0.005	-0.001	0.000	0.763	0.000	-0.001	0.000	0.284
Fruit and vegetables juices	0.000	-0.001	0.000	0.111	0.000	-0.001	0.000	0.283

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, physical activity, total energy intake, BMI and city. Level of significance was set to 0.05.

Table S3: Association between food portion size and TC/HDL-c ratio between gender in selected sample of European adolescents.

Food Groups (g/day)	**TC/HDL-c ratio**							
	Males (n=230)				**Females (n=265)**			
	β	**95% CI**		**P-value**	**β**	**95% CI**		**P-value**
		Lower	**Upper**			**Lower**	**Upper**	
Bread and Cereals								
Bread and rolls	0.001	-0.001	0.003	0.376	0.004	-0.005	0.002	0.259
Breakfast cereals	0.006	-0.002	0.013	0.125	0.003	-0.005	0.011	0.467
Grains and potato								
Rice and other grains	0.001	-0.001	0.003	0.421	0.001	-0.002	0.004	0.574
Starch roots, potatoes	0.001	-0.002	0.004	0.542	0.001	-0.001	0.002	0.583
Pasta	0.000	-0.002	0.003	0.928	-0.002	-0.004	0.001	0.197
Fruits	0.002	-0.002	0.001	0.742	0.001	-0.001	0.002	0.322
Vegetables	0.000	-0.002	0.001	0.402	0.001	-0.003	0.001	0.530
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	0.001	-0.002	0.001	0.861	0.000	0.000	0.001	0.664
Desserts and puddings milk based	0.002	-0.003	0.007	0.497	0.002	-0.001	0.005	0.209
Cheese	-0.002	-0.006	0.003	0.475	0.005	-0.001	0.000	0.050
Meat/poultry/fish/eggs								
Meat and poultry	-0.001	-0.002	0.000	0.058	0.000	-0.001	0.001	0.590
Fish and fish products	0.001	-0.002	0.005	0.447	0.000	-0.002	0.003	0.765
Eggs	-0.001	-0.012	0.010	0.849	-0.003	-0.007	0.002	0.222
Meat substitutes, nuts, pulses	-0.005	-0.014	0.005	0.342	-0.002	-0.001	0.002	0.958
Spread and cooking fats								
Margarines and vegetable oils	0.001	-0.004	0.007	0.629	-0.004	-0.015	0.008	0.538
Butter and animal fats	0.009	-0.003	0.021	0.134	-0.001	-0.015	0.013	0.906
Low nutrient energy- dense food								
Cakes, pies, biscuits	0.001	-0.002	0.003	0.490	-0.001	-0.003	0.001	0.223
Savoury snacks	0.003	-0.006	0.013	0.475	-0.004	-0.017	0.009	0.551
Sugar, honey, jams, chocolate	0.000	-0.002	0.003	0.819	0.001	-0.002	0.001	0.619
Sauces and creams	0.004	-0.002	0.001	0.052	-0.002	-0.005	0.001	0.145
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	0.000	0.000	0.001	0.533	0.000	-0.001	0.000	0.299
Fruit and vegetables juices	0.000	0.000	0.000	0.105	0.000	-0.001	0.001	0.659

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, physical activity, total energy intake, BMI and city. Level of significance was set to 0.05.

Table S4: Association between food portion size and sum of six Skin folds between gender in selected sample of European adolescents.

	Sum of six Skin folds							
	Males (n=230)				**Females (n=265)**			
Food Groups (g/day)	**β**	**95% CI**		**P-value**	**β**	**95% CI**		**P-value**
		Lower	**Upper**			**Lower**	**Upper**	
Bread and Cereals								
Bread and rolls	-0.003	-0.024	0.017	0.749	-0.016	-0.042	0.017	0.204
Breakfast cereals	0.073	-0.006	0.151	0.069	-0.037	-0.123	0.048	0.387
Grains and potato								
Rice and other grains	0.017	-0.006	0.040	0.159	-0.037	-0.009	0.050	0.058
Starch roots, potatoes	0.003	-0.020	0.026	0.776	0.005	-0.017	0.024	0.650
Pasta	-0.013	-0.034	0.008	0.216	0.008	-0.022	0.037	0.610
Fruits	-0.004	-0.017	0.009	0.515	-0.006	-0.021	0.010	0.480
Vegetables	0.001	-0.009	0.006	0.850	0.006	-0.009	0.022	0.409
Milk, milk desserts and yogurt								
Milk, yoghurt, and milk beverages	-0.002	-0.007	0.003	0.480	-0.001	-0.009	0.007	0.827
Desserts and puddings milk based	-0.022	-0.071	0.026	0.359	-0.020	-0.060	0.027	0.396
Cheese	0.040	-0.003	0.082	0.067	0.002	-0.055	0.058	0.951
Meat/poultry/fish/eggs								
Meat and poultry	-0.008	-0.016	0.000	0.050	0.014	-0.002	0.001	0.059
Fish and fish products	-0.003	-0.024	0.017	0.734	0.019	-0.008	0.045	0.163
Eggs	-0.049	-0.063	0.095	0.492	0.002	-0.039	0.042	0.938
Meat substitutes, nuts, pulses	-0.024	-0.113	0.065	0.580	0.007	-0.028	0.053	0.756
Spread and cooking fats								
Margarines and vegetable oils	0.038	-0.033	0.010	0.289	-0.074	-0.059	0.015	0.374
Butter and animal fats	-0.041	-0.155	0.073	0.476	0.052	-0.080	0.184	0.433
Low nutrient energy- dense food								
Cakes, pies, biscuits	-0.023	-0.045	0.000	0.052	0.003	-0.017	0.023	0.794
Savoury snacks	-0.005	-0.060	0.051	0.860	-0.003	-0.047	0.039	0.465
Sugar, honey, jams, chocolate	-0.009	-0.033	0.015	0.451	-0.010	-0.039	0.015	0.503
Sauces and creams	0.004	-0.027	0.034	0.816	0.029	-0.004	0.030	0.058
Low nutrient energy- dense drinks								
Carbonated soft/isotonic drinks	-0.002	0.006	0.003	0.536	-0.001	-0.008	0.005	0.664
Fruit and vegetables juices	0.000	-0.005	0.002	0.890	-0.002	-0.011	0.007	0.666

β: regression coefficient. CI: confidence interval; Adjusting for confounders: age, maternal education, physical activity, total energy intake, BMI and city. Level of significance was set to 0.05.

Table S5. Portion size mean intake from the main contributing food groups by median cut off metabolic risk score categories between gender (ANCOVA).

	Males (n=230)					**Females (n=265)**				
Food groups portion size (g/day)	Group 1*		Group 2*		p-value	Group 1		Group 2		p-value
	N	Mean (SD)	N	Mean (SD)		N	Mean (SD)	N	Mean (SD)	
Bread and rolls	117	135.4 (78.2)	86	139.9 (91.7)	0.589	60	98.0 (57.8)	179	107.9 (67.5)	0.247
Breakfast cereals	39	51.9 (31.2)	36	68.0 (48.3)	0.129	20	48.7 (23.9)	64	43.7 (27.7)	0.458
Rice and other grains	42	186.6 (123.5)	36	190.1 (146.0)	0.882	17	154.1 (107.9)	60	146.8 (85.6)	0.779
Starch roots, potatoes	61	159.7 (90.1)	41	143.6 (72.7)	0.273	45	144.6 (79.2)	109	137.1 (88.5)	0.627
Pasta	49	214.9 (111.1)	34	216.9 (103.9)	0.758	31	199.6 (101.6)	73	183.8 (77.6)	0.472
Fruits	81	240.8 (153.7)	54	238.5 (149.8)	0.878	52	172.8 (99.0)	118	211.6 (135.0)	0.083
Vegetables	101	154.9 (132.5)	78	134.9 (123.7)	0.436	54	137.3 (123.7)	162	132.1 (109.5)	0.789
Milk, yoghurt, and milk beverages	97	417.1 (349.2)	70	385.5 (288.2)	0.620	55	308.7 (197.2)	140	307.9 (201.6)	0.927
Desserts and puddings milk based	22	100.5 (57.3)	16	88.8 (82.6)	0.927	21	82.2 (53.2)	50	86.7 (69.5)	0.748
Cheese	93	57.5 (43.6)	66	70.5 (50.1)	0.100	43	39.2 (23.2)	135	45.9 (35.4)	0.234
Meat and poultry	112	248.2 (197.2)	85	238.9 (209.2)	0.769	51	165.4 (130.6)	166	165.5 (133.7)	0.952
Fish and fish products	21	191.7 (188.6)	21	159.9 (121.4)	0.562	11	143.7 (105.1)	32	156.4 (134.7)	0.930
Eggs	19	57.9 (35.1)	26	56.8 (48.9)	0.776	23	57.9 (44.5)	49	54.3 (50.1)	0.740
Meat substitutes, nuts, pulses	22	75.1 (57.0)	24	44.8 (38.1)	0.146	13	60.1 (41.9)	41	88.1 (77.9)	0.217
Margarines and vegetable oils	80	27.6 (13.4)	57	30.4 (26.1)	0.793	35	19.2 (16.8)	108	19.4 (16.4)	0.834

Butter and animal fats	40	28.1 (21.2)	34	31.2 (27.6)	0.487	17	22.3 (15.7)	66	21.2 (18.7)	0.804
Cakes, pies, biscuits	88	112.2 (81.1)	56	122.8 (95.1)	0.456	56	126.8 (110.9)	133	89.1 (67.6)	0.377
Savoury snacks	31	65.6 (55.8)	18	56.6 (41.2)	0.532	22	37.1 (23.4)	36	36.2 (23.3)	0.769
Sugar, honey, jams, chocolate	82	73.5 (74.2)	60	85.9 (65.3)	0.413	53	43.0 (39.8)	141	62.2 (56.3)	0.052
Sauces and creams	82	66.2 (52.1)	58	73.3 (53.2)	0.370	41	68.2 (52.5)	120	66.1 (55.3)	0.854
Carbonated soft/isotonic drinks	79	526.9 (342.3)	54	571.8 (354.8)	0.481	33	400.5 (216.7)	105	473.9 (317.9)	0.236
Fruit and vegetables juices	84	342.6 (227.6)	59	462.9 (351.0)	0.053	45	284.6 (132.9)	115	358.9 (243.4)	0.077

Group1 and Group 2: classified according to median cut off metabolic risk score. SD: Standard deviation. p-value < 0.05.

5. Discussion

The findings from this Doctoral Thesis suggest that psychosomatic and emotional status could be a trigger to consume large PS from sweet-fatty energy dense foods. Large food PS may be associated with positive energy, as well as macro- and micronutrient intake. Low intakes of some vitamins and micronutrients were noticed when larger portions of high ED foods such as ‘desserts and pudding’, ‘margarines and vegetable oils’ and ‘butter and animal fats’ were consumed. Moreover, we found that large PS from high ED food is associated with elevated energy intake which leads to obesity and other metabolic complication in childhood and adolescent. Moreover, it is the first to study the association between food portion sizes, insulin resistance, VO2 max and metabolic syndrome, and we found that large PS from vegetables, fruits, dairy products were associated with higher Vo2 max and lower probability of obesity.

In article I, the review of the literature suggested that there is a need for research studies in both, laboratory and free-living contexts, to determine the causal link between increased PS, energy intake, obesity, and related metabolic complications in childhood and adolescents. Also, strategies are needed on PS estimation and on the relationship of PS with certain health problems such as obesity, insulin resistance, and emotional eating in all age groups, in order to provide information for parents, teachers, and health professionals aiming to promote healthy eating. A wide range of controlled laboratory studies have found that food PS had the strongest effect on the amount of food consumed in comparison to other studied factors such as food variety, and food palatability. The effect of PS on total energy intake has been already observed with different types of foods and beverages, especially with high ED foods. Although a direct causal link between PS and obesity remains controversial, some health and dietetics organizations recommend to moderate PS, especially for energy-dense foods. The influence of large PS was persistent and happened regardless of demographic characteristics such as age, gender, income level, or body mass index.

5.1. Psychosomatic and emotional status and selected food portion sizes

The main results of article II, indicate that, in cross-sectional and longitudinal analysis, females with high motional and peer problems score tend to consume more sugar-fatty food products at school age adolescents. However, in the longitudinal analysis, higher KINDL score, that refers to emotional well-being and self-esteem, was associated with consumption of larger PS from ‘milk and yoghurt’ in both genders in school age children. On the other hand, higher peer problems score was associated with consumption of large PS from ‘bread and rolls’, ‘margarine and lipids’, and ‘dairy products’ in all genders and age groups.

Psychosomatic and emotional status and food portion sizes

The theory of emotional eating implies that overeating can occur in response to negative emotions (142). In 14 years adolescents, it has been found that a high intake of fried food, cakes, chocolate, biscuits, and soft drinks were linked to poorer behavioural and emotional problems scores (143). Moreover, previous I. Family study results found that a higher perception of warmth at home was robustly associated with a 16 % increase in fruits and vegetables consumption frequency (144) and ED food consumption (58). These results support our finding in which adolescents’ females with higher emotional and peer problems score tend to consume larger PS from sugar-fatty food products.

In our study we found that higher KINDL score in children, which meant high well-being, was associated with consumption of smaller PS from high ED foods. The same finding were observed in previous studies which found that participants who are in the top 33% on the SDQ hyperactivity sub-scale at age 7 years were eating a diet high in “junk food” in early childhood (145). Moreover, positive associations were observed between peer problems and both sweet and fatty foods consumption, while a negative association was observed for fruits and vegetables consumption in children (63).

There are several possible explanation for our results; firstly, high ED foods that are generally rich in fats and often in added sugars are palatable, easily accessible, and convenient (146). It was shown that eating palatable foods reduced negative mood in the short run, especially among emotional eaters (147). The underlying mechanism could be a difference in sensitivity to the reward properties of food in emotional eaters compared with non-emotional eaters (148, 149). It is also possible that the consumption of such foods relies on their ability to distract from negative emotions in emotional eaters (150). “Comfort foods” were also posited to counter the influence of the physiologic effects of stress (150) with blunted hypothalamic–pituitary–adrenal axis reactivity and cortisol stress responses in emotional eaters (151). Finally, emotional eaters' preferences for high ED foods could also be explained by the fact that pleasure may be derived from eating “forbidden” foods in the context of cognitive control impairment triggered by negative affect (152).

Gender and age differences

In the present study, associations between emotional status and consumption of PS of high ED snack foods in both genders were found, with generally stronger associations in females. However, all of the previous studies in children and adolescents did not take into account gender differences even though it's well known that males and females grow in different dietary pattern especially during adolescence, with boys increasing energy intake in order to increase satiety and with an important proportion of females controlling their energy intake to control body weight (153). Moreover, in this age group meal size decreased among females, while it remains stable or increased among males, highlighting the necessity to stratify by gender. Among the possible explanations is that comfort foods preferences are influenced by gender, with females preferring sweet snack foods (154); in addition, ovarian hormones that were shown to predict changes in emotional status across the menstrual cycle, suggesting that females would be more susceptible to engage in emotional status at some hormonal phases (155). Another potential explanation in relation to psychosomatic and emotional status could be due to an interaction with genetic vulnerability (156). Among older adolescents, the serotonin-transporter gene-linked polymorphic region genotype was shown to moderate the relation between depressive feelings and an increase in emotional status in females only (156). In our study we found that age groups differ in their response to psychosomatic and emotional status. Several factors may explain the difference according to age for the psychosomatic and emotional score. Firstly, the diet of primary school children is still highly influenced and controlled by parents (157). Therefore, psychosomatic children may have a high desire to eat, but do eventually not get access to the food via their parents or at least not that their parents know (158). This explains our results of an inverse relation between higher SDQ score, and large PS consumption from high ED food in children only.

5.2. Food portion sizes, energy and nutrient intakes

In article II we found that energy intake increased with elevated intakes of high ED foods. Specifically, larger portions of cheese and butter and animal fat were significantly associated with a higher fat intake. Lower intakes of some vitamins and micronutrients were related to consumption of larger portions of high energy-dense foods, such as 'desserts and pudding', 'margarine and vegetable oil', and 'butter and animal fat'. Previous HELENA and other European studies found that carbohydrate and fat intake were similar to the European food based dietary guidelines (159), while protein intake was twice as high (121, 160). The findings of this study are in line with current dietary guidelines by WHO (161) and European food based dietary guidelines (159) which recommend choosing cereals, roots, fruit and vegetables, nuts and seeds, and dairy products as a principal source for carbohydrates intake. These food groups have higher fibre (except dairy) content and considered as low carbohydrate content food and low glycaemic index in addition to higher water content (159, 161). We found that lower intakes of fat were observed when larger portions of sugar-based ED foods were consumed. A possible explanation for this finding is the 'sugar–fat see-saw' phenomenon, i.e., when the energy percentage from sugar intakes increase, the fat intakes decrease (162, 163).

Moreover, we found that large portions from 'butter and fats' were associated with lower intakes of several vitamins such as vitamin C, vitamin B12 and minerals like calcium, iron, potassium, and zinc. One possible explanation is that when fat content increased, water-soluble vitamins content, including niacin, folate, vitamin B12 and vitamin C decreased, as well as minerals such as iron, and potassium (164).

In our study, large portions from 'meat substitutes, nuts and pulses' were associated with higher intakes of iron, potassium, zinc, and vitamin K. However, when the HELENA study was performed, the food market of the meat substitutes was not that large and common like it is today.

In addition, large portions from 'cheese' were associated with higher vitamin D intake, and higher 'eggs' PS were associated with higher iron, sodium, potassium, and vitamin B12 intake. The same results have been found in Irish children and adolescents; their vitamin D intake increased when large portions from cheese were consumed, while their iron intakes were significantly increased on the days larger portions of baked beans were eaten (69).

However, the possible explanation of the current observations is food displacement. For instance, adolescents who consumed large portions from 'dessert and puddings' had decreased intakes of many macronutrients and micronutrients on the days they were consumed. As the 'dessert and puddings' cannot be responsible for the decreased micronutrients intake per se, but it is possible that the consumption of large portions from this food group displaced other more nutrient-dense snacks, such as fruits or vegetables, from the diet on those days. Moreover, larger food PS may be associated with increased intake of a specific nutrient as a consequence of the composition of the food itself. For example, larger portions of 'cheese' were associated with significantly increased vitamin D intakes on the days they were consumed. Finally, food fortification or enrichments may play an important role in increasing intake of special nutrients, such as increasing vitamin D intake when large portions from 'bread and rolls' were consumed.

5.3. Food portion sizes and body composition

The main results in **article III** suggested that there is an association between PS of specific high ED foods and BMI in adolescence. Specifically, 'Carbonated soft drinks' in boys and 'Bread and rolls' in girls are associated with a high probability of having obesity. Meanwhile, PS from 'Sweet bakery products' was associated with lower probability of having obesity in girls.

In this study, a positive association was observed between PS and BMI for some high ED foods, and there were differences between plausible reporters and under-reporters. Similarly, a positive correlation was found for PS of cakes, biscuits, and cheese and BMI in plausible reporters' adolescents but not in the under-reporters. Meanwhile, the PS of high-fibre breakfast cereals was positively associated with BMI in under-reporters and among all adolescents (25). The possible explanation of the positive association between 'breakfast cereals' and BMI is that may be some type of breakfast cereals contain nuts, sugars, honey, and fruit which increased the ED. However, it was observed that under-reporter children and adolescents were more likely to have overweight or obesity than normal reporters (165). Also, subjects with obesity tend to underreport their consumption to provide socially desirable answers, even in adolescence (166). Noteworthy, several studies in children and adolescents found that one of the main reasons of dietary assessment errors was mis-reporting, mainly because of underreporting (135, 167), which happen frequently in adolescents (168, 169). In this age, under-reporters generally provide lower intakes of ED foods and snacks than plausible reporters because they tend to give socio desirable answers (170), easily forget what they consumed, or/and they tend to have lower ability to report their own dietary intake (171). In addition, adolescents tend to omit their foods consumption by following a dietary restriction as a step to reduce their weight (171). Moreover, it has been noticed that the exclusion of under-reporters or introduced them as covariate can strongly enhance the associations between dietary factors, including ED foods, and obesity (172).

Contrarily, the possible explanation of an inverse relation between PS of 'sweet bakery products' and BMI in plausible reporters' girls, is that adolescents with obesity tend to restrict their intake from sugars and fat foods, as a primary step to reduce weight (173). A hallmark of PS from these food groups is that they belong to the category of 'convenience foods' or fast-food chains, which are sometimes packaged for single-serving consumption, and whose PS has been reported to be increasing such as chocolate, bread, soda, and burgers (174).

Regarding PS from ‘carbonated soft drinks’ and higher probability of having obesity in boys, it should be considered that, in the last decades, PS of some foods, especially those consumed in restaurants such as burgers and soda, has increased dramatically concurrently with obesity prevalence (175). The possible explanation of these results is that liquid carbohydrate such as those contained in soda, or solid Jelly causes less satiety compared with solid carbohydrate sources; thus, increasing consumption of energy-yielding fluids that may enhance the positive energy balance (176, 177).

5.4. Food portion sizes, insulin resistance and metabolic syndrome

The main results of **article IV** suggest that there is an association between PS of some food groups and a metabolic risk score in adolescence. Specifically, we identified that large PS from ‘cakes, pies, biscuits’ in males and females were associated with a higher metabolic risk score. Meanwhile, PS from ‘fish’; ‘meat substitutes, nuts, pulses’; and ‘sugar, honey, jams, chocolate’ were associated with a higher metabolic risk score in males.

Portion sizes of specific food groups and VO2 max

We found that larger PS from vegetables in both genders and ‘milk, yoghurt, and milk beverages’ were associated with higher VO2 max in males, while large PS from ‘margarines and vegetable oils’ were associated with lower VO2 max. In general, fruit and vegetables are one of the most abundant source of natural flavonoids Quercetin (134). Noteworthy, these compounds play an important role as having antioxidant and anti-inflammatory activity, in addition to the most prominent role which is the ability to increase mitochondrial biogenesis in both muscle and brain in mice (178). Similarly, it has been found that adolescents with the highest cardiorespiratory fitness, are the most active (133) and tend to consume more fruits and vegetables (179).

Portion sizes of specific food groups and metabolic risk score

We found that large PS from high ED foods were associated with higher metabolic risk score in males. In the same vein, a systematic review focusing on European dietary patterns and MS from various age groups concluded that, high intake of meat or meat products, desserts and sugar-sweetened beverages, which are considered as good source of saturated fatty acids, salts, and added sugars (180), were associated with higher risk of MS (181). In contrast, high intake from vegetables, fruits, whole cereals and fish were associated with a reduced risk of MS (181).

Interestingly the associations between PS of sugar-rich products such as ‘cakes, pies, biscuits’ and ‘sugar, honey, jams, and chocolate’ were associated with higher metabolic risk score. Several clinical studies have confirmed that sucrose and mainly fructose induce MS in adults (182, 183, 184). In addition, sugar sweetened beverages consumption has the same result on MS development, which may be explained by less satiety-inducing effects and a high-glycaemic-index, thus raising the postprandial glucose levels (185, 186). The mechanism was related to the inability of sugar to acutely stimulate insulin and leptin and to inhibit ghrelin, that are known to affect the satiety centre in the central nervous system (187). Moreover, sweetness of fructose or sucrose often makes food more palatable and this may stimulate an increase in food intake (188).

Portion sizes of specific food groups and HOMA-IR index

Our results indicated that males with lower HOMA-IR values, were consuming higher mean PS from ‘vegetables’, and ‘milk, yoghurt and milk beverages’. At the opposite, females with higher HOMA-IR values, were consuming high mean PS from ‘butter and animal fats’. These results are in line with other studies which observed that consumption of vegetables, low-fat dairy, cruciferous vegetables, tomato, chicken, beans and low consumption of butter, red meat and cereals were associated with low levels of HOMA-IR in adults (189). A previous HELENA study also found that nuts, chocolates, burgers and meat stick frequently consumption in females, and burgers and pizzas in males, were directly associated with HOMA-IR index (94). Moreover, a marked preference for sweet and low fruit consumption and insulin resistance were observed in other study in adolescents (97).

The possible explanation of these results is that vegetables, fruits, and cereals are a good source of antioxidants mainly polyphenols, and fibres, in addition to the significant amount of magnesium, calcium, potassium and having a limited amount of sodium which play an important role in insulin resistance in all age groups (190, 191). For instance, individuals with low levels of serum magnesium have impaired blood sugar levels (19); it has been found that the lack of magnesium can result in disordered transfer of the cellular glucose, which influence in insulin signalling pathways or even reduce the pancreatic secretion of insulin (192).

Moreover, type and quality of fats in the diet play an important role in homeostasis and insulin sensitivity (193). It seems that the fatty acid combination or fat type can affect independently on insulin function and lead to change the cellular sensitivity to insulin (194, 195). Consumption of milk and yogurt is another factor that has been examined on insulin resistance syndrome; studies have shown that the daily consumption of dairy and calcium may cause a reduction of the insulin resistance syndrome, cardiovascular disease, blood pressure, and stroke in young adults (24, 189). These could be explanation on our results in which males with lower HOMA-IR values were consuming higher mean PS from milk, yoghurt, and milk beverages.

5.5. Strengths and limitations

The articles included in this Doctoral Thesis are based on the initial (T0) and follow-up assessment (T1) of IDEFICS and I. Family (T3) and on the HELENA cross-sectional study.

IDEFICS/I. Family study

The main objective of the design of this study was to obtain comparable regions for the development of the intervention, also including a control group. Due to economic limitations and practical considerations, the IDEFICS/I. Family study did not attempt to obtain a representative sample from each country. In addition, since it was a study in which parents/guardians were contacted through schools, it is possible that those individuals without health problems or less aware of their children's health may have presented less motivation to participate. Also, the participation of groups of low and high socioeconomic levels is usually low in this type of study. Without information on non-participants in the study, this bias cannot be quantified. These limitations must be considered when interpreting the data, stratifying by level of education, income, immigration status, and other sociodemographic characteristics. Regarding the socioeconomic distribution in the different participating countries, a low representation of families of low socioeconomic status was observed in the samples of some countries.

The strength of this study is its large, international sample comprising eight European countries, and the longitudinal nature allowing studying emotional status and their relationship with food PS in a larger context than has previously been done. In addition, the fieldwork in the survey centres was performed at the same time using the same standardized protocol. In order to increase the accuracy, highly standardized and validated procedures were used to collect the data. Nevertheless, in article II there were some specific methodological issues. Firstly, this study only assessed a limited number of psychosomatic and emotional outcomes, which were exclusively parent-reported and did not consider children’s perspectives. Unfortunately, we could not examine the severity of the psychosomatic and emotional status as the IDEFICS/I. Family parental questionnaire did not allow to study this objective. Also, a selection or non-participation bias related to education or income level, as well as a response bias cannot be ruled out and may, thus, have influenced prevalence results in both directions (100).

HELENA study

The adolescents' samples in the HELENA study are representative of 10 selected European cities. Selection of participant cities was not random, but was decided according to established criteria, which is the existence of a research group with the capacity to carry out this study. In addition, the cities had to have a population greater than 100,000 inhabitants and be equivalent and comparable in relation to each of the countries and with a large enough sample to ensure the diversity of the population. The schools were randomly selected after stratification by school district. Once again, this mode of contact with parents/guardians and the adolescents themselves can give rise to a bias, as only those subjects who have a real concern for the health of their adolescent consent to participate. In order to increase the accuracy, highly standardized and validated procedures were used to collect the sample and assess anthropometric measurements.

The cross-sectional design of the HELENA study does not allow us to assess the behaviour over a period of time and did not provide information in determining the cause-and-effect association. Moreover, the HELENA study was performed some years ago and not as accurate as the reality now. Also, self-reported questionnaires were used for collecting the food consumption data, and therefore, a recall bias must be considered. The information from holidays or from Fridays and Saturdays was not included, as the 24-h recalls were completed during school days. are considered as the main limitation of all articles (II-V)

However, there are some specific strengths and limitations that need to be taken into account for each paper included in the present thesis:

Article (III), in which we investigated the association between food PS, energy and nutrient intake, there were several strengths. Firstly, the data are based on two 24-h recall of food intake that have been collected from a wide geographical spread and with large cultural dietary diversity. The present study is the first to investigate the association between the food PS and energy, macronutrients and micronutrients intake among European adolescents. The work is novel for its focus on examining a wide range of foods, rather than just high ED foods, which are more typically involved in discussions on food PS. The on the other hand, main limitation of the current work is the high percentage of under- and over-reporters that were detected and the exclusion of all under-reporters and over-reporters could have introduced a secondary 'selection bias' to this analysis. The intake data for Vitamin D is difficult to assess because of the high amount of fortified foods which was not included in the food databases. In addition, vitamin D intake is not a strong determinant for vitamin D status; the most important factor is the skin production within sunlight exposure.

Article (IV), was the first study that investigate the association between the PS of selected high ED foods and body composition among European adolescents. Although residual confounding should be considered when interpreting the results, potential confounders such as age, PA, and SES were taken into account. However, the main limitation is that ED was not calculated from the food groups, so the main selected criteria for analysis were based on those foods identified in other studies as high sources of energy.

In article V, where we assessed the relationship between food PS insulin resistance, VO2 max and metabolic syndrome, there were several strengths in this study that need to be mentioned. To our best of knowledge, the present study is the first to investigate the association between the PS of different food groups and both insulin resistance and metabolic risk among European adolescents, considering potential confounders such as age, total energy intake, BMI, PA, city and maternal education. In order to increase the accuracy, highly standardized and validated procedures were used to collect the sample and assess anthropometric measurements. Despite the limitation, these results may suggest useful information to promote proper selection of healthy foods for early prevention of MS and other health concerns. However, the main limitation of this study is the relatively small sample size. Moreover, the food groups did not differentiate between type of chocolate (black, with milk, etc) and artificially sweetened products from sugar-sweetened products.

5.6. Implications for public health

The main results obtained in this Doctoral Thesis support the theory that, on one hand, large food PS are associated with obesity and other metabolic complications in adolescence, on the other hand, that emotional status could be a trigger to consume large PS from unhealthy food groups especially high ED food in children and adolescents, which could be a trigger to overweight in early stages of life.

These results justify the implementation of preventive strategies on lifestyles, with special emphasis on diet, to prevent obesity and related health complications in adulthood.

In article I of this Thesis, it has been described that food and drink PS have been increasing in recent years. However, it has not been possible to establish a direct causal link between large food PS, especially in the case of high ED foods, and obesity as well as certain MS features. This result is important to develop a well-articulated research framework that systematically tests the interaction between selection of food PS and development of obesity, insulin resistance, and metabolic syndrome in both children and adolescents. **Article II** shows an association between psychosomatic and emotional status and consumption of large PS from unhealthy food groups, especially high ED foods in children and adolescents. These findings call for a consideration of individual psychological states when aiming decreasing unhealthy dietary habits, especially in females. Moreover, children and adolescents should be trained on their emotional coping skills such as problem-solving thinking or asking help instead of seeking solace in food.

The nutrient intake from an early age influenced by the food PS in which large portions consumption can lead to positive energy, and nutrient intakes. In practice, the consumption of nutrients is carried out in a combined way in the form of food. For this reason, conducting studies that assess the association between food PS and macronutrient and micronutrients intake, such as the analysis carried out in **article III** of this Thesis, is of greater clinical relevance when designing clinical practice guidelines to prevent malnutrition. The results of this article support the recommendations found in the guide of the Panel of Experts and the NAOS strategy, in which it is proposed to increase the consumption of fruits and vegetables and reduce the consumption of sugary drinks, to increase the intake of minerals, vitamins and fibre, while reducing the energy supply.

Additionally, in **article IV** of this Thesis, we have analysed associations between PS of high ED foods and obesity in European adolescents. The results of this article have great clinical implication as they show that there is a relationship between food PS consumption mainly high ED food and the risk of obesity. Thus, not only foods individually, but the diet as a whole, must be considered when establishing preventive guidelines for obesity, trying to avoid the development of insulin resistance and other metabolic disorders. When proposing prevention strategies, the diet as a whole should be the main objective. Regarding the relationship between food PS and IR, VO2 max and metabolic syndrome, it must be considered that food PS is a precursor of the development of insulin resistance, and cardiorespiratory fitness which, in turn, are also related with cardiometabolic disturbances. On other hand, **article V** has shown that, as early as adolescence, larger PS from dairy products, cereals, and high ED foods are a significant determinant of IR and VO2 max and larger PS from food with higher content of sugar were associated with higher metabolic risk score. These findings suggest that intervention studies should focus on the food PS, and not only on the potential effect of food habits and ED, in order to prevent insulin resistance and metabolic risk in youth.

A lack of articles has been found on the relationship between food PS and both of obesity, MS development, and emotional status as exposure, so this Thesis contributes to increase the scientific evidence on the importance of a healthy diet, from initial stages of life. In the future, longitudinal studies that explore these associations should be promoted to confirm the results obtained and thus be able to promote effective prevention strategies, with the aim of reducing metabolic complications in adulthood.

6. Main contributions of the thesis

This thesis highlights important results that can be relevant from future studies that aim to assess PS and its associations with obesity and some cardiometabolic complications. The articles included in the thesis add relevant information obtained on the European child and adolescents' population, regarding various aspects such as food PS, food intake, body composition, eating behaviours, and other variables.

These studies will be helpful to:

Article I: Assess the actual impact of PS in children's and adolescence's health such as obesity, insulin resistance and other metabolic disorders, as there are not prior reviews assessing these associations.

Article II: Estimate the association between psychosomatic and emotional status on food PS from high ED groups in childhood and adolescence and innovate ideas that may contribute to delay its effect on eating large food portions. This could include providing individualized counselling, creating personalized nutrition plans, and offering support from family and friends. Take into consideration individual psychological states when aiming to decrease unhealthy dietary habits in children.

Article III: This study could act as helpful guide to plan suitable nutritional and health prevention programs for children and adolescents as we investigated the associations between PS and macro and micronutrients. Prevent malnutrition is key to avoid comorbidities related to dietary intake of large PS by identifying age dependent optimal amounts of foods per portion.

Article IV: Identifying subjects at risk of having obesity or at risk of having cardiometabolic complications by identifying their PS could help to develop tailored diet restriction plans. Enhance nutritional status of children by educating parents about the role of large PS, high ED foods on obesity and encourage them to change food patterns, and lifestyle.

Article V: The findings of this study suggest that intervention studies should focus on the food PS and not only on the potential effect of food habits and high ED. Innovate ideas that may contribute to encourage people and delay the effect of large PS on obesity, insulin resistance, and other metabolic syndrome features according to, culture, lifestyle pattern and socio-economic status. This could involve providing education and resources on healthy eating and exercise habits that could help people make better decisions about their health. In addition, to create a supportive community of peers who are also trying to make healthier choices could support individual choices.

7. Conclusions

Article I. PS of food and beverages has been increasing in the recent years. Although it has not been possible to establish a direct causal link between large food PS, especially from high ED foods, with obesity and certain metabolic syndrome features. To date there are no long-term randomized controlled trials to assess the exposure to large portions and the changes on body weight. Clearly, there is an urgent need to develop a well-articulated research framework that systematically tests the interaction between selection of food PS and development of obesity, insulin resistance and metabolic syndrome in both children and adolescents.

Article II. According to the main results, emotional status may be a factor that leads to larger PS of unhealthy food groups, particularly in female adolescents, which could be linked to overweight. Generally, children and adolescents tend to eat smaller portions of ED food, which may be due to parental control of their food choices. However, it is important to teach children and adolescents how to cope with their emotions in a healthy way, such as problem-solving thinking or asking for help instead of using food as a source of comfort. These findings suggest that individual psychological states should be taken into account when attempting to reduce unhealthy dietary habits, particularly in females. Further research is needed to determine the causal links and investigate the mechanisms that connect emotional status, larger food portion sizes, and weight status.

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

Article IV. large PS of ‘sweet bakery products’ were found to be associated with a lower body composition among plausible females’ reporters, while increase PS from ‘breakfast cereals’ groups were correlated with higher BMI in males. Moreover, in subjects who were considered as plausible reporters, the results showed that large PS from ‘carbonated soft and isotonic drinks' in males and 'bread and rolls' in females were associated with higher probability of having obesity, while large PS of 'sweet bakery products' is associated with lower probability of having obesity in females. Further studies are needed to examine the prolonged exposure to large PS from several high ED food sources and their effect on obesity development. If results are confirmed, this should be followed by nutritional health promotion programs directed to European adolescents to enhance their PS food selection.

Article V. Large PS from 'cakes, pies, biscuits' were associated with higher metabolic risk score, meanwhile PS from 'fish', 'meat substitutes, nuts, pulses' and 'sugar, honey, jams, chocolate' were associated with higher metabolic risk score in males. Noteworthy, these results suggests that there are associations between PS of sugar-based foods and metabolic risk already in adolescence. Large PS from 'vegetables', 'cereals' and 'dairy products' improves the VO2 max and might reduce the risk of developing insulin resistance. Overall, these findings suggest that intervention studies should focus on the food PS, and not only on the influence of food habits and energy density, in order to prevent insulin resistance and metabolic risk in youth.

7. Conclusiones

Artículo I: Las porciones de los alimentos y bebidas ha ido en aumento en los últimos años. Aunque no ha sido posible establecer una relación causal directa entre las grandes pociones de los alimentos, especialmente de los alimentos de alta DE, con la obesidad y ciertas características del síndrome metabólico. Hasta la fecha, no existen ensayos controlados aleatorios a largo plazo para evaluar la exposición a porciones grandes y los cambios en el peso corporal. Claramente, existe una necesidad urgente de desarrollar un marco de investigación bien articulado que pruebe sistemáticamente la interacción entre la selección de porciones de alimentos y el desarrollo de obesidad, resistencia a la insulina y síndrome metabólico en niños y adolescentes.

Artículo II: De acuerdo con los principales resultados, el estado emocional puede ser un factor que lleve a mayores PA poco saludables, especialmente en adolescentes femeninas, lo que podría estar relacionado con el sobrepeso. En general, los niños y adolescentes tienden a comer porciones más pequeñas de alimentos de alta DE, lo que puede deberse al control parental de sus elecciones alimentarias. Sin embargo, es importante enseñar a los niños y adolescentes a lidiar de manera saludable con sus emociones, como el pensamiento de resolución de problemas o pedir ayuda en lugar de usar la comida como fuente de consuelo. Estos hallazgos sugieren que los estados psicológicos individuales deben tenerse en cuenta al intentar reducir los hábitos alimenticios poco saludables, especialmente en las mujeres. Se necesitan más investigaciones para determinar los vínculos causales e investigar los mecanismos que conectan el estado emocional, las porciones de alimentos más grandes y el estado de peso.

Artículo III:

Las grandes PA pueden estar asociadas con una ingesta energética y de nutrientes positiva. Grandes porciones de ‘arroz y otros granos’, ‘raíces y tubérculos almidonados’, y ‘sustitutos de carne, nueces y legumbres’ se asociaron con un aumento en la ingesta de carbohidratos y fibra. Porciones más grandes de ‘queso’ y ‘mantequilla y grasas animales’ se asociaron significativamente con una mayor ingesta de grasas. Se observaron ingestas más bajas de algunas vitaminas y micronutrientes cuando se consumieron porciones más grandes de alimentos de alta densidad energética, como ‘postres y budín’, ‘margarina y aceite vegetal’, y ‘mantequilla y grasas animales’. El presente trabajo identifica qué grandes PA pueden estar asociadas con una ingesta de nutrientes positiva. Además, los hallazgos de este estudio pueden ayudar al desarrollo futuro de orientación dietética en general y específicamente para porciones, y apoyar estrategias dirigidas para abordar la ingesta de ciertos nutrientes en adolescentes.

Artículo IV: Se encontró que las porciones grandes de ‘productos de panadería dulce’ estaban asociados con una composición corporal más saludable entre las chicas, mientras que el aumento de las porciones de los grupos de ‘cereales para el desayuno’ se correlacionó con un índice de masa corporal más alto en los chicos. Además, en los sujetos que se consideraban informantes plausibles, los resultados mostraron que una gran porción de ‘bebidas carbonatadas e isotónicas’ en hombres y pan y panecillos’ en mujeres se asociaron con una mayor probabilidad de tener obesidad, mientras que una gran porción de ‘bebidas dulces’, ‘productos de panadería’ se asociaba con una menor probabilidad de tener obesidad en las mujeres. Se necesitan más estudios para examinar la exposición prolongada a grandes PA de varias fuentes de alimentos de alta DE y su efecto sobre el desarrollo de la obesidad. Si se confirman los resultados, esto debería ir seguido de programas de promoción de la salud nutricional dirigidos a los adolescentes europeos para mejorar las porciones de los alimentos y la selección de éstos.

Artículo V: Las porciones grandes de ‘pasteles, tartas y galletas’ se asociaron con una puntuación de riesgo metabólico más alta, mientras que las porciones de ‘pescado’, ‘sucedáneos de la carne’, ‘nueces y legumbres’ y ‘azúcar, miel, mermeladas y chocolate’ se asociaron con una puntuación de riesgo metabólico más alta en los chicos. Cabe destacar que estos resultados sugieren que existen asociaciones entre las porciones de los alimentos a base de azúcar y el riesgo metabólico ya en la adolescencia. Una porción elevada de ‘vegetales’, ‘cereales’ y ‘productos lácteos’ mejoró el VO2 máx. y podría reducir el riesgo de desarrollar resistencia a la insulina. En general, estos hallazgos sugieren que los estudios de intervención deben centrarse en las porciones de alimentos, y no solo en la influencia de los hábitos alimentarios y la densidad energética, para prevenir la resistencia a la insulina y el riesgo metabólico en los jóvenes.

8. References

1. World Health Organisation. Obesity and overweight [Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. Sinha R, Fisch G, Teague B, Tamborlane WV, Banyas B, Allen K, et al. Prevalence of impaired glucose tolerance among children and adolescents with marked obesity. N Engl J Med. 2002;346(11):802-10.
3. Tounian P, Aggoun Y, Dubern B, Varille V, Guy-Grand B, Sidi D, et al. Presence of increased stiffness of the common carotid artery and endothelial dysfunction in severely obese children: a prospective study. Lancet. 2001;358(9291):1400-4.
4. Ludwig DS, Ebbeling CB. Type 2 diabetes mellitus in children: primary care and public health considerations. Jama. 2001;286(12):1427-30.
5. organisation Wh. Diet, nutrition and the prevention of chronic diseases. WHO. 2014.
6. Ludwig D, Peterson K, Gortmaker S. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet (London, England). 2001;357(9255).
7. French S, Story M, Neumark-Sztainer D, Fulkerson J, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 2001;25(12).
8. Lewis HB, Ahern AL, Jebb SA. How much should I eat? A comparison of suggested portion sizes in the UK. Public Health Nutr. 2012;15(11):2110-7.
9. Prentice AM, Jebb SA. Fast foods, energy density and obesity: a possible mechanistic link. Obes Rev. 2003;4(4):187-94.
10. Wrieden W, Gregor A, Barton KL, Dundee Uo, K515325@abertay.ac.uk, editors. Have food portion sizes increased in the UK over the last 20 years? Nutrition society Scottish Meeting; 2008: CAMBRIDGE UNIV PRESS.
11. Piernas. C PB. Increased portion sizes from energy-dense foods affect total energy intake at eating occasions in US children and adolescents: patterns and trends by age group and sociodemographic characteristics, 1977–2006. The American Journal of Clinical Nutrition. 2011;94(5):1324-32.
12. Fisher JO, Liu Y, Birch LL, Rolls BJ. Effects of portion size and energy density on young children's intake at a meal. Am J Clin Nutr. 2007;86(1):174-9.
13. O'Brien SA, Livingstone MB, McNulty BA, Lyons J, Walton J, Flynn A, et al. Secular trends in reported portion size of food and beverages consumed by Irish adults. Br J Nutr. 2015;113(7):1148-57.
14. Kral TV, Rolls BJ. Energy density and portion size: their independent and combined effects on energy intake. Physiol Behav. 2004;82(1):131-8.
15. Rolls BJ, Roe LS, Meengs JS, Wall DE. Increasing the portion size of a sandwich increases energy intake. J Am Diet Assoc. 2004;104(3):367-72.
16. Flood JE, Roe LS, Rolls BJ. The effect of increased beverage portion size on energy intake at a meal. J Am Diet Assoc. 2006;106(12):1984-90; discussion 90-1.
17. Diliberti N, Bordi PL, Conklin MT, Roe LS, Rolls BJ. Increased portion size leads to increased energy intake in a restaurant meal. Obes Res. 2004;12(3):562-8.
18. Wansink B, Cheney MM. Super Bowls: serving bowl size and food consumption. Jama. 293. United States2005. p. 1727-8.
19. Ferguson MA, Gutin B, Owens S, Litaker M, Tracy RP, Allison J. Fat distribution and hemostatic measures in obese children. Am J Clin Nutr. 1998;67(6):1136-40.

20. Olza J, Gil-Campos M, Leis R, Bueno G, Aguilera C, Valle M, et al. Presence of the Metabolic Syndrome in Obese Children at Prepubertal Age. Annals of nutrition & metabolism. 2011;58(4).
21. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. http://dxdoiorg/101056/NEJMoa031049. 2009.
22. Cruz ML, Weigensberg MJ, Huang TT, Ball G, Shaibi GQ, Goran MI. The metabolic syndrome in overweight Hispanic youth and the role of insulin sensitivity. J Clin Endocrinol Metab. 2004;89(1):108-13.
23. Williams DE, Prevost AT, Whichelow MJ, Cox BD, Day NE, Wareham NJ. A cross-sectional study of dietary patterns with glucose intolerance and other features of the metabolic syndrome. Br J Nutr. 2000;83(3):257-66.
24. Pereira MA, Jacobs DR, Jr., Van Horn L, Slattery ML, Kartashov AI, Ludwig DS. Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. Jama. 2002;287(16):2081-9.
25. Albar SA, Alwan NA, Evans CE, Cade JE. Is there an association between food portion size and BMI among British adolescents? Br J Nutr. 2014;112(5):841-51.
26. Thompson FE, Byers T. Dietary assessment resource manual. J Nutr. 1994;124(11 Suppl):2245s-317s.
27. Peter Herman C, Polivy J, Pliner P, Vartanian LR. Mechanisms underlying the portion-size effect. Physiol Behav. 2015;144:129-36.
28. Burger KS, Kern M, Coleman KJ. Characteristics of self-selected portion size in young adults. J Am Diet Assoc. 2007;107(4):611-8.
29. Dubois S. Accuracy of visual estimates of plate waste in the determination of food consumption. J Am Diet Assoc. 1990;90(3):382-7.
30. Gittelsohn J, Shankar AV, Pokhrel RP, West KP, Jr. Accuracy of estimating food intake by observation. J Am Diet Assoc. 1994;94(11):1273-7.
31. Vereecken C, Dohogne S, Covents M, Maes L. How accurate are adolescents in portion-size estimation using the computer tool Young Adolescents' Nutrition Assessment on Computer (YANA-C)? The British journal of nutrition. 2010;103(12).
32. Almiron-Roig E, Navas-Carretero S, Emery P, Martinez JA. Research into food portion size: methodological aspects and applications. Food Funct. 2018;9(2):715-39.
33. Faulkner GP, Livingstone MB, Pourshahidi LK, Spence M, Dean M, O'Brien S, et al. An evaluation of portion size estimation aids: precision, ease of use and likelihood of future use. Public Health Nutr. 2016;19(13):2377-87.
34. Pollard CM, Daly AM, Binns CW. Consumer perceptions of fruit and vegetables serving sizes. Public Health Nutr. 2009;12(5):637-43.
35. Britten P, Haven J, Davis C. Consumer research for development of educational messages for the MyPyramid Food Guidance System. J Nutr Educ Behav. 2006;38(6 Suppl):S108-23.
36. Lanerolle P, Thoradeniya T, de Silva A. Food models for portion size estimation of Asian foods. J Hum Nutr Diet. 2013;26(4):380-6.
37. Faggiano F, Vineis P, Cravanzola D, Pisani P, Xompero G, Riboli E, et al. Validation of a method for the estimation of food portion size. Epidemiology. 1992;3(4):379-82.
38. Subar AF, Crafts J, Zimmerman TP, Wilson M, Mittl B, Islam NG, et al. Assessment of the accuracy of portion size reports using computer-based food photographs aids in the development of an automated self-administered 24-hour recall. J Am Diet Assoc. 2010;110(1):55-64.

39. Boushey CJ, Spoden M, Zhu FM, Delp EJ, Kerr DA. New mobile methods for dietary assessment: review of image-assisted and image-based dietary assessment methods. Proc Nutr Soc. 2017;76(3):283-94.
40. Haraldsdottir J, Tjonneland A, Overvad K. Validity of individual portion size estimates in a food frequency questionnaire. Int J Epidemiol. 1994;23(4):786-96.
41. Japur CC, Diez-Garcia RW. Food energy content influences food portion size estimation by nutrition students. J Hum Nutr Diet. 2010;23(3):272-6.
42. Slawson DL, Eck LH. Intense practice enhances accuracy of portion size estimation of amorphous foods. J Am Diet Assoc. 1997;97(3):295-7.
43. Sharp D, Sobal J. Using plate mapping to examine sensitivity to plate size in food portions and meal composition among college students. Appetite. 2012;59(3):639-45.
44. Wansink B, Wansink CS. The largest Last Supper: depictions of food portions and plate size increased over the millennium. Int J Obes (Lond). 2010;34(5):943-4.
45. Szenczi-Cseh J, Horvath Z, Ambrus A. Validation of a food quantification picture book and portion sizes estimation applying perception and memory methods. Int J Food Sci Nutr. 2017;68(8):960-72.
46. Baranowski T, Baranowski JC, Watson KB, Martin S, Beltran A, Islam N, et al. Children's accuracy of portion size estimation using digital food images: effects of interface design and size of image on computer screen. Public Health Nutr. 2011;14(3):418-25.
47. Bryant R, Dundes L. Portion Distortion: A Study of College Students. The Journal of Consumer Affairs. 2005;39(2):399-408.
48. Almiron-Roig E, Solis-Trapala I, Dodd J, Jebb SA. Estimating food portions. Influence of unit number, meal type and energy density. Appetite. 2013;71:95-103.
49. Elmquist JK, Coppari R, Balthasar N, Ichinose M, Lowell BB. Identifying hypothalamic pathways controlling food intake, body weight, and glucose homeostasis. J Comp Neurol. 2005;493(1):63-71.
50. Treasure J, Cardi V, Kan C. Eating in eating disorders. Eur Eat Disord Rev. 2012;20(1):e42-9.
51. Zheng H, Lenard NR, Shin AC, Berthoud HR. Appetite control and energy balance regulation in the modern world: reward-driven brain overrides repletion signals. Int J Obes (Lond). 2009;33 Suppl 2:S8-13.
52. Macht M. How emotions affect eating: a five-way model. Appetite. 2008;50(1):1-11.
53. Cornah D. Feeding minds: the impact of food on mental health. Ment Health Found. 2005 [updated 2006-06-01. Available from: https://www.mentalhealth.org.uk/sites/default/files/ Feeding-Minds.pdf.
54. Washington T. Psychological stress and anxiety in middle to late childhood and early adolescence: manifestations and management. Journal of pediatric nursing. 2009;24(4).
55. Evers C, Marijn S, F, de Ridder D. Feeding your feelings: emotion regulation strategies and emotional eating. Personality & social psychology bulletin. 2010;36(6).
56. van Strien T, Ouwens M. Effects of distress, alexithymia and impulsivity on eating. Eating behaviors. 2007;8(2).
57. BRUCH H. PSYCHOLOGICAL ASPECTS OF OVEREATING AND OBESITY. Psychosomatics. 1964;5.
58. Coumans J, Danner U, Intemann T, De Decker A, Hadjigeorgiou C, Hunsberger M, et al. Emotion-driven impulsiveness and snack food consumption of European adolescents: Results from the I.Family study. Appetite. 2018;123.
59. Cardi V, Leppanen J, Treasure J. The effects of negative and positive mood induction on eating behaviour: A meta-analysis of laboratory studies in the healthy population and eating and weight disorders. Neurosci Biobehav Rev. 2015;57:299-309.

60. Lim E, Sim A, Forde C, Cheon B. The role of perceived stress and gender on portion selection patterns. Physiology & behavior. 2018;194.

61. Torres S, Nowson C. Relationship between stress, eating behavior, and obesity. Nutrition (Burbank, Los Angeles County, Calif). 2007;23(11-12).

62. O'Neil A, Quirk S, Housden S, Brennan S, Williams L, Pasco J, et al. Relationship between diet and mental health in children and adolescents: a systematic review. American journal of public health. 2014;104(10).

63. Michels N, Sioen I, Braet C, Eiben G, Hebestreit A, Huybrechts I, et al. Stress, Emotional Eating Behaviour and Dietary Patterns in Children. Appetite. 2012;59(3).

64. George S, Khan S, Briggs H, Abelson J. CRH-stimulated cortisol release and food intake in healthy, non-obese adults. Psychoneuroendocrinology. 2010;35(4).

65. Gale C, O'Callaghan F, Godfrey K, Law C, Martyn C. Critical periods of brain growth and cognitive function in children. Brain : a journal of neurology. 2004;127(Pt 2).

66. Zohra L, Anoosh M, Zulfiqar B. Nutrition in Middle Childhood and Adolescence. 2017.

67. Kearney J. Food consumption trends and drivers. Philosophical transactions of the Royal Society of London Series B, Biological sciences. 2010;365(1554).

68. Fileh S, González Gil E, Miguel-Berges M, Moreno A, LA. Food portion sizes, obesity, and related metabolic complications in children and adolescents. Nutricion hospitalaria. 2020.

69. Lyons J, Walton J, Flynn A. Food portion sizes and dietary quality in Irish children and adolescents. Public health nutrition. 2015;18(8).

70. Rippin H, Hutchinson J, Jewell J, Breda J, Cade J. Child and adolescent nutrient intakes from current national dietary surveys of European populations. Nutrition research reviews. 2019;32(1).

71. Fulgoni V, Gaine P, Scott M, Ricciuto L, DiFrancesco L. Association of Added Sugars Intake with Micronutrient Adequacy in US Children and Adolescents: NHANES 2009-2014. Current developments in nutrition. 2019;3(12).

72. Fernández Fernández E, Martínez Hernández J, Martínez Suárez V, Moreno Villares J, Collado Yurrita L, Hernández Cabria M, et al. [Consensus document: nutritional and metabolic importance of cow's milk]. Nutricion hospitalaria. 2014;31(1).

73. Holick M. Vitamin D deficiency. The New England journal of medicine. 2007;357(3).

74. Geleijnse J, Grobbee D, Hofman A. Sodium and potassium intake and blood pressure change in childhood. BMJ (Clinical research ed). 1990;300(6729).

75. Novaković R, Cavelaars A, Bekkering G, Roman-Viñas B, Ngo J, Gurinović M, et al. Micronutrient intake and status in Central and Eastern Europe compared with other European countries, results from the EURRECA network. Public health nutrition. 2013;16(5).

76. Rippin H, Hutchinson J, Evans C, Jewell J, Breda J, Cade J. National nutrition surveys in Europe: a review on the current status in the 53 countries of the WHO European region. Food & nutrition research. 2018;62.

77. Flieh S, Miguel-Berges M, González-Gil E, Gottrand F, Censi L, Widhalm K, et al. The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study. Nutrients. 2021;13(3).

78. Agostoni C, Braegger C, Decsi T, Kolacek S, Koletzko B, Mihatsch W, et al. Role of dietary factors and food habits in the development of childhood obesity: a commentary by the ESPGHAN Committee on Nutrition. Journal of pediatric gastroenterology and nutrition. 2011;52(6).

79. Ledikwe JH, Ello-Martin JA, Rolls BJ. Portion sizes and the obesity epidemic. J Nutr. 2005;135(4):905-9.

80. Westerterp-Plantenga M. Analysis of energy density of food in relation to energy intake regulation in human subjects. The British journal of nutrition. 2001;85(3).

81. Rolls B, Roe L, Beach A, Kris-Etherton P. Provision of Foods Differing in Energy Density Affects Long-Term Weight Loss. Obesity research. 2005;13(6).

82. World Cancer Research Fund (WCRFUK). Energy density: finding the balance for cancer prevention 2007 [Available from: http://www.wcrf-uk. org/PDFs/EnergyDensity.pdf.

83. Bechthold A. Food Energy Density and Body Weight. A scientific statement from the DGE Ernahrungs Umschau. 2014;61(1): 2–11.

84. Rippin HL, Hutchinson J, Jewell J, Breda JJ, Cade JE. Portion Size of Energy-Dense Foods among French and UK Adults by BMI Status. Nutrients. 2018;11(1).

85. Jeffery RW, Rydell S, Dunn CL, Harnack LJ, Levine AS, Pentel PR, et al. Effects of portion size on chronic energy intake. Int J Behav Nutr Phys Act. 2007;4:27.

86. McConahy KL, Smiciklas-Wright H, Birch LL, Mitchell DC, Picciano MF. Food portions are positively related to energy intake and body weight in early childhood. J Pediatr. 2002;140(3):340-7.

87. Huang TT, Howarth NC, Lin BH, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. Obes Res. 2004;12(11):1875-85.

88. Lioret S, Volatier JL, Lafay L, Touvier M, Maire B. Is food portion size a risk factor of childhood overweight? Eur J Clin Nutr. 2009;63(3):382-91.

89. Fisher JO, Birch LL. Eating in the absence of hunger and overweight in girls from 5 to 7 y of age. Am J Clin Nutr. 2002;76(1):226-31.

90. Zimmermann M, Aeberli I. Dietary determinants of subclinical inflammation, dyslipidemia and components of the metabolic syndrome in overweight children: a review. International journal of obesity (2005). 2008;32 Suppl 6.

91. Reaven G. Insulin resistance: the link between obesity and cardiovascular disease. The Medical clinics of North America. 2011;95(5).

92. Aeberli I, Spinas G, Lehmann R, l'Allemand D, Molinari L, Zimmermann M. Diet determines features of the metabolic syndrome in 6- to 14-year-old children. International journal for vitamin and nutrition research Internationale Zeitschrift fur Vitamin- und Ernahrungsforschung Journal international de vitaminologie et de nutrition. 2009;79(1).

93. Karatzi K, Moschonis G, Barouti A, Lionis C, Chrousos G, Manios Y. Dietary patterns and breakfast consumption in relation to insulin resistance in children. The Healthy Growth Study. Public health nutrition. 2014;17(12).

94. Sesé M, Jiménez-Pavón D, Gilbert C, González-Gross M, Gottrand F, de Henauw S, et al. Eating behaviour, insulin resistance and cluster of metabolic risk factors in European adolescents. The HELENA study. Appetite. 2012;59(1).

95. Kynde I, Johnsen N, Wedderkopp N, Bygbjerg I, Helge J, Heitmann B. Intake of total dietary sugar and fibre is associated with insulin resistance among Danish 8-10- and 14-16-year-old girls but not boys. European Youth Heart Studies I and II. Public health nutrition. 2010;13(10).

96. Harrington S. The role of sugar-sweetened beverage consumption in adolescent obesity: a review of the literature. The Journal of school nursing : the official publication of the National Association of School Nurses. 2008;24(1).

97. Pedrozo W, Rascón M, Bonneau G, de Pianesi M, Olivera C, de Aragón S, et al. [Metabolic syndrome and risk factors associated with life style among adolescents in a city in Argentina, 2005]. Revista panamericana de salud publica = Pan American journal of public health. 2008;24(3).

98. Ambrosini G, Huang R, Mori T, Hands B, O'Sullivan T, de Klerk N, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. Nutrition, metabolism, and cardiovascular diseases : NMCD. 2010;20(4).

99. Ahrens W, Bammann K, de Henauw S, Halford J, Palou A, Pigeot I, et al. Understanding and preventing childhood obesity and related disorders--IDEFICS: a European

multilevel epidemiological approach. Nutrition, metabolism, and cardiovascular diseases : NMCD. 2006;16(4).

100. 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 (2005). 2011;35 Suppl 1.

101. 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. Int J Epidemiol. 462017. p. 1394-5j.

102. UNESCO. International Standard Classification of Education. 2017 [Available from: http://www.uis.unesco.org/ Education/Documents/isced-2011-en.pdf.

103. www.uis.unesco.org UIscoe. UNESCO International standard classifcation of education. www.uis.unesco.org 2013 [

104. Vanaelst B, De Vriendt T, Ahrens W, Bammann K, Hadjigeorgiou C, Konstabel K, et al. Prevalence of psychosomatic and emotional symptoms in European school-aged children and its relationship with childhood adversities: results from the IDEFICS study. European child & adolescent psychiatry. 2012;21(5).

105. Ravens-Sieberer U, Bullinger M. Assessing health-related quality of life in chronically ill children with the German KINDL: first psychometric and content analytical results. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 1998;7(5).

106. Dey M, Landolt M, Mohler-Kuo M. Health-related quality of life among children with mental disorders: a systematic review. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 2012;21(10).

107. Goodman R, Meltzer H, Bailey V. The Strengths and Difficulties Questionnaire: a pilot study on the validity of the self-report version. European child & adolescent psychiatry. 1998;7(3).

108. Hebestreit AR, A. Huybrechts, I. Computer based 24-hour dietary recall: the SACINA program. Measurement tools for a health survey on nutrition, physical activity and lifestyle in children: the European IDEFICS Study,1st edn. Springer, Berlin. 2013.

109. Vereecken C, Covents M, Sichert-Hellert W, Alvira J, Le Donne C, De Henauw S, et al. Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. International journal of obesity (2005). 2008;32 Suppl 5.

110. Börnhorst C, Huybrechts I, Hebestreit A, Krogh V, De Decker A, Barba G, et al. Usual energy and macronutrient intakes in 2-9-year-old European children. International journal of obesity (2005). 2014;38 Suppl 2.

111. Börnhorst C, Bel-Serrat S, Pigeot I, Huybrechts I, Ottavaere C, Sioen I, et al. Validity of 24-h recalls in (pre-)school aged children: comparison of proxy-reported energy intakes with measured energy expenditure. Clinical nutrition (Edinburgh, Scotland). 2014;33(1).

112. Tooze J, Krebs-Smith S, Troiano R, Subar A. The accuracy of the Goldberg method for classifying misreporters of energy intake on a food frequency questionnaire and 24-h recalls: comparison with doubly labeled water. European journal of clinical nutrition. 2012;66(5).

113. Black A, Ravenscroft C, Paul A. Footnotes to food tables: 1. Differences in nutrient intakes of dietitians as calculated from the DHSS food tables and the fourth edition of McCance and Widdowson's 'The composition of foods'. Human nutrition Applied nutrition. 1985;39(1).

114. Hebestreit A, Börnhorst C, Barba G, Siani A, Huybrechts I, Tognon G, et al. Associations between energy intake, daily food intake and energy density of foods and BMI z-score in 2-9-year-old European children. European journal of nutrition. 2014;53(2).

115. Nagy P, Kovacs E, Moreno L, Veidebaum T, Tornaritis M, Kourides Y, et al. Percentile reference values for anthropometric body composition indices in European children from the IDEFICS study. International journal of obesity (2005). 2014;38 Suppl 2.

116. Cole T, Bellizzi M, Flegal K, Dietz W. Establishing a Standard Definition for Child Overweight and Obesity Worldwide: International Survey. BMJ (Clinical research ed). 2000;320(7244).

117. Moreno L, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L, et al. Assessing, Understanding and Modifying Nutritional Status, Eating Habits and Physical Activity in European Adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public health nutrition. 2008;11(3).

118. Henauw SD, Gottrand F, Bourdeaudhuij ID, Gonzalez-Gross M, Leclercq C, Kafatos A, et al. Nutritional status and lifestyles of adolescents from a public health perspective. The HELENA Project—Healthy Lifestyle in Europe by Nutrition in Adolescence. Journal of Public Health. 2007;15(3):187-97.

119. Moreno L, De Henauw S, González-Gross M, Kersting M, Molnár D, Gottrand F, et al. Design and Implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. International journal of obesity (2005). 2008;32 Suppl 5.

120. Nagy E, Vicente-Rodriguez G, Manios Y, Béghin L, Iliescu C, Censi L, et al. Harmonization Process and Reliability Assessment of Anthropometric Measurements in a Multicenter Study in Adolescents. International journal of obesity (2005). 2008;32 Suppl 5.

121. Diethelm K, Huybrechts I, Moreno L, De Henauw S, Manios Y, Beghin L, et al. Nutrient Intake of European Adolescents: Results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public health nutrition. 2014;17(3).

122. Vereecken C, Covents M, Matthys C, Maes L. Young adolescents' nutrition assessment on computer (YANA-C). European journal of clinical nutrition. 2005;59(5).

123. 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(2).

124. Harttig U, Haubrock J, Knüppel S, Boeing H. The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. European journal of clinical nutrition. 2011;65 Suppl 1.

125. Ireland J, van Erp-Baart A, Charrondière U, Møller A, Smithers G, Trichopoulou A. Selection of a food classification system and a food composition database for future food consumption surveys. European journal of clinical nutrition. 2002;56 Suppl 2.

126. Pereira J, Mendes A, Crispim S, Marchioni D, Fisberg R. Association of Overweight With Food Portion Size Among Adults of São Paulo - Brazil. PloS one. 2016;11(10).

127. Slaughter M, Lohman T, Boileau R, Horswill C, Stillman R, Van Loan M, et al. Skinfold Equations for Estimation of Body Fatness in Children and Youth. Human biology. 1988;60(5).

128. Kyle U, Schutz Y, Dupertuis Y, Pichard C. Body composition interpretation. Contributions of the fat-free mass index and the body fat mass index. Nutrition (Burbank, Los Angeles County, Calif). 2003;19(7-8).

129. Lohman T, G., Roche AF, Martorell R. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics Books; 1988.

130. Hagströmer M, Bergman P, De Bourdeaudhuij I, Ortega F, Ruiz J, Manios Y, et al. Concurrent Validity of a Modified Version of the International Physical Activity Questionnaire (IPAQ-A) in European Adolescents: The HELENA Study. International journal of obesity (2005). 2008;32 Suppl 5.

131. Ainsworth B, Haskell W, Whitt M, Irwin M, Swartz A, Strath S, et al. Compendium of physical activities: an update of activity codes and MET intensities. Medicine and science in sports and exercise. 2000;32(9 Suppl).

132. Léger L, Lambert J, Goulet A, Rowan C, Dinelle Y. [Aerobic capacity of 6 to 17-year-old Quebecois--20 meter shuttle run test with 1 minute stages]. Canadian journal of applied sport sciences Journal canadien des sciences appliquees au sport. 1984;9(2).
133. Ottevaere C, Huybrechts I, De Bourdeaudhuij I, Sjöström M, Ruiz J, Ortega F, et al. Comparison of the IPAQ-A and actigraph in relation to VO2max among European adolescents: the HELENA study. Journal of science and medicine in sport. 2011;14(4).
134. Harwood M, Danielewska-Nikiel B, Borzelleca J, Flamm G, Williams G, Lines T. A critical review of the data related to the safety of quercetin and lack of evidence of in vivo toxicity, including lack of genotoxic/carcinogenic properties. Food and chemical toxicology : an international journal published for the British Industrial Biological Research Association. 2007;45(11).
135. Butte N, Cai G, Cole S, Wilson T, Fisher J, Zakeri I, et al. Metabolic and behavioral predictors of weight gain in Hispanic children: the Viva la Familia Study. The American journal of clinical nutrition. 2007;85(6).
136. González-Gross M, Breidenassel C, Gómez-Martínez S, Ferrari M, Béghin L, Spinneker A, et al. Sampling and processing of fresh blood samples within a European multicenter nutritional study: evaluation of biomarker stability during transport and storage. International journal of obesity (2005). 2008;32 Suppl 5.
137. Singh RB, Niaz MA, Ghosh S. Effect on central obesity and associated disturbances of low-energy, fruit- and vegetable-enriched prudent diet in north Indians. Postgrad Med J. 1994;70(830):895-900.
138. Matthews D, Hosker J, Rudenski A, Naylor B, Treacher D, Turner R. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985;28(7).
139. Katz A, Nambi S, Mather K, Baron A, Follmann D, Sullivan G, et al. Quantitative insulin sensitivity check index: a simple, accurate method for assessing insulin sensitivity in humans. The Journal of clinical endocrinology and metabolism. 2000;85(7).
140. Andersen L, Harro M, Sardinha L, Froberg K, Ekelund U, Brage S, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). Lancet (London, England). 2006;368(9532).
141. Rey-López J, Bel-Serrat S, Santaliestra-Pasías A, de Moraes A, Vicente-Rodríguez G, Ruiz J, et al. Sedentary behaviour and clustered metabolic risk in adolescents: the HELENA study. Nutrition, metabolism, and cardiovascular diseases : NMCD. 2013;23(10).
142. KAPLAN H, KAPLAN H. The psychosomatic concept of obesity. The Journal of nervous and mental disease. 1957;125(2).
143. Robinson M, Kendall G, Jacoby P, Hands B, Beilin L, Silburn S, et al. Lifestyle and demographic correlates of poor mental health in early adolescence. Journal of paediatrics and child health. 2011;47(1-2).
144. Ghazy Elsayed H, Lissner L, Mehlig K, Thumann B, Hebestreit A, Pala V, et al. Relationship between perception of emotional home atmosphere and fruit and vegetable consumption in European adolescents: results from the I.Family survey. Public health nutrition. 2020;23(1).
145. Wiles N, Northstone K, Emmett P, Lewis G. 'Junk food' diet and childhood behavioural problems: results from the ALSPAC cohort. European journal of clinical nutrition. 2009;63(4).
146. Drewnowski A. The role of energy density. Lipids. 2003;38(2).
147. Macht M, Mueller J. Immediate effects of chocolate on experimentally induced mood states. Appetite. 2007;49(3).
148. Bohon C, Stice E, Spoor S. Female emotional eaters show abnormalities in consummatory and anticipatory food reward: a functional magnetic resonance imaging study. The International journal of eating disorders. 2009;42(3).

149. Volkow N, Wang G, Maynard L, Jayne M, Fowler J, Zhu W, et al. Brain dopamine is associated with eating behaviors in humans. The International journal of eating disorders. 2003;33(2).

150. Gibson E. The psychobiology of comfort eating: implications for neuropharmacological interventions. Behavioural pharmacology. 2012;23(5-6).

151. van Strien T, Roelofs K, de Weerth C. Cortisol reactivity and distress-induced emotional eating. Psychoneuroendocrinology. 2013;38(5).

152. Cools J, Schotte D, McNally R. Emotional arousal and overeating in restrained eaters. Journal of abnormal psychology. 1992;101(2).

153. Askovic B, Kirchengast S. Gender differences in nutritional behavior and weight status during early and late adolescence. Anthropologischer Anzeiger; Bericht uber die biologisch-anthropologische Literatur. 2012;69(3).

154. Wansink B, Cheney M, Chan N. Exploring comfort food preferences across age and gender. Physiology & behavior. 2003;79(4-5).

155. Klump K, Keel P, Racine S, Burt S, Neale M, Sisk C, et al. The interactive effects of estrogen and progesterone on changes in emotional eating across the menstrual cycle. Journal of abnormal psychology. 2013;122(1).

156. van Strien T, van der Zwaluw C, Engels R. Emotional eating in adolescents: a gene (SLC6A4/5-HTT) - depressive feelings interaction analysis. Journal of psychiatric research. 2010;44(15).

157. Longbottom P, Wrieden W, Pine C. Is there a relationship between the food intakes of Scottish 5(1/2)-8(1/2)-year-olds and those of their mothers? Journal of human nutrition and dietetics : the official journal of the British Dietetic Association. 2002;15(4).

158. Brown R, Ogden J. Children's eating attitudes and behaviour: a study of the modelling and control theories of parental influence. Health education research. 2004;19(3).

159. References to Food-Based Dietary Guidelines in Europe | Knowledge for policy 2021 [Available from: https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/references-food-based-dietary-guidelines-europe_en.

160. Elmadfa I, Meyer A, Nowak V, Hasenegger V, Putz P, Verstraeten R, et al. European Nutrition and Health Report 2009. Forum of nutrition. 2009;62.

161. healthy diet: World health organization 2020 [Available from: https://www.who.int/news-room/fact-sheets/detail/healthy-diet.

162. Gibson S. Are High-Fat, High-Sugar Foods and Diets Conducive to Obesity? International journal of food sciences and nutrition. 1996;47(5).

163. Sadler M, McNulty H, Gibson S. Sugar-fat seesaw: a systematic review of the evidence. Critical reviews in food science and nutrition. 2015;55(3).

164. Tonstad S, Sivertsen M. Relation between dietary fat and energy and micronutrient intakes. Archives of disease in childhood. 1997;76(5).

165. Livingstone M, Robson P, Wallace J. Issues in dietary intake assessment of children and adolescents. The British journal of nutrition. 2004;92 Suppl 2.

166. Gomes D, Luque V, Xhonneux A, Verduci E, Socha P, Koletzko B, et al. A simple method for identification of misreporting of energy intake from infancy to school age: Results from a longitudinal study. Clinical nutrition (Edinburgh, Scotland). 2018;37(3).

167. van Sluijs E, Sharp S, Ambrosini G, Cassidy A, Griffin S, Ekelund U. The independent prospective associations of activity intensity and dietary energy density with adiposity in young adolescents. The British journal of nutrition. 2016;115(5).

168. Collins C, Watson J, Burrows T. Measuring dietary intake in children and adolescents in the context of overweight and obesity. International journal of obesity (2005). 2010;34(7).

169. Forrestal S. Energy intake misreporting among children and adolescents: a literature review. Maternal & child nutrition. 2011;7(2).

170. Börnhorst C, Huybrechts I, Ahrens W, Eiben G, Michels N, Pala V, et al. Prevalence and determinants of misreporting among European children in proxy-reported 24 h dietary recalls. The British journal of nutrition. 2013;109(7).

171. Bel-Serrat S, Julián-Almárcegui C, González-Gross M, Mouratidou T, Börnhorst C, Grammatikaki E, et al. Correlates of dietary energy misreporting among European adolescents: the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study. The British journal of nutrition. 2016;115(8).

172. Börnhorst C, Huybrechts I, Hebestreit A, Vanaelst B, Molnár D, Bel-Serrat S, et al. Diet-obesity associations in children: approaches to counteract attenuation caused by misreporting. Public health nutrition. 2013;16(2).

173. Parnell W, Wilson N, Alexander D, Wohlers M, Williden M, Mann J, et al. Exploring the Relationship Between Sugars and Obesity. Public health nutrition. 2008;11(8).

174. Young L, Nestle M. Expanding portion sizes in the US marketplace: implications for nutrition counseling. Journal of the American Dietetic Association. 2003;103(2).

175. Benton D. Portion size: what we know and what we need to know. Crit Rev Food Sci Nutr. 2015;55(7):988-1004.

176. Pan A, Hu F. Effects of carbohydrates on satiety: differences between liquid and solid food. Current opinion in clinical nutrition and metabolic care. 2011;14(4).

177. DiMeglio D, Mattes R. Liquid versus solid carbohydrate: effects on food intake and body weight. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 2000;24(6).

178. Davis J, Murphy E, Carmichael M, Davis B. Quercetin increases brain and muscle mitochondrial biogenesis and exercise tolerance. American journal of physiology Regulatory, integrative and comparative physiology. 2009;296(4).

179. Howe A, Skidmore P, Parnell W, Wong J, Lubransky A, Black K. Cardiorespiratory fitness is positively associated with a healthy dietary pattern in New Zealand adolescents. Public health nutrition. 2016;19(7).

180. Srinath RK, Katan M. Diet, nutrition and the prevention of hypertension and cardiovascular diseases. Public health nutrition. 2004;7(1A).

181. Martínez-González M, Martín-Calvo N. The major European dietary patterns and metabolic syndrome. Reviews in endocrine & metabolic disorders. 2013;14(3).

182. Raben A, Vasilaras T, Møller A, Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. The American journal of clinical nutrition. 2002;76(4).

183. Akinyanju P, Qureshi R, Salter A, Yudkin J. Effect of an "atherogenic" diet containing starch or sucrose on the blood lipids of young men. Nature. 1968;218(5145).

184. Taskinen M, Packard C, Borén J. Dietary Fructose and the Metabolic Syndrome. Nutrients. 2019;11(9).

185. Janssens J, Shapira N, Debeuf P, Michiels L, Putman R, Bruckers L, et al. Effects of soft drink and table beer consumption on insulin response in normal teenagers and carbohydrate drink in youngsters. European journal of cancer prevention : the official journal of the European Cancer Prevention Organisation (ECP). 1999;8(4).

186. McKeown N, Meigs J, Liu S, Saltzman E, Wilson P, Jacques P. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes care. 2004;27(2).

187. Teff K, Elliott S, Tschöp M, Kieffer T, Rader D, Heiman M, et al. Dietary fructose reduces circulating insulin and leptin, attenuates postprandial suppression of ghrelin, and increases triglycerides in women. The Journal of clinical endocrinology and metabolism. 2004;89(6).

188. Yudkin J. Evolutionary and historical changes in dietary carbohydrates. The American journal of clinical nutrition. 1967;20(2).
189. Ehrampoush E, Nazari N, Homayounfar R, Ghaemi A, Osati S, Tahamtan S, et al. Association between dietary patterns with insulin resistance in an Iranian population. Clinical nutrition ESPEN. 2020;36.
190. Evans J, Goldfine I, Maddux B, Grodsky G. Are oxidative stress-activated signaling pathways mediators of insulin resistance and beta-cell dysfunction? Diabetes. 2003;52(1).
191. Guasch-Ferré M, Merino J, Sun Q, Fitó M, Salas-Salvadó J. Dietary Polyphenols, Mediterranean Diet, Prediabetes, and Type 2 Diabetes: A Narrative Review of the Evidence. Oxidative medicine and cellular longevity. 2017;2017.
192. Sales C, Pedrosa L, Lima J, Lemos T, Colli C. Influence of magnesium status and magnesium intake on the blood glucose control in patients with type 2 diabetes. Clinical nutrition (Edinburgh, Scotland). 2011;30(3).
193. Sears B, Perry M. The role of fatty acids in insulin resistance. Lipids in health and disease. 2015;14.
194. Silva Figueiredo P, Carla Inada A, Marcelino G, Maiara Lopes Cardozo C, de Cássia Freitas K, de Cássia Avellaneda Guimarães R, et al. Fatty Acids Consumption: The Role Metabolic Aspects Involved in Obesity and Its Associated Disorders. Nutrients. 2017;9(10).
195. Han P, Zhang Y, Lu Y, He B, Zhang W, Xia F. Effects of different free fatty acids on insulin resistance in rats. Hepatobiliary & pancreatic diseases international : HBPD INT. 2008;7(1).

9. Appendix

Impact factor and quartile of the journals in "ISI Web of Knowledge - Journal Citation Report (JCR)" in their corresponding area and the year of publication.

(INDEX TABLE MODE)

ARTICLE I: Food portion sizes, obesity and related metabolic complications in children and adolescents (2021). Nutrición Hospitalaria. Impact Factor 1.169 (2021). Rank 79/90 (Nutrition & Dietetics).

ARTICLE II: The association between psychosomatic and emotional status and selected food portion sizes, in European children and adolescents: IDEFICS/I. Family study. (Submitted to nutrition)

ARTICLE III: Food portion sizes and their relationship with energy, and nutrient intakes in European adolescents: the HELENA study. (2022) Nutrition. Impact Factor 4.893 (2021). Rank 33/90 (Nutrition & Dietetics).

ARTICLE IV: The Association between Portion Sizes from High-Energy-Dense Foods and Body Composition in European Adolescents: The HELENA Study. (2021). Nutrients. Impact Factor 6.706 (2021). Rank 15/90 (Nutrition & Dietetics).

ARTICLE V: Associations between food portion sizes, insulin resistance, VO2 max and metabolic syndrome in European adolescents: the HELENA study. (2022). Nutrition Metabolism and Cardiovascular Diseases. Impact Factor 4.666 (2021). Rank 52/143 (Cardiac & Cardiovascular systems). Rank 39/90 (Nutrition & Dietetics). Rank 59/146 (Endocrinology & Metabolism)

The articles have been carried out with data from three European projects:

- IDEFICS study (Identification and prevention of dietary- and lifestyle-induced health effects in children and infants). The project funded by the European Union: European Union Sixth RTD Framework Program (contract FOOD-CT-2006-016181-2). Coordinator: Wolfgang Ahrens. www.idefics.eu .

- I. Family study (Investigating the determinants of food choice, lifestyle and health in European children, adolescents and their parents) coordinated by the University of Bremen and BIPS – the Institute for Epidemiology and Prevention Research under the joint leadership of Professor Wolfgang Ahrens, Professor Iris Pigeot and Dr Alfonso Siani of ISA-CNR. This

project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 266044. www.ifamilystudy.eu .

- HELENA study (119). Project funded by the European Union: European Union Sixth RTD Framework Program (Contract FOOD-CT-2005-007034). Coordinator: Luis Alberto Moreno Aznar. www.helenastudy.com .

10. Acknowledgements

‘A dream doesn't become reality through magic it takes sweat determination and hard work’.

Colin Powell

‘Firstly, thank you God for giving me the strength to keep going and to bring hope through even the toughest of times, strengthening me for my purposes.

I am deeply grateful for all the help and support from the many individuals without whom this PhD research would have been impossible. I would particularly like to express my sincere appreciation to my supervisors, Professor Luis Moreno, Dr. Esther González Gil, and Dr. Maria Miguel-Berges for their tireless support and trust in me during the research. They have provided me with insightful and critical comments with great enthusiasm whenever I needed guidance. Many thanks to GENUD family, for the feeling of unity that we share even though we didn’t meet frequently.

Lastly, but by no means least, I would like to express my deepest appreciation to my family and friends for their loving support during both difficult and happier times during the research process. I would especially like to thank my father Mahmoud Flieh, my mother, brothers, my little sister Raghad, and my mother-in-law, for their inexhaustible selfless support which helped and encouraged me to complete the research. Also, my father-in-law, who never got to see me complete my thesis, but remains part of my life and a source of great inspiration.

My acknowledgements would not be complete without thanking my immediate family: my husband, Mohammad Bataineh, and my twin daughters Pilar & Layar Bataineh, without whom the PhD journey would have been impossible.’

11. Annex

Questionnaires which this Doctoral Thesis has been based on are presented below.

idefics study

Version 2009-11-16

Please stick the child's ID here.

ID_no (7 digits)

Logo of

national institution

Dear parents

You and your child are participating in a large European study. The aim of the study is to provide data and new insights, in order to improve the health and conditions for development of the young generation in Europe. You were selected to represent [*insert country*] in this study. In participating, you have taken on a highly responsible task, and for this, we wish to thank you.

Your answers will be treated in accordance with the regulations regarding data protection. Our project has been checked by the data protection authorities and the ethics committee. The information you provide will be evaluated completely anonymously. It will not be possible for another person to determine the name of the respondent to which the information applies.

Not all children live with both their natural parents. You can indicate in the questionnaire which parent the child lives with most of the time. For questions relating to the mother or father, or the parents, we mean the **people whom the child lives with in the home**. The words “mother” or “father” also describe the people who represent the child’s biological parents, such as the father’s partner, the child’s stepfather, etc.

You are welcome to contact us at any time should you have any questions, or require further explanation.

Institute name
Address
Phone
Website

Instructions for filling out the questionnaire

The questionnaire contains answers and statements to be marked with a cross. Please give one answer, unless stated otherwise.	○
If you are asked to write down text, please use the lines provided.	____________________
For questions referring to a quantity or date, please use the boxes for filling in the required data.	|___|___|
Only skip a question when the following applies:	**“→→→ Please continue with question ...”**
If you want to amend a written answer, please cross out the written words and enter the corrected answer above the cancelled words.	2 4 “When my child was |___|___| ~~1~~ ~~8~~ months old.”
If you would like to correct a marked answer, please completely cross out the wrong answer and mark the desired answer.	~~☒ 1 Breakfast~~ ☒ 2 Lunch

General information

1. What is your relationship with the selected child?

○1 Biological parent

○2 Adoptive parent relation

○3 Stepfather or stepmother

○4 Parent in a foster home

○5 Other, please specify: ________ relation_t ________

2. You are:

○1 Male sex ○2 Female

3. How old are you?

Please give the ages of parents with whom the child is living.

Mother Father

|___|___| years age_m __| years age_f

4. What is your height and weight?

Please give information for parents with whom the child is living.

Mother Father

Height (cm) height_m |__|__|__| height_f |__|__|__|

Weight (kg) weight_m |__|__|__| weight_f |__|__|__|

5. What is the date of birth of the child?

Write day, month, and year.

|___|___| Day |___|___| Month |___|___|___|___| Year dob_dd, dob_mm, dob_yy

6. What sex is the child?

○1 Male sex_child ○2 Female

7. How many persons live permanently in the household where your child usually lives?

Number of persons (adults and children): |__|__| persons. househ
Number of persons below 18 years: |__|__| person(s). househ_u18

8. Who does your child live with most of the time?
Please tick the answer that applies most.

○1 With his/her parents
○2 With his/her mother
○3 With his/her mother and her new partner cohabit
○4 With his/her father
○5 With his/her father and his new partner
○6 Half of the time with his/her mother and the other half with his/her father
○7 With his/her grandparents or other relatives
○8 With foster parents or adoptive parents
○9 In an institution e.g. orphanage
○10 Elsewhere, please specify: ________ cohabit_t ________

9. How many older and younger siblings does your child live with?
Count also half brothers and sisters / siblings in-law.

My child lives together with |___|___| older siblings. siblingold
My child lives together with |___|___| younger siblings. siblingyou
My child lives together with |___|___| siblings of the same age. siblingsam

○ 0 My child does not live together with any siblings. siblingno

Day-care, pre-school and school

10. Do you currently use a day care service or have a babysitter for your child?

daycare_h

daycare ○1 Yes, for approximately |___|___| hours per week.

○2 No ➔➔➔ **Please continue with question 12.**

11. Which of the following types of day-care or babysitting do you mainly use for your child?
Please tick each that applies.

daycare_1 ○1 School day-care service

daycare_2 ○1 Other day-care service or centre (including one located in the workplace)

daycare_3 ○1 A child's brother or sister baby-sits the child in your home

daycare_4 ○1 A relative other than your child's sibling baby-sits the child in your home

daycare_5 ○1 A non-relative baby-sits the child in your home

daycare_6 ○1 A relative baby-sits your child elsewhere

daycare_7 ○1 A non-relative baby-sits your child elsewhere

12. Is your child ever left on his/her own, for example, before or after kindergarten, pre-school or school?

alone_h

alone ○1 Yes, approximately |___|___| hours per week.

○2 No

13. Does your child currently attend kindergarten, pre-school or school?

○1 He/She currently attends kindergarten/pre-school.

school_gr

school ○2 He/She currently attends school and visits the |___|. grade.

○3 He/She (still) does not attend kindergarten, pre-school or school.
➔➔➔ **Please continue with question 19.**

14. How often does your child usually eat kindergarten, pre-school or school meals?
Please tick each meal that applies.

		Daily during the week	***Several times per week***	***Once a week***	***On fewer occasions / never***
smealbreak	Breakfast	○1	○2	○3	○4
smeallunch	Lunch	○1	○2	○3	○4
smealdin	Dinner	○1	○2	○3	○4
smealot smealot_t	Other, please specify: ______________________	○1	○2	○3	○4

smealnone
○1 My child usually does not eat kindergarten, pre-school or school meals.

15. Do you regularly give your child money to buy food before, at, or after kindergarten, preschool or school (e.g. for vending machines, vending trucks, kiosks)?

money2buy
○1 Yes
○2 No

16. How far is your child's kindergarten, pre-school or school located from your home?

waylength
○1 Up to 1 kilometre
○2 From 1 kilometre to 2 kilometres
○3 From 2 kilometres to 3 kilometres

○ 4 From 3 kilometres to 4 kilometres

○ 5 4 kilometres or more

17. How does your child usually get to/from kindergarten, pre-school or school?
Please tick any applying answer for the travel back and forth.

	Travel forth	***Travel home***
Walking	walking_f ○ 1	○ 1 walking_h
Cycling	cycling_f ○ 1	○ 1 cycling_h
By school bus and/or public transport	bus_f ○ 1	○ 1 bus_h
By car	car_f ○ 1	○ 1 car_h
Other, please specify: transpo_t ______________________________	transpo_f ○ 1	○ 1 transpo_h

18. If your child covers (parts of) the distance walking and/or cycling: What distance has he/she to walk or cycle to kindergarten, pre-school or school per day (please count both ways, back and forth)?

distwalkcy

Approximately |___|___|, |___| kilometres per school day.

Pregnancy and early childhood

The questions on pregnancy relate to the child's biological mother.
In case that you are not the biological mother, ➔➔➔ **Continue with question 23!**

19. What was your age at the birth of your child?

age_birth
I was |__|__| years old at the birth of my child.

20. How often did you consume alcoholic beverages during the pregnancy with your child?

		Never	*Once a month or less often*	*Several occasions a month*	*Several occasions a week*
cons_beer	Beer, wine, sparkling wine or similar	○ 1	○ 2	○ 3	○ 4
cons_liq	Sherry, port, liqueur or similar	○ 1	○ 2	○ 3	○ 4
cons_whis	Whisky, vodka, schnapps or similar	○ 1	○ 2	○ 3	○ 4

21. How often did you smoke during your pregnancy with your child?

		Never	*Rarely, at maximum once a month*	*Several occasions a week*	*Daily*
smoke_cig	Cigarettes	○ 1	○ 2	○ 3	○ 4
smoke_tob	Other tobacco products	○ 1	○ 2	○ 3	○ 4

22. How many kilograms did you gain in total during pregnancy with your child?

preg_w_up
I gained approximately |__|__| kilograms.

23. In which week of pregnancy was your child delivered?

weeksearly

birth_term ○ 1 My child was delivered preterm, |__|__| weeks before calculated date of birth

○ 2 My child was delivered in time or late.

24. Was a C-section done?

○ 1 Yes c_section ○ 2 No

25. What was the weight and height of your child at birth?

birth_w birth_h

Approximately |__|__|__|__| grams |__|__| centimetres

26. Did your child suffer from health problems during the first four weeks after birth?

Please indicate all health problems that occurred.

hp_resp ○ 1 Respiratory difficulties, adjustment disorders

hp_inf ○ 1 Infection

hp_jaund ○ 1 Jaundice

hp_underw ○ 1 Underweight, premature birth

hp_other ○ 1 Other, please specify: ____hp_other_t________________________

hp_none ○ 1 My child did not suffer from health problems during the first four weeks after birth.

27. At what age was your child's diet fully integrated into the usual household's diet?

hd_month

When my child was |__|__| months old.

hd_not ○ 1 My child's diet is not yet fully integrated into the usual household diet.

28. What type of feeding was used with your child prior to being fully integrated into the usual household diet?

Please tick all applying answers and give the starting and ending age of your child when the specified type of feeding was used.

		Type of feeding	***Starting age***	***Ending age***
breastf	○1	Exclusive breast-feeding	|breastf_st| months	|breastf_en| months
breastc	○1	Breast-feeding in combination with other types of feeding	|breastc_st| months	|breastc_en| months
formula	○1	Formula milk	|formula_st| months	|formula_en| months
tfeed	○1	Other types of infant feeding – please specify: otfeed_t ________________________________	otfeed_st| months	otfeed_en| months

29. At what age did you first introduce...

	Type of food	***Age of the child when this type of food was introduced***
intrcereal	Cereals or food containing rye, wheat or barley (<*please include country-specific examples*>)	At month |___|___|.
intrveget	Vegetables	At month |___|___|.
intrfruit	Fruit	At month |___|___|.
intrmeat	Meat	At month |___|___|.
intrcowm	Cow milk	At month |___|___|.

Family Lifestyle

30. To what extent would the following describe your relationship to your child?

		Not true	*Hardly true*	*Rather true*	*Exactly true*
relation_1	I ask what my child is doing with his/her friends.	○ 0	○ 1	○ 2	○ 3
relation_2	I tell my child when she/he does a good job.	○ 0	○ 1	○ 2	○ 3
relation_3	I am pleased with the behaviour of my child.	○ 0	○ 1	○ 2	○ 3
relation_4	I sometimes forget the rules I make for my child.	○ 0	○ 1	○ 2	○ 3
relation_5	I can be talked into things easily by my child.	○ 0	○ 1	○ 2	○ 3
relation_6	I am often too busy to talk to my child.	○ 0	○ 1	○ 2	○ 3
relation_7	I like my child just the way he/she is.	○ 0	○ 1	○ 2	○ 3

31. To what extent would the following describe your family?

		Not true	*Hardly true*	*Rather true*	*Exactly true*
famdescr_1	We get along with each other really well.	○ 0	○ 1	○ 2	○ 3
famdescr_2	We often go on trips together.	○ 0	○ 1	○ 2	○ 3
famdescr_3	No weekend passes without having undertaken something.	○ 0	○ 1	○ 2	○ 3
famdescr_4	At our home it is laid down quite exactly what is allowed and what not.	○ 0	○ 1	○ 2	○ 3
famdescr_5	At home we are rather tolerant when things do not succeed a hundred per cent.	○ 0	○ 1	○ 2	○ 3
famdescr_6	On weekends it is often quite boring at home.	○ 0	○ 1	○ 2	○ 3

32. How many persons – including your family – do you know that you can definitely rely on in cases of need?

○1 Nobody

coneedpers ○2 1 person

○3 2 to 3 persons

○4 More than 3 persons

33. Below you find some statements regarding children.
Please indicate how much you agree or disagree with each statement.

		Agree	*Moderately agree*	*Moderately disagree*	*Disagree*
childst_01	When children are significantly overweight or underweight, Social Services should step in.	○1	○2	○3	○4
childst_02	The school has a responsibility for making sure my child gets enough exercise.	○1	○2	○3	○4
childst_03	If a child is significantly overweight, it is primarily the responsibility of the parents.	○1	○2	○3	○4
childst_04	Parents have the main responsibility for helping their children be fit and active.	○1	○2	○3	○4
childst_05	I restrict my child's outdoor activities for safety reasons.	○1	○2	○3	○4
childst_06	I don't like to let my child walk/cycle to kindergarten, pre-school or school for safety reasons.	○1	○2	○3	○4
childst_07	I feel that the authorities don't do enough to support healthy eating.	○1	○2	○3	○4
childst_08	There should be a controlled restriction on advertising of high-fat and high-sugar foods.	○1	○2	○3	○4
childst_09	Very unhealthy foods should be highly taxed while healthy foods should be subsidised.	○1	○2	○3	○4
childst_10	Children's TV, electronic games and computer use should be restricted by their parents.	○1	○2	○3	○4

Health and well-being

34. Each item below is a statement about your health to which you may agree or disagree.
Please mark for each statement the extent to which you agree or disagree.

		Agree	*Moderately agree*	*Moderately disagree*	*Disagree*
healthst_1	If I see an excellent doctor regularly, I am less likely to have health problems.	○1	○2	○3	○4
healthst_2	It seems that my health is greatly influenced by accidental happenings.	○1	○2	○3	○4
healthst_3	I can only maintain my health by consulting health professionals.	○1	○2	○3	○4
healthst_4	Whatever goes wrong with my health is my own fault.	○1	○2	○3	○4
healthst_5	When I feel ill, I know it is because I have not taken care of myself properly.	○1	○2	○3	○4
healthst_6	The type of care I receive from other people is responsible for how well I recover from an illness.	○1	○2	○3	○4
healthst_7	Even when I take care of myself it's easy to get sick.	○1	○2	○3	○4
healthst_8	When I become ill it's a matter of fate.	○1	○2	○3	○4
healthst_9	I can pretty much stay healthy by taking good care of myself.	○1	○2	○3	○4

35. How would you describe the general health of your child?

chldhealth

○1 Very good
○2 Good
○3 Fair
○4 Bad
○5 Very bad

36. Do you think your child is…

○1 Much too underweight?
○2 Slightly too underweight?

chldweight ○ 3 Proper weight?
○ 4 Slightly too overweight?
○ 5 Much too overweight?

37. How concerned are you about your child…

		Unconcerned	***A little concerned***	***Concerned***	***Very concerned***
chldconc_1	…eating too much when you are not around him/her?	○ 0	○ 1	○ 2	○ 3
chldconc_2	…having to diet to maintain a desirable weight?	○ 0	○ 1	○ 2	○ 3
chldconc_3	…becoming overweight?	○ 0	○ 1	○ 2	○ 3
chldconc_4	…becoming underweight?	○ 0	○ 1	○ 2	○ 3

38. Emotional well-being

	During the last week…	***Not at all***	***Hardly ever***	***Sometimes***	***Often or always***
emot_wb_1	… my child laughed and had lots of fun.	○ 0	○ 1	○ 2	○ 3
emot_wb_2	… my child did not feel much like doing anything.	○ 0	○ 1	○ 2	○ 3
emot_wb_3	… my child felt lonely.	○ 0	○ 1	○ 2	○ 3
emot_wb_4	… my chid was insecure or anxious.	○ 0	○ 1	○ 2	○ 3

39. Self-Esteem

	During the last week…	***Not at all***	***Hardly ever***	***Sometimes***	***Often or always***
self_est_1	… my child was proud of him/herself.	○ 0	○ 1	○ 2	○ 3

self_est_2	… my child felt on top of the world.	○ 0	○ 1	○ 2	○ 3
self_est_3	… my child liked him/herself.	○ 0	○ 1	○ 2	○ 3
self_est_4	… my child had many good ideas.	○ 0	○ 1	○ 2	○ 3

40. Family

	During the last week…	***Not at all***	***Hardly ever***	***Sometimes***	***Often or always***
family_1	… my child got on well with us as parents.	○ 0	○ 1	○ 2	○ 3
family_2	… my child felt fine at home.	○ 0	○ 1	○ 2	○ 3
family_3	… we had heated arguments at home.	○ 0	○ 1	○ 2	○ 3
family_4	… my child felt patronised by us.	○ 0	○ 1	○ 2	○ 3

41. Social Contacts

	During the last week…	***Not at all***	***Hardly ever***	***Sometimes***	***Often or always***
socicont_1	… my child spent time with his/her friends.	○ 0	○ 1	○ 2	○ 3
socicont_2	… my child was liked by other children.	○ 0	○ 1	○ 2	○ 3
socicont_3	… my child got along well with his/her friends.	○ 0	○ 1	○ 2	○ 3
socicont_4	… my child felt like he/she was different from others.	○ 0	○ 1	○ 2	○ 3

42. Which of the following events did your child encounter?

Please indicate all events your child encountered and report also how old your child was at that time and, according to your estimation, how strongly he/she was troubled by this event.

	Event	***Age of the child at the time of the event***	***My child was troubled by this event ...***
event1 ○ 1	Divorce or separation of parents	event1_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event1_tr
event2 ○ 1	Death of a parent	event2_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event2_tr
event3 ○ 1	Death of a sibling	event3_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event3_tr
event4 ○ 1	Addition of new family members e.g. step-parent	event4_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event4_tr
event5 ○ 1	Job loss of mother and/or father	event5_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event5_tr
event6 ○ 1	Major frustrations, e.g. at school or with peers, please specify: __________event6_t__________	event6_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event6_tr
event7 ○ 1	Severe diseases or accidents of the child, please specify: event7_t	event7_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event7_tr
event8 ○ 1	Other important events, please specify: event8_t	event8_y |___|___| years	○ 1 .. rather strong ○ 2 .. rather little event8_tr

43. To what extent do the following characterisations apply to your child?

Please give your answers on the basis of the child's behaviour **over the last six months.**

	Not true	***Somewhat true***	***Certainly true***	
Considerate of other people's feelings	○ 0	○ 1	○ 2	childchr01
Often complains of headaches, stomach-aches or sickness	○ 0	○ 1	○ 2	childchr02
Shares readily with other children (toys, etc.)	○ 0	○ 1	○ 2	childchr03
Often has temper tantrums or hot tempers	○ 0	○ 1	○ 2	childchr04
Rather solitary, tends to play alone	○ 0	○ 1	○ 2	childchr05
Generally obedient, usually does what adults request	○ 0	○ 1	○ 2	childchr06
Has many worries, often seems worried	○ 0	○ 1	○ 2	childchr07
Has at least one good friend	○ 0	○ 1	○ 2	childchr08
Often fights with other children or bullies them	○ 0	○ 1	○ 2	childchr09
Often unhappy, downhearted or tearful	○ 0	○ 1	○ 2	childchr10
Generally liked by other children	○ 0	○ 1	○ 2	childchr11
Nervous or clingy in new situations, easily loses confidence	○ 0	○ 1	○ 2	childchr12
Kind to younger children	○ 0	○ 1	○ 2	childchr13
Picked on or bullied by other children	○ 0	○ 1	○ 2	childchr14
Often volunteers to help others	○ 0	○ 1	○ 2	childchr15
Gets on better with adults than with other children	○ 0	○ 1	○ 2	childchr16
Has many fears, is easily scared	○ 0	○ 1	○ 2	childchr17

Leisure time activities and consumer behaviour

44. How much time does your child usually spend per day playing <u>in the yard or street around your house</u> (or the house of a friend, neighbour or relative)?

Please indicate for every timeframe.

	0 minutes	*1-15 minutes*	*16-30 minutes*	*31-60 minutes*	*Over 60 minutes*	
Wake-up time until noon	○ 1	○ 2	○ 3	○ 4	○ 5	playyard1
Noon until 6 PM	○ 1	○ 2	○ 3	○ 4	○ 5	playyard2
6 PM until bedtime	○ 1	○ 2	○ 3	○ 4	○ 5	playyard3

45. How much time does your child usually spend per day <u>at a park, playground, or outdoor recreation area</u> (e.g. swimming pool, zoo or amusement park)?

Please indicate for every timeframe. Include times while the child is at day care, kindergarten, preschool or school.

	0 minutes	*1-15 minutes*	*16-30 minutes*	*31-60 minutes*	*Over 60 minutes*	
Wake-up time until noon	○ 1	○ 2	○ 3	○ 4	○ 5	playgrd1
Noon until 6 PM	○ 1	○ 2	○ 3	○ 4	○ 5	playgrd2
6 PM until bedtime	○ 1	○ 2	○ 3	○ 4	○ 5	playgrd3

46. Think for a moment about a typical weekday for your child in the last month. How much time would you say your child spends playing outdoors on a typical weekday?

plweekd_h plweekd_m

|___|___| hours |___|___| minutes

47. Now think about a typical weekend day for your child in the last month. How much time would you say your child spends playing outdoors on a typical weekend day?

plweeken_h plweeken_m
|___|___| hours |___|___| minutes

48. Is your child member in a sports club?

club_mbr

○1 Yes

○2 No ➔➔➔ **Please continue with question 49.**

How much time does he/she spend doing sport in a sports club per week?

club_h club_m
|___|___| hours |___|___| minutes

What kind of sport does your child do in a sports club?
Please tick all appropriate.

sport1 ○1 *<country-specific categories>*

sport2 ○1 *<country-specific categories>*

sport3 ○1 *<country-specific categories>*

sport4 ○1 *<country-specific categories>* sport5

sporto ○1 Other, please specify: ____sporto_t____________________

49. Is your child able to…

	Yes	**No**	
…ride a bicycle?	○1	○2	bicycling
…swim?	○1	○2	swimming
…*<add country-specific relevant category>*	○1	○2	ctrysp_act

50. How long does your child usually watch TV / video / DVD per day?

	Not at all	*Less than 30 min. per day*	*Less than 1 hour per day*	*Approx. 1 – 2 hrs. per day*	*Approx. 2– 3 hrs. per day*	*More than 3 hours per day*	
Weekdays	○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	tv_dur_wd
Saturday/Sunday	○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	tv_dur_we

51. How long does your child usually sit at a computer / game console per day?

	Not at all	*Less than 30 min. per day*	*Less than 1 hour per day*	*Approx. 1 – 2 hrs. per day*	*Approx. 2– 3 hrs. per day*	*More than 3 hours per day*	
Weekdays	○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	pc_dur_wd
Saturday/Sunday	○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	pc_dur_we

52. Which of the following media devices are located in the bedroom your child is using?

Please tick all applying answers.

bedrmedia1 ○ 1 TV

bedrmedia2 ○ 1 Computer

bedrmedia3 ○ 1 Internet connection

bedrmedia4 ○ 1 Video/DVD player

bedrmedia5 ○ 1 Playstation / Game console

bedrmedian ○ 1 None of these.

53. With whom does your child usually watch TV?

Please mark one situation that applies most.

tv_attend

○ 1 Alone

○ 2 With his/her parents/guardians

○ 3 With his/her siblings

○ 4 With friends

○ 5 My child hardly watches TV. ➔➔➔ **Please continue with question 57.**

54. When watching TV do you discuss the programmes/ads with your child?

tv_discuss

○ 1 Never

○ 2 Sometimes

○ 3 Often

○ 4 Always

55. When does your child usually watch TV?

Please tick all applying answers.

for SAS-Dataset corrected:

tv_time_1 – tv_time_6

tv_time_1 ○ 1 Early morning (6-9 a.m.)

tv_time_2 ○ 2 Late morning (9-12 a.m.)

tv_time_3 ○ 3 Noon time (12-3 p.m.)

tv_time_4 ○ 4 Afternoon (3-6 p.m.)

tv_time_5 ○ 5 Evening (6-9 p.m.)

tv_time_6 ○ 6 Late night (9-12 p.m.)

56. What does your child like most when watching TV?
You can tick several answers.

tv_pref_1 ○1 Cartoons

tv_pref_2 ○1 Soap operas

tv_pref_3 ○1 Advertisements

tv_pref_4 ○1 Shopping channels

tv_pref_5 ○1 Children's programmes

(discard/include country-specific categories if necessary)
tv_pref_6 tv_pref_7 tv_pref_8

tv_pref_o ○1 Other, please specify: tv_pref_ot ____________________

57. Below you find some statements regarding TV food advertising.
Please indicate how much you agree or disagree with each statement.

		Agree	***Moderately agree***	***Moderately disagree***	***Disagree***
tvfood_st1	TV food advertising is a good source of information for children and parents.	○1	○2	○3	○4
tvfood_st2	TV food advertising assists parents in their efforts to feed their child a healthy and balanced diet.	○1	○2	○3	○4
tvfood_st3	A child clearly understands just how good the product presented in TV advertising is.	○1	○2	○3	○4
tvfood_st4	TV food advertising informs children and parents about things they would otherwise never learn about.	○1	○2	○3	○4
tvfood_st5	TV food advertising leads children and their parents to spend their money on unnecessary and sometimes even harmful products.	○1	○2	○3	○4
tvfood_st6	TV food advertising is largely responsible for the weight problems and bad teeth of many children.	○1	○2	○3	○4
tvfood_st7	TV food advertising can hardly have an influence on what children eat and drink.	○1	○2	○3	○4
tvfood_st8	TV food advertising directed to children should be banned.	○1	○2	○3	○4

Children’s spending

58. What is your child’s weekly amount of available money?
Please include pocket money, money gifts etc.

pocmoney

○1 Up to *<country-specific categories>*

○2 *<country-specific categories>* per week

○3 *<country-specific categories>* per week

○4 More than *<country-specific categories>* per week

○5 My child does not have any money to spend on his/her own. ➔➔➔ **Please continue with question 61.**

59. Do you allow your child to spend his/her money on whatever he/she likes?

pocmondec

○1 Yes

○2 No

○3 To a certain degree

60. What are the things your child spends his/her money on?
Please tick any.

pocmonsp1 ○1 Salty snacks (e.g. chips, nuts)

pocmonsp2 ○1 Sweets (e.g. chocolate bars, chewing gum, candies)

pocmonsp3 ○1 Toys / entertainment (e.g. movie theatre)

pocmonsp4 ○1 School items

pocmonsp5 ○1 Equipment for hobbies

pocmonspo ○ 1 Others, please specify ______pocmonspot______________________.

61. Do you usually take your child along to grocery shopping?

grocshop

- ○ 1 I try to avoid it because it is faster alone.
- ○ 2 I try to avoid it because he/she is pushing for treats.
- ○ 3 I enjoy choosing the food together with my child.
- ○ 4 I have to, but don't enjoy it.

62. Does your child ask for items he/she saw on TV?

tvitemask

- ○ 1 Never
- ○ 2 Sometimes
- ○ 3 Often
- ○ 4 My child hardly watches TV.

63. When your child asks for a specific food item which is not on your shopping list, do you buy it?

buyrequest

- ○ 1 Usually not
- ○ 2 Sometimes
- ○ 3 Often
- ○ 4 Only if I have the money for extras.
- ○ 5 Only if it is something healthy.

Socio-demographic information

The following questions will help us to compare the health of your child with that of other children with the same characteristics.

64. Was your child born in <*insert country*> ?

cobchild ○1 Yes ○2 No, he/she was born in: cobchild_t

____

Was the mother of the child born in <*insert country*> ?

cobmoth ○1 Yes ○2 No, she was born in: cobmoth_t

____

Was the father of the child born in <*insert country*> ?

cobfath ○1 Yes ○2 No, No, he was born in: cobfath_t

____

65. In what language(s) do you usually speak with your child at home?

language
○1 *<insert national language>*
○2 Other language, please specify: ________ language_t ________

66. What is the highest level of education you and your spouse/partner have?
Please indicate only one per person.

edulevel_1 edulevel_2

	Me	*Spouse/partner*
<Country-specific categories>	○1	○1
<Country-specific categories>	○2	○2
<Country-specific categories>	○3	○3
<Country-specific categories>	○4	○4
…	○5	○5
No graduation (yet)	○8	○8
Unknown	○9	○9

67. What is the highest level of professional qualification you and your spouse/partner have?

Please indicate only one per person.

	qualific_1 *Me*	qualific_2 *Spouse/partner*
<Country-specific categories>	○ 1	○ 1
<Country-specific categories>	○ 2	○ 2
<Country-specific categories>	○ 3	○ 3
<Country-specific categories>	○ 4	○ 4
...	○ 5	○ 5
No training (yet)	○ 8	○ 8
Unknown	○ 9	○ 9

68. At the present time, which of the following does best describe your main occupational status and that of your spouse/partner?

Please indicate only one per person.

	occupst_1 *Me*	occupst_2 *Spouse/partner*
Full-time job (30 hrs. or more a week)	○ 1	○ 1
Part-time job (less than 30 hrs. a week)	○ 2	○ 2
Attend school or university	○ 3	○ 3
Homemaker	○ 4	○ 4
Retired (also early retirement)	○ 5	○ 5
Temporary company leave (e.g. maternity or paternity leave)	○ 6	○ 6
Unemployed, for less than one year	○ 7	○ 7
Unemployed, for a year or more	○ 8	○ 8
On welfare (social assistance)	○ 9	○ 9
Other, please specify: occupst_t ________________	○ 10	○ 10

69. In what occupational position are you and your spouse/partner presently occupied?
If you or your spouse/partner is no longer occupied or currently not occupied, please indicate the last occupational position.

worker_1 worker_2

	Me	*Spouse/partner*
Worker		
Non-skilled worker	○ 1	○ 1
Semi-skilled worker	○ 2	○ 2
Skilled worker, craftsman	○ 3	○ 3
Master craftsman, foreman	○ 4	○ 4
Employers and self-employed (including helping family members)	employer_1	employer_2
Self-employed agriculturist, farmer	○ 1	○ 1
Self-employed, Freelancer	○ 2	○ 2
Employers with up to 9 employees	○ 3	○ 3
Employers with 10 and more employees	○ 4	○ 4
Helping family member	○ 5	○ 5
Employee	employee_1	employee_2
Employee with simple tasks (e.g. salesperson, clerk)	○ 1	○ 1
Employee with qualified tasks (e.g. accounting clerk, dental assistant)	○ 2	○ 2
Employee with highly qualified tasks or management functions (e.g. scientist, department manager)	○ 3	○ 3
Employee with comprehensive executive functions (e.g. director, managing director, executive board)	○ 4	○ 4
Civil servant	civil_1	civil_2
<Country-specific categories>	○ 1	○ 1
<Country-specific categories>	○ 2	○ 2
<Country-specific categories>	○ 3	○ 3
<Country-specific categories>	○ 4	○ 4
Never employed	○ 1	○ 1

never_1 never_2

70. What is your monthly household income, i.e. the net income that you (altogether) have after taxes and deductions?

Household includes everyone living in the same residence as the selected child and sharing expenses.

Please include also income from rent and lease, pensions, child allowances, alimonies etc.

income

Under	*<Country-specific cut-points>*		○ 1
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 2
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 3
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 4
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 5
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 6
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 7
<Country-specific cut-points>	up to under	*<Country-specific cut-points>*	○ 8
<Country-specific cut-points>	and more		○ 9

Thank you for answering these questions!
Please check once more that you have answered in full.

Please note the date, when you finished filling in the questionnaire:

dofill_dd, dofill_mm, dofill_yy

|___|___| Day |___|___| Month |___|___|___|___| Year

6.6. Annex

Healthy Lifestyle
in Europe
by Nutrition
in Adolescence
HELENA

Healthy Lifestyle in Europe by Nutrition in Adolescence in 13-16 years adolescents across Europe,
Cross-sectional study (HELENA-CSS).

QUICK
EUROPEAN
SOCIO-ECONOMIC
STATUS
QUESTIONNAIRE

From UL2 November 2005

Subject number : H 1 ___ Number of centre ___ Number of school ___ Number of class ___ Number of subject

Subjects initials: ___ first name/second name/family name

Evaluation date : ___ Day ___ Month ___ Year

SOCIO-ECONOMIC STATUS QUESTIONNAIRE

Please tick the appropriate box to answer each question (Colour one bullet for each questions unless otherwise indicated).

The term family is meaning members living together : father, mother and Sibling) in one home.

For some of them, if you live in two families, please give an answer relating to the family where you live most of the time.

Please respond with honesty and sincerity

All theses information will remain confidential and be analysed anonymously

GENERAL INFORMATIONS ABOUT YOUR LIVING CONDITIONS

1. Do you have own bedroom for yourself ?

Yes	**No**
☐ (1)	☐ (01)

2. How many cars possess your family?

0	**1**	**2**	**≥ 3**
☐	☐	☐	☐

3. How many computers possess your family?

0	**1**	**2**	**≥ 3**
☐	☐	☐	☐

	Yes	**No**
4. Do you have an internet connection at home?	☐(1)	☐(0)

Family structure and way of life

5. How many of your sisters and brothers, including stepsisters and stepbrothers live at home (exclude yourself)?

0	1	2	3	4	≥ 5
☐	☐	☐	☐	☐	☐

6. With whom do you live most of the time? (if you live half of the time with your mother and half of the time with your father, you may tick 2 boxes)

With your two parents .... ☐(1)

With your mother alone .... ☐(2)

With your mother and her partner .... ☐(3)

With your father alone .... ☐(4)

With your father and his partner .... ☐(5)

With your grandparents or other relatives .... ☐(6)

With your foster parents/adoptive parents .... ☐(7)

In a children's home .... ☐(8)

With Someone or somewhere else ☐(9)

Please specify: ....

OCCUPATION OF PARENTS

7. Which of the following applies to your parents (please give information for both parents, tick one in each column)

	Mother	Father
1. Managerial Staff (ex : public administration manager, firm director, Head of department, President)	☐ (1)	☐ (1)
2. Intellectual and scientific occupations (ex : architects, engineers biologist, chemist, doctor, informatics specialist, lawyer, university teacher, pharmacist, psychologist, sociologist...)	☐ (2)	☐ (2)
3. Intermediate occupations (ex : Technician/ technician specialist, nurse, dietetician, clerks, teacher, commercial representative)	☐ (3)	☐ (3)
4. Administrative/clerical (ex: Shop or ba NA officer, policeman)	☐ (4)	☐ (4)
5. Business services/Services workers (ex : Shop and market sales workers, cooker)	☐ (5)	☐ (5)
6. Skilled agricultural and fishery worker (ex : Farmers, fishers, forest worker…)	☐ (6)	☐ (6)
7. Craft and manual worker (ex : Hairdresser, electrician, working man, operative, craft, mechanic, shoe maker, cloth maker…)	☐ (7)	☐ (7)
8. Machine operators and assemblers (ex : Industrial worker, machine operator, crane driver, track chart)	☐ (8)	☐ (8)
9. Workers man and elementary occupation (ex : worker man, seller, house keeper/building, nanny guardian, washer)	☐(9)	☐ (9)
10. Army	☐ (10)	☐ (10)
11. other	☐ (11)	☐ (11)
12. Don't work		

15. Please indicate the kind of studies your parents have?

	Mother	**Father**
Elementary education	☐(1)	☐(1)
Finished lower secondary education	☐(2)	☐(2)
Finished higher secondary education	☐(3)	☐(3)
Finished tertiary education	☐(4)	☐(4)
Don't know	☐(-9)	☐(-9)

16. PERCEIVED FAMILY WEALTH

Very well off	☐(1)
Quite well off	☐(2)
Average	☐(3)
Not very well off	☐(4)
Not at all well off	☐(5)

THANK FOR YOUR REPLY *HELENA !!!*

END OF THE SES questionnaire

12.4. Annex: IPAQ adapted for adolescents

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at school, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the last 7 days. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: SCHOOL-RELATED PHYSICAL ACTIVITY

Please try to think about all types of physical activity you do in School (during breaks, free time between classes and during class) Do not include transportation to and from school (this will be asked later).

1. Do you currently attend school or participate in any other education?

☐ Yes
☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of school. This does not include traveling to and from school.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like activities you do for fun, activities at brakes or during physical education **as part of school**? Think about only those physical activities that you did for at least 10 minutes at a time.

____ **days per week**

☐ No vigorous school-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of school?

____ **hours per day**
____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days,** on how many days did you do **moderate** physical activities like activities for fun or during physical education **as part of school**? Please do not include walking.

____ **days per week**

☐ No moderate school-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of school?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **at school**? Please do not count any walking you did to travel to or from school.

_____ **days per week**

☐ No school-related walking ➡ ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your school?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like school, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** *like a train,* bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle ➡ ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place?**

_____ **days per week**

☐ No bicycling from place to place ➡ ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place?**

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE AND GARDENING

This section is about some of the physical activities you might have done in the **last 7 days** in *and around your home*, like housework, gardening, yard work and general maintenance work.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home ➡ ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time ➡ ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time ➡ ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time?**

_____ **days per week**

☐ No moderate activity in leisure time ➡ ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at school, at home and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.