Environmental Research 201 (2021) 111548

Contents lists available at ScienceDirect

Environmental Research

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

# Dietary exposure to parabens and body mass index in an adolescent Spanish population

Celia Monteagudo [a,b,1], Virginia Robles-Aguilera [a,1], Inmaculada Salcedo-Bellido [b,c,d,*], Yolanda Gálvez-Ontiveros [a,b], Cristina Samaniego-Sánchez [a], Margarita Aguilera [b,e], Alberto Zafra-Gómez [b,f], Maria Alba Martínez Burgos [g], Ana Rivas [a,b]

[a] Department of Nutrition and Food Science, University of Granada, Campus of Cartuja, 18071, Granada, Spain
[b] Instituto de Investigación Biosanitaria. Ibs-Granada, 18012, Granada, Spain
[c] Department of Preventive Medicine and Public Health, University of Granada, Campus of Cartuja, 18071, Granada, Spain
[d] Consortium for Biomedical Research in Epidemiology & Public Health (CIBER en Epidemiología y Salud Pública - CIBERESP), Monforte de Lemos 5, 2809, Madrid, Spain
[e] Department of Microbiology, Faculty of Pharmacy, University of Granada, Campus of Cartuja, 18071, Granada, Spain
[f] Department of Analytical Chemistry, University of Granada, Campus of Fuentenueva, 18071, Granada, Spain
[g] Department of Physiology, Faculty of Pharmacy, Institute of Nutrition and Food Technology 'José Matáix' (INYTA), Center for Biomedical Research (CIBM), Health Sciences Technological Park, Avda. del Conocimiento s/n, 18071, Armilla, Granada, Spain

ARTICLE INFO

*Keywords:*
Parabens
Overweight
Obesity
Adolescents
Dietary exposure

ABSTRACT

Parabens are alkyl esters of p-hydroxybenzoic acid which are extensively used in cosmetics, pharmaceuticals and foodstuffs due to their antimicrobial properties. The most commonly used parabens are methyl-(MeP), ethyl-(EtP), propyl-(PrP) and butyl-(BuP) paraben. Most human exposure to parabens is achieved through the consumption of food or pharmaceutical products and the use of personal care products. However, studies on dietary parabens exposure and the associated factors are very scarce. The main aim of the present study was to explore factors associated with dietary exposure to parabens in Spanish adolescents according to gender. Dietary data and anthropometric measures were collected from 585 adolescents (53.4% boys) aged 12–16 years. Parabens exposure through diet was assessed using a food frequency questionnaire with food products providing more than 95% of energy and macronutrient intake being included in analysis. Stepwise regression was used to identify the foods that most contributed to parabens intake. Logistic regression was used to evaluate factors predicting higher dietary exposure to parabens. The main contributors to dietary MeP, EtP, PrP and BuP exposure in adolescent boys were eggs (41.9%), canned tuna (46.4%), bakery and baked goods products (57.3%) and pineapple (61.1%). In adolescent girls, the main contributors were apples and pears (35.3%), canned tuna (42.1%), bakery and baked goods products (55.1%) and olives (62.1%). Overweight/obese girls were more likely to belong to the highest tertile of overall parabens intake (odds ratio [OR]: 3.32; 95% confidence interval [95% CI]: 1.21–9.15) and MeP (OR: 3.05; 95% CI: 1.14–8.12) than those with a body mass index lower than 25 $kg/m^2$. These findings suggest a positive association between dietary exposure to parabens and overweight/obesity in adolescent girls.

## 1. Introduction

Parabens are alkyl esters of p-hydroxybenzoic acid, being the most widely used methyl- (MeP), ethyl- (EtP), propyl- (PrP) and butyl- (BuP) parabens (Jiménez-Díaz et al., 2016). They are especially found in cosmetics, pharmaceuticals, foodstuffs and beverages where they are used as antimicrobials (Halla et al., 2018; Liao et al., 2013a, 2013b; Ursino et al., 2011). Processed food products that contain parabens for preservation include cookies, cooking oils, seasonings, meat, dairy products, snacks, cereal (Liao et al., 2013a, 2013b; Maher et al., 2020) and cereal-based foodstuffs (Azzouz et al., 2020), although parabens have also been found in mussels (Álvarez-Muñoz et al., 2018), clams and

* Corresponding author. Department of Preventive Medicine and Public Health, Faculty of Pharmacy, Campus de Cartuja s/n, 18071, Granada, Spain.
*E-mail address:* isalcedo@ugr.es (I. Salcedo-Bellido).
[1] These authors have contributed equally to this work.

https://doi.org/10.1016/j.envres.2021.111548
Received 12 January 2021; Received in revised form 22 May 2021; Accepted 15 June 2021
Available online 21 June 2021

oysters (Azzouz et al., 2019). Some fruits and vegetables also contain parabens as a naturally occurring preservative (Hagel et al., 2019).

These compounds are extensively used as preservatives because of their low toxicity, broad antimicrobial activity, regulatory acceptance and affordability (Soni et al., 2005). However, *in vitro* and *in vivo* studies have demonstrated estrogenic (Boberg et al., 2010; Charles and Darbre, 2013; Pollock et al., 2017) and antiandrogenic activity of parabens in humans (Chen et al., 2007; Oishi, 2002). This estrogenic activity has been associated with an increased risk of breast cancer (Giulivo et al., 2016) and with uterine histological changes in experimental studies (Boberg et al., 2010; Lemini et al., 2004; Zhang et al., 2016). Furthermore, parabens have been shown to disturb the function of thyroid hormones and to activate the peroxisome proliferator-activated receptor gamma (PPARg), playing an important role in adipogenesis and lipid accumulation (Pereira-Fernandes et al., 2013) and making their obesogenic potential of increasing concern (Kolátorová et al., 2018).

The high concentration and detection frequency of parabens in biological samples indicate a broad exposure to parabens from various sources. The main source of exposure to these compounds comes through the use of personal care products and pharmaceutical products and the consumption of foodstuffs containing parabens (Feizabadi et al., 2020a). Several studies have reported an association between exposure to parabens, measured according to their presence in biological samples, and some sociodemographic characteristics. This suggests that exposure to these compounds is highly correlated with socioeconomic characteristics and lifestyle factors (Hajizadeh et al., 2020). Age, place of residence, occupation, smoking status and educational level have all been found to be related (Calafat et al., 2010; Engel et al., 2014; Feizabadi et al., 2020a, 2020b, 2020b; Iribarne-Durán et al., 2020; Kang et al., 2016; Yu et al., 2019). However, as paraben usage patterns may differ by country, associations between variables may also vary. These differences may be due to changes in the rate of use of cosmetics and foodstuffs and, potentially, changes in lifestyle habits (Feizabadi et al., 2020a). Given that food is considered the main source of parabens exposure in humans, different national and international agencies seek to regulate this exposure to ensure public health and safety. In 2004, the European Food Safety Authority (EFSA, 2004) established that a daily intake of 10 mg $kg^{-1}$ body weight/day was acceptable for MeP and EtP. This guideline was reiterated in 2006 through the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2006). However, neither regulation established health protective levels for other types of parabens. Some countries such as China do not allow the use of parabens in certain food items such as jam, sausage and baby food (Ministry of Health of the People's Republic of China, 2011). However, dietary paraben contributions is not well characterized, mostly because of a lack of measurement data (Jo et al., 2020). The presence of parabens has been reported in foodstuffs examined in the USA and China (Liao et al., 2013a, 2013b). Moreover, recently we have demonstrated the presence of parabens in food items commonly consumed by the Spanish population (Gálvez-Ontiveros et al., 2021). Recently, Iribarne-Durán et al. (2020) demonstrated that the consumption frequency of some food items was related to menstrual blood concentrations of some parabens. This suggests that dietary parabens intake may make a relevant contribution to human exposure to these compounds.

Overweight and obesity are one of the most important public health issues in children and adolescents (Garrido-Miguel et al., 2019; Roth and Jain, 2018). The association between parabens exposure and body weight has been evaluated in different epidemiological studies. Prenatal exposure to parabens has been linked with increased birth weight (Philippat et al., 2014) but also with lower birth weight and height (Geer et al., 2017). As for the impact of postnatal exposure to parabens on body growth, the available literature is scarce. Xue et al. (2015) showed a non-significant association between postnatal exposure to parabens and childhood obesity. However, the same study found a positive association between exposure to 3,4-dihydroxybenzoic acid (3,4-DHB) and obesity (Xue et al., 2015). Guo and colleagues compared different anthropometric parameters with paraben concentrations in the urine of 3-year-old children and found that the sum of molar concentrations of five parabens was positively associated with height z scores (Guo et al., 2017). These positive associations were seen only in boys. Deierlein et al. (2017) found that exposure to MeP, EtP and PrP was not associated with different adiposity measurements (body mass index [BMI], body fat percentage, and waist circumference) in girls aged 6–8 years. Recently, the Canadian Health Measures Survey reported no association of paraben concentrations in urine with obesity and metabolic syndrome (Kim and Chevrier, 2020).

Understanding dietary parabens exposure in vulnerable populations such as adolescents is highly important for improving current understanding of dietary contributions to parabens exposure and for developing appropriate exposure mitigation programs. In order to address the lack of information on dietary parabens exposure, the present study explored the association of BMI and other factors with estimated dietary exposure to parabens in 585 Spanish adolescents according to gender.

## 2. Material and methods

### 2.1. Study population

The study population formed part of a larger sample (n = 708) from a previous research project funded by *Instituto de Salud Carlos III* (Ministry of Health, Spain). All participants were students attending a high school located in Talavera de la Reina (Toledo, Spain) and were recruited in 2017–2018. A total of 585 participants (53.5% male) aged 12–16 years for whom anthropometric measures (height and weight) and food frequency questionnaire (FFQ) responses were recorded were included in the present study.

Approval for this study was given by the Ethics Committee of the University of Granada.

### 2.2. Data collection

The data used in the present study form part of a larger database which includes more than 200 variables. For the purpose of the present study, anthropometric measures (weight and height), sociodemographic variables (gender, age, parent's occupational ranking, number of siblings), lifestyle (smoking habit) and general dietary habits estimated from the food frequency questionnaire (FFQ) were used. Parent's occupational ranking was determined from international standard occupational classifications (International Labour Office, 2012). In this sense, classifications were as follows: 1) High level: managers and professionals; 2) Mid-level: technicians and associate professionals, clerical support workers, services and sales workers, and skilled agricultural, forestry and fishery workers; 3) Low-level: craft and related trades workers, plant and machine operators and assemblers, and elementary occupations.

Participants' height and weight were measured by trained personnel using calibrated electronic scales and a wall-mounted stadiometer. BMI was calculated by dividing weight (kg) by height squared (m). The sample population was classified as underweight, normal, overweight or obese as described by Cole and colleagues (Cole et al, 2000, 2007).

FFQ administration was overseen by trained nutritionists. The questionnaire includes 96 food items classified according to 12 categories: dairy products (10), eggs, meat and luncheon meat products (7), fish (3), vegetables (15), fruit and dried fruits (15), legumes (4), cereals (5), bakery products, pastries and sweets (10), fats (5), non-alcoholic beverages (9), alcoholic beverages (4), and miscellaneous (9). Consumption frequency was classified as never, 1–3 times/month, 1 time/week, 2–4 times/week, 5–6 times/week, 1 time/day, 2–3 times/day, 4–6 times/day and more than 6 times/day. Information regarding the food packaging type (plastic, glass, metal, cardboard) was recorded. FFQ outcomes were validated *vs* 24 h recall with good agreement seen between both methods (Figures S1 and S2, Supplementary Material).

### 2.3. Paraben concentrations in food and estimation of dietary exposure

Since not all food types could be analyzed, the following approach was developed for food selection (Bemrah et al., 2014): (1) identification of the foods most commonly consumed by the present population and represent the main energy sources and macronutrients based on FFQ responses; (2) estimation of mean consumption of the identified foods; (3) sampling and analysis of the selected foods; (4) assessment of exposure via the integration of data on consumption, frequency, quantity and contamination.

A total of 82 of the 96 food items listed in the FFQ were selected and analyzed. These foods had been selected, through stepwise regression, as the main contributors to energy and macronutrient intake (dependent variable: total energy (kcal/day)/carbohydrate/lipid/protein (g/day) intake; predictive factors: energy contribution (kcal/day)/carbohydrate/lipid/protein (g/day) for each food item. Model iteration was stopped when new iterations failed to improve fit to the data ($p>0.05$). All compounds explained >95% of the variance in the model. Mean intake (g/day) of these foods was estimated by multiplying consumption frequency (servings/day) with portion size using standard servings (g/serving) established for the Spanish population (Moreiras et al., 2018).

The method used for determination and analysis of parabens in the selected foods has been described elsewhere (Gálvez-Ontiveros et al., 2021; García-Córcoles et al., 2018). Briefly, the foods selected for analysis were acquired from different national supermarkets and grocery stores. Once food extracts were obtained, they were directly injected into an ultrahigh performance liquid chromatography-tandem mass spectrometry system. From this, 56 of the 98 foods analyzed were seen to have a parabens concentration higher than the quantification level. Total daily dietary exposure to parabens was calculated for each participant by multiplying their daily food intake (g/day) with the paraben concentrations analyzed in each food product (ng/g). Estimated dietary exposure was obtained by dividing estimated dietary intake for each participant by their weight.

### 2.4. Statistical analysis

Means, standard deviations (SD) and percentages were used to describe the quantitative and qualitative variables where relevant. Student's t-test was used to compare continuous variables. Chi-square and Fisher Exact tests were used, when expected frequency was <0.05, to compare qualitative variables.

Stepwise regression (forward selection) was used to select the foods that most contributed to paraben intake (MeP, EtP, PrP and BuP). The dependent variable was provided by total intake of each paraben (ng/day). Covariates were provided by the contribution of each food to each compound (ng/day). The model for MeP included: sliced bread, luncheon meat products, olives, melon, eggs, rice, apple and pear, hamburger, onions and salted snacks. The model for EtP included: sliced bread, semi-cured cheese, carrots and pumpkin, canned tuna, pineapple, olives and mushrooms. The model for PrP included: olives, canned tuna, ham, pineapple, and bakery and baked goods. Finally, the model for BuP included salted snacks, mushrooms, pineapple, bakery and baked goods and olives. Selection was finalized when new iterations failed to improve the stepwise-regression model ($p>0.05$). Logistic regression models were used to estimate odds ratios (OR) and their associated 95% confidence intervals (95% CI) identifying the role of examined factors on predicting above average paraben intake. The dependent variable was paraben intake (ng/day) (total parabens, MeP, EtP, PrP and BuP) which was categorized according to tertiles and later dichotomized to ease interpretation (1st and 2nd tertiles vs 3rd tertile). The first two tertiles provided the reference category (lowest paraben intake), whilst high paraben intake corresponded to the highest tertile. Gender, age, BMI, large family, smoking habit and parent's occupational ranking were examined as potential factors. SPSS v.23 (version 23, IBM® SPSS® Statistics, Armonk, NY, USA) was used for all statistical analyses and significance was set at $p < 0.05$.

## 3. Results

The characteristics of the sample population distributed by gender are shown in Table 1. The table shows that adolescent boys were heavier [62.9 kg (SD 16.8) vs 57.1 kg (SD 12.2)] and taller [1.7 m (SD 0.1) vs 1.6 m (SD 0.1)] than girls. The number of never smokers was higher amongst boys (73.8 vs 66.9%). No significant differences were observed in relation to age, BMI, number of siblings, cigarettes per day and parent's occupational ranking.

Higher daily intake of MeP was associated with higher egg consumption, with the relationship being stronger in boys than in girls (5653.6 ng/day [SD 5593.1] vs 3816.5 ng/day [SD 3113.7], respectively; p-value: <0.01). This increased MeP was also associated with higher hamburger consumption, again to a greater extent in boys than in girls (2156.9 ng/day [SD 2404.7] vs 1647.1 ng/day [SD 1662.4], respectively; p-value: 0.01). Additionally, daily PrP intake was higher in adolescent boys than in girls (1316.7 ng/day [SD, 1857.6] vs 963.8 ng/day [SD 1575.5], respectively; p-value: 0.03). BuP intake was also greater in boys than girls (51.0 ng/day [SD 72.0] vs 37.4 ng/day [SD 61.1], respectively; p-value: 0.03), with this being related with an increased consumption of bakery and baked goods products (Table 2).

Estimated dietary exposure MeP and EtP values did not exceed the limit of 10 mg $kg^{-1}$ by $day^{-1}$ set by the EFSA (EFSA, 2004). In addition, PrP dietary exposure did not exceed the 1.25 mg $kg^{-1}$ by $day^{-1}$ limit established by the European Medicines Agency (EMA), below which there is no evidence of adverse health effects (European Public MRL Assessment Report (EPMAR), 2015). Evaluation of BuP was not possible because no limits have yet been set by international organizations (Table 2).

The food products that most contributed to MeP intake in adolescent boys were eggs (41.9%) and onions (21.6%). In contrast, the food products in girls were apples and pears (35.3%), followed by onions (25.3%). In addition, canned tuna (46.4% and 42.1% in boys and girls, respectively) and mushrooms (29.8% and 31.8% for boys and girls,

**Table 1**
Overall characteristics of participants (n = 585).

| | Boys (n = 313) | Girls (n = 272) | *p*-value |
|---|---|---|---|
| **Age (years), mean (SD)** | 15.4 (2.2) | 15.2 (2.3) | 0.44[a] |
| **Weight (kg), mean (SD)** | 62.9 (16.8) | 57.1 (12.2) | **<0.01**[a] |
| **Height (m), mean (SD)** | 1.7 (0.1) | 1.6 (0.1) | **<0.01**[a] |
| **BMI (kg/m$^2$), mean (SD)** | 22.5 (4.7) | 22.5 (4.2) | 0.88[a] |
| **BMI, n (%)** | | | 0.52[b] |
| Underweight | 8 (5.6) | 3 (2.6) | |
| Normal weight | 88 (61.5) | 77 (67.5) | |
| Overweight | 28 (19.6) | 23 (20.2) | |
| Obesity | 19 (13.3) | 11 (9.7) | |
| **Number of siblings, mean (SD)** | 1.2 (0.9) | 1.2 (0.9) | 0.99[a] |
| **Smoking status, n (%)** | | | **0.04**[c] |
| Never | 231 (73.8) | 182 (66.9) | |
| Former | 28 (8.9) | 42 (15.4) | |
| Current | 54 (17.3) | 48 (17.7) | |
| **Number of cigarettes a day, mean (SD)** | 1.03 (2.9) | 1.14 (3.1) | 0.65[a] |
| **Father's occupational ranking, n (%)** | | | 0.83 [c] |
| Low qualified | 127 (45.7) | 100 (43.3) | |
| Medium qualified | 132 (47.5) | 113 (48.9) | |
| High qualified | 19 (6.8) | 18 (7.8) | |
| **Mother's occupational ranking, n (%)** | | | 0.70 [c] |
| Low qualified | 223 (76.6) | 186 (76.2) | |
| Medium qualified | 32 (11.0) | 23 (9.4) | |
| High qualified | 36 (12.4) | 35 (14.3) | |

SD: standard deviation; BMI: body mass index. Values with a p-value < 0.050 are highlighted in bold. a: Student's t-test; b: Fisher Exact test; c: Chi-square.

**Table 2**
Dietary intake of parabens (ng/day) according to gender.

| | Boys | | | | Girls | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Average food intake, g/day (SD) | Parabens (ng/day), mean (SD) | Parabens (ng/day/kg), mean (SD)[a] | N | Average food intake, g/day (SD) | Parabens (ng/day), mean (SD) | Parabens (ng/day/kg), mean (SD)[a] | *p*-value |
| **Methylparaben** | | | | 344.7 (298.4) | | | | 334.9 (292.1) | |
| Sliced bread | 240 | 21.2 (36.2) | 272.1 (361.2) | | 221 | 26.7 (40.8) | 324.0 (397.8) | | 0.14 |
| Luncheon meat products | 272 | 29.0 (43.9) | 200.9 (244.7) | | 229 | 25.2 (43.5) | 194.6 (287.8) | | 0.79 |
| Olives | 195 | 8.8 (20.0) | 66.8 (91.0) | | 173 | 11.0 (32.2) | 56.4 (80.4) | | 0.25 |
| Melon | 195 | 42.5 (115.2) | 6368.6 (9960.3) | | 155 | 42.4 (122.9) | 6370.9 (9826.1) | | 0.99 |
| Eggs | 287 | 24.7 (34.5) | 5653.6 (5593.1) | | 256 | 16.7 (22.0) | 3816.5 (3113.7) | | **<0.01** |
| Rice | 295 | 18.6 (27.8) | 1690.6 (2074.2) | | 251 | 15.9 (28.0) | 1430.4 (1706.0) | | 0.11 |
| Apple and pear | 258 | 78.6 (138.1) | 3317.5 (3788.0) | | 212 | 74.9 (171.9) | 3425.2 (6299.9) | | 0.82 |
| Hamburger | 270 | 9.6 (21.4) | 2156.9 (2404.7) | | 230 | 7.5 (20.4) | 1647.1 (1662.4) | | **0.01** |
| Onion | 209 | 14.6 (32.5) | 4139.8 (4755.2) | | 164 | 15.5 (38.3) | 4322.7 (4936.2) | | 0.72 |
| Salted snacks | 258 | 11.1 (21.8) | 89.50 (131.45) | | 234 | 13.0 (29.3) | 76.9 (111.3) | | 0.25 |
| **Ethylparaben** | | | | 39.6 (39.3) | | | | 49.3 (62.9) | |
| Sliced bread | 239 | 21.2 (36.2) | 483.7 (605.5) | | 221 | 26.7 (40.8) | 597.5 (733.5) | | 0.07 |
| Semi-cured cheese | 182 | 19.1 (46.1) | 550.6 (688.1) | | 168 | 14.9 (37.9) | 436.8 (587.4) | | 0.09 |
| Carrot and pumpkin | 179 | 19.2 (53.0) | 164.5 (224.2) | | 155 | 17.1 (45.3) | 157.0 (198.6) | | 0.75 |
| Canned tuna | 167 | 6.2 (13.2) | 1481.8 (1539.7) | | 130 | 5.7 (15.2) | 1322.1 (1544.2) | | 0.38 |
| Pineapple | 170 | 12.1 (37.3) | 70.6 (80.5) | | 130 | 8.8 (30.3) | 77.3 (84.1) | | 0.48 |
| Olives | 195 | 8.8 (20.0) | 555.3 (756.1) | | 173 | 11.0 (32.2) | 468.7 (668.2) | | 0.25 |
| Mushrooms | 144 | 26.9 (81.9) | 1083.5 (1322.1) | | 141 | 36.1 (134.9) | 973.9 (1557.9) | | 0.52 |
| **Propylparaben** | | | | 32.3 (44.6) | | | | 29.7 (40.9) | |
| Olives | 195 | 8.8 (20.0) | 1095.1 (1491.2) | | 173 | 11.0 (32.2) | 924.3 (1317.8) | | 0.25 |
| Canned tuna | 167 | 6.2 (13.2) | 257.2 (267.3) | | 130 | 5.7 (15.2) | 229.5 (268.0) | | 0.38 |
| Ham | 221 | 10.1 (20.7) | 111.9 (134.5) | | 176 | 9.3 (20.1) | 108.3 (125.9) | | 0.79 |
| Pineapple | 175 | 12.1 (37.3) | 40.3 (66.9) | | 130 | 8.8 (30.3) | 33.3 (36.2) | | 0.25 |
| Bakery and baked goods | 227 | 15.7 (34.1) | 1316.7 (1857.6) | | 201 | 13.8 (38.6) | 963.8 (1575.5) | | **0.03** |
| **Butylparaben** | | | | 19.3 (27.2) | | | | 23.2 (34.8) | |
| Salted snacks | 258 | 11.1 (21.8) | 16.3 (23.9) | | 237 | 13.0 (29.3) | 16.9 (33.4) | | 0.78 |
| Mushrooms | 143 | 26.9 (81.9) | 48.8 (59.9) | | 140 | 36.1 (134.9) | 43.8 (70.7) | | 0.52 |
| Pineapple | 172 | 12.1 (37.3) | 948.7 (1395.0) | | 130 | 8.8 (30.3) | 918.7 (998.8) | | 0.84 |
| Bakery and baked goods | 227 | 15.7 (34.1) | 51.0 (72.0) | | 201 | 13.8 (38.6) | 37.4 (61.1) | | **0.03** |
| Olives | 195 | 8.8 (20.0) | 841.9 (1146.4) | | 173 | 11.0 (32.2) | 710.6 (1013.1) | | 0.25 |

SD: standard deviation. Values with a p-value $< 0.050$ are highlighted in bold.
[a] Daily intake of each paraben type standardised according to child's weight (kg).

respectively) were the main contributors to EtP intake. The main contributors to PrP dietary exposure were bakery and baked goods (57.3% and 55.1% for boys and girls, respectively) and olives (40.7% and 42.9% for boys and girls, respectively). Lastly, raw pineapple (61.1%) and olives cured in brine (37.5%) were the food items that most contributed to BuP dietary exposure in boys, whilst the main food products in girls were olives (62.1%), followed by pineapple (36.9%) (Table 3).

Table 4 shows a significant association of high BMI with high total parabens (OR: 3.32, p-value: 0.020) and MeP intake girls (OR: 3.05, p-value: 0.026). Moreover, girls with a BMI $\geq$25 and 30 kg/m$^2$ had a 5.8-fold and 5.9-fold greater likelihood of belonging to the highest tertile of dietary exposure to total parabens and MeP, respectively (OR: 5.82, p-value: 0.004; OR: 5.90, p-value: 0.003) (data not shown). Adolescent boys were 50% more likely than girls to belong to the highest tertile of dietary exposure to total parabens and PrP. Other significant factors in relation to PrP were coming from a large family and smoking in the case of boys, whereas father's occupational ranking predicted BuP in girls.

## 4. Discussion

To the best of our knowledge, this is the first study to use the FFQ to estimate daily dietary exposure to parabens and its relationship with sociodemographic, anthropometric and lifestyle characteristics. Nevertheless, previous studies have used per capita daily intake rates of food items from nationwide or regional surveys (Liao et al., 2013a, 2013b; Maher et al., 2020) to estimate parabens intake but these may

**Table 3**
Food products that contribute to more than 95% of dietary exposure to parabens according to gender (stepwise regression).

| | Methyl | %[a] | $R^2$ [b] | Ethyl | %[a] | $R^2$ [b] | Propyl | %[a] | $R^2$ [b] | Butyl | %[a] | $R^2$ [b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boys** | Eggs | 41.9 | 0.54 | Canned tuna | 46.4 | 0.50 | Bakery and baked goods | 57.3 | 0.63 | Pineapple | 61.1 | 0.59 |
| | Onions | 21.6 | 0.77 | Mushrooms | 29.8 | 0.78 | Olives | 40.7 | 0.98 | Olives | 37.5 | 0.99 |
| | Apple and pear | 16.7 | 0.90 | Olives | 10.2 | 0.88 | | | | | | |
| | Hamburger | 15.3 | 0.96 | Semi-cured cheese | 7.8 | 0.94 | | | | | | |
| | | | | Sliced bread | 4.3 | 0.99 | | | | | | |
| **Girls** | Apples and pears | 35.3 | 0.44 | Canned tuna | 42.1 | 0.50 | Bakery and baked goods | 55.1 | 0.62 | Olives | 62.1 | 0.63 |
| | Onions | 25.3 | 0.75 | Mushrooms | 31.8 | 0.77 | Olives | 42.9 | 0.98 | Pineapple | 36.9 | 0.99 |
| | Eggs | 23.9 | 0.93 | Sliced bread | 15.3 | 0.88 | | | | | | |
| | Hamburger | 14.3 | 0.96 | Olives | 6.8 | 0.95 | | | | | | |

[a] Percentage contribution for each food added to the model as a predictor of overall compound intake.
[b] $R^2$: determination coefficient as a proxy of model goodness of fit (range 0–1; $R^2$ of 1 indicates that regression predictions perfectly fit the data).

**Table 4**
Factors predicting belonging to the highest tertile of overall dietary exposure to parabens, methylparaben, ethylparaben, propylparaben and butylparaben according to gender.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total parabens** | | | | | | | |
| | | ***p*** | **OR** | **95% CI** | | | |
| Sex | *Ref. Girls* | | | | | | |
| | Boys | **0.026** | **1.49** | **1.05–2.10** | | | |
| | | **Boys** | | | **Girls** | | |
| | | ***p*** | **OR** | **95% CI** | ***p*** | **OR** | **95% CI** |
| Age | *Ref. Age* > 14 yrs | | | | | | |
| | Age ≤14 yrs | 0.549 | 1.28 | 0.57–2.85 | **0.045** | **3.10** | **1.03–9.39** |
| BMI | *Ref. BMI* < 25 kg/m$^2$ | | | | | | |
| | BMI ≥25 kg/m$^2$ | 0.336 | 0.66 | 0.29–1.53 | **0.020** | **3.32** | **1.21–9.15** |
| Large family | *Ref. No* | | | | | | |
| | Yes | 0.285 | 1.55 | 0.70–3.44 | 0.357 | 1.62 | 0.58–4.56 |
| Smoking status | *Ref. Never* | | | | | | |
| | Current | 0.540 | 1.43 | 0.46–4.46 | 0.802 | 1.17 | 0.34–4.06 |
| | Former | 0.575 | 0.71 | 0.22–2.32 | 0.699 | 1.33 | 0.32–5.52 |
| Father's occupational ranking | *Ref. Low qualified* | | | | | | |
| | Medium-high qualified | 0.545 | 1.27 | 0.59–2.73 | 0.312 | 1.65 | 0.63–4.34 |
| Mother's occupational ranking | *Ref. Medium-high qualified* | | | | | | |
| | Low qualified | 0.739 | 1.16 | 0.48–2.85 | 0.415 | 1.78 | 0.45–7.05 |
| **Methylparaben** | | | | | | | |
| | | ***p*** | **OR** | **95% CI** | | | |
| Sex | *Ref. Girls* | | | | | | |
| | Boys | 0.168 | 1.28 | 0.90–1.81 | | | |
| | | **Boys** | | | **Girls** | | |
| | | ***p*** | **OR** | **95% CI** | ***p*** | **OR** | **95% CI** |
| Age | *Ref. Age* > 14 yrs | | | | | | |
| | Age ≤14 yrs | 0.963 | 0.98 | 0.44–2.17 | 0.136 | 2.25 | 0.78–6.49 |
| BMI | *Ref. BMI* < 25 kg/m$^2$ | | | | | | |
| | BMI ≥25 kg/m$^2$ | 0.643 | 0.82 | 0.36–1.87 | **0.026** | **3.05** | **1.14–8.12** |
| Large family | *Ref.* Yes | | | | | | |
| | *No* | 0.312 | 0.66 | 0.30–1.47 | 0.651 | 0.79 | 0.29–2.17 |
| Smoking status | *Ref. Never* | | | | | | |
| | Current | 0.651 | 1.30 | 0.42–4.03 | 0.513 | 1.48 | 0.46–4.83 |
| | Former | 0.947 | 0.96 | 0.31–2.98 | 0.867 | 1.13 | 0.28–4.50 |
| Father's occupational ranking | *Ref.* Medium-high qualified | | | | | | |
| | *Low qualified* | 0.451 | 0.75 | 0.35–1.60 | 0.323 | 0.63 | 0.25–1.59 |
| Mother's occupational ranking | *Ref. Medium-high qualified* | | | | | | |
| | Low qualified | 0.949 | 0.97 | 0.40–2.34 | 0.707 | 1.28 | 0.36–4.58 |
| **Ethylparaben** | | | | | | | |
| | | ***p*** | **OR** | **95% CI** | | | |
| Sex | *Ref. Girls* | | | | | | |
| | Boys | 0.295 | 1.20 | 0.85–1.69 | | | |
| | | **Boys** | | | **Girls** | | |
| | | ***p*** | **OR** | **95% CI** | ***p*** | **OR** | **95% CI** |
| Age | *Ref. Age* > 14 yrs | | | | | | |
| | Age ≤14 yrs | 0.256 | 0.61 | 0.26–1.43 | 0.061 | 2.70 | 0.96–7.61 |
| BMI | *Ref. BMI* < 25 kg/m$^2$ | | | | | | |
| | BMI ≥25 kg/m$^2$ | 0.192 | 1.77 | 0.75–4.17 | 0.846 | 1.10 | 0.41–2.96 |
| Large family | *Ref.* Yes | | | | | | |
| | *No* | 0.708 | 0.85 | 0.37–1.98 | 0.988 | 1.01 | 0.37–2.77 |
| Smoking status | *Ref. Never* | | | | | | |
| | Current | 0.733 | 0.81 | 0.25–2.66 | 0.763 | 0.83 | 0.24–2.82 |
| | Former | 0.308 | 1.82 | 0.58–5.77 | 0.290 | 2.03 | 0.55–7.57 |
| Father's occupational ranking | *Ref.* Medium-high qualified | | | | | | |
| | *Low qualified* | 0.051 | 0.45 | 0.20–1.00 | 0.963 | 0.98 | 0.40–2.41 |
| Mother's occupational ranking | *Ref. Medium-high qualified* | | | | | | |
| | Low qualified | 0.915 | 1.05 | 0.41–2.69 | 0.731 | 1.24 | 0.36–4.33 |
| **Propylparaben** | | | | | | | |
| | | ***p*** | **OR** | **95% CI** | | | |
| Sex | Ref. Girls | | | | | | |
| | Boys | **0.028** | **1.47** | **1.04–2.07** | | | |
| | | **Boys** | | | **Girls** | | |
| | | ***p*** | **OR** | **95% CI** | ***p*** | **OR** | **95% CI** |
| Age | *Ref. Age* > 14 yrs | | | | | | |
| | Age ≤14 yrs | 0.963 | 0.98 | 0.43–2.26 | 0.218 | 1.96 | 0.67–5.71 |
| BMI | *Ref. BMI* < 25 kg/m$^2$ | | | | | | |
| | BMI ≥25 kg/m$^2$ | 0.600 | 0.79 | 0.33–1.90 | 0.983 | 1.01 | 0.36–2.83 |
| Large family | *Ref.* Yes | | | | | | |
| | *No* | **0.011** | **0.34** | **0.15–0.79** | 0.750 | 1.20 | 0.41–3.46 |
| Smoking status | *Ref. Never* | | | | | | |
| | Current | **0.025** | **4.14** | **1.20–14.33** | 0.679 | 0.76 | 0.21–2.75 |

(*continued on next page*)

**Table 4** (*continued*)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Former | 0.682 | 1.28 | 0.40–4.11 | 0.410 | 1.76 | 0.46–2.96 |
| Father's occupational ranking | *Ref.* Medium-high qualified | | | | | | |
| | *Low qualified* | 0.304 | 0.65 | 0.29–1.47 | 0.747 | 1.17 | 0.46–2.96 |
| Mother's occupational ranking | *Ref. Medium-high qualified* | | | | | | |
| | Low qualified | 0.358 | 1.57 | 0.60–4.06 | 0.355 | 1.95 | 0.48–8.00 |
| **Butylparaben** | | | | | | | |
| | | ***p*** | **OR** | **95% CI** | | | |
| Sex | Ref. Girls | | | | | | |
| | Boys | 0.371 | 1.17 | 0.38–1.64 | | | |
| | | **Boys** | | | **Girls** | | |
| | | ***p*** | **OR** | **95% CI** | ***p*** | **OR** | **95% CI** |
| Age | *Ref. Age* > 14 yrs | | | | | | |
| | Age ≤14 yrs | 0.621 | 1.23 | 0.54–2.79 | 0.578 | 1.34 | 0.48–3.78 |
| BMI | *Ref. BMI* < 25 kg/m$^2$ | | | | | | |
| | BMI ≥25 kg/m$^2$ | 0.061 | 0.43 | 0.18–1.04 | 0.981 | 0.99 | 0.36–2.75 |
| Large family | *Ref.* Yes | | | | | | |
| | *No* | 0.077 | 0.48 | 0.21–1.08 | 0.162 | 0.48 | 0.17–1.34 |
| Smoking status | *Ref. Never* | | | | | | |
| | Current | 0.146 | 2.39 | 0.38–7.72 | 0.145 | 0.39 | 0.11–1.39 |
| | Former | 0.554 | 0.70 | 0.21–2.30 | 0.545 | 1.50 | 0.40–5.59 |
| Father's occupational ranking | *Ref.* Medium-high qualified | | | | | | |
| | *Low qualified* | 0.572 | 0.80 | 0.36–1.75 | **0.036** | **0.36** | **0.14–0.94** |
| Mother's occupational ranking | *Ref. Medium-high qualified* | | | | | | |
| | Low qualified | 0.719 | 1.18 | 0.47–2.95 | 0.905 | 0.93 | 0.27–3.17 |

BMI: body mass index; Ref: reference category; OR: odds ratio; 95% CI: confidence interval. Values with a p-value < 0.050 are highlighted in bold.

underestimate actual exposure. Moreover, a study conducted by Liao and colleagues (Liao et al., 2013b) with teenagers from the United States is the only prior study to have estimated daily dietary intake of total parabens. Despite this, they did not consider ingested amounts of each food as was the case in the present study. In addition, the present study estimated the paraben concentrations of foods through direct measurements taken by research group members. These measurements have been reported previously (Gálvez-Ontiveros et al., 2021).

Although the main source of parabens in food is not entirely clear (Liao et al., 2013a, 2013b; Maher et al., 2020), their use as antimicrobial agents explains why they are found in higher concentrations in processed foods in comparison with unprocessed/raw foods (Soni et al., 2005). In fact, in 2004 the EFSA approved the use of MeP and EtP as food additives (food additives E218 and E214, respectively) and antimicrobial preservatives in some processed foods (EFSA, 2004). Moreover, an additional source of parabens could be the packaging material used for certain foods (Liao et al., 2013b).

PrP and BuP are not allowed as food additives. Their presence in food might be explained by contamination during primary production, for example, through fruits and vegetables cultivated in soils irrigated with reclaimed water or treated with sewage sludge. Wastewater treatments do not remove specifically emerging pollutants and so, depending on soil and pollutant properties, these parabens could be accumulated in soil to a greater extent than in irrigated water. Once in the soil, they may be absorbed by vegetables or accumulated by roots depending on their pollutant physicochemical properties (Aparicio et al., 2018). The ubiquity of parabens elsewhere could also be related to the unexpected presence of these parabens in food. Recently, we found PrP and BuP in frequently consumed food (Gálvez-Ontiveros et al., 2021). Moreover, environmental contamination with these two parabens in Spain has also been reported. Specifically, they have been found in compost from sewage sludge (Benítez-Villalba et al., 2013; Luque-Muñoz et al., 2017), marine echinoderms and sediments (Martín et al., 2017). In addition, we have further demonstrated this environmental contamination through the presence of PrP and BuP in human biological samples such as serum (Vela-Soria et al., 2013), milk (Rodríguez-Gómez et al., 2015), nail (Martín-Pozo et al., 2020), hair (Rodríguez-Gómez et al., 2017), placenta (Jiménez-Díaz et al., 2011; Vela-Soria et al., 2015) and urine (Vela-Soria et al., 2014).

The presence of parabens in eggs might be explained by the ingestion of paraben-contaminated feed or soil, which then penetrates into chicken tissue and is subsequently transferred into eggs (Pajurek et al., 2019). On the other hand, parabens may naturally occur in some unprocessed fruits and vegetables and may, therefore, contribute to disease resistance through their antimicrobial and antifungal properties (Blazević et al., 2010; Hagel et al., 2019; Martínez, 2012). Furthermore, EtP has been reported to have allelopathic functions (Huang et al., 2015; Liu et al., 2011), whilst MetP has also been found in a wide variety of plant species and can be applied to the manufacturing of bio-based poly (ether ester) materials (Hu et al., 2017). Concretely, parabens have been found to be naturally produced in some organisms. Thus, MeP, also called knows as nipagin, and EtP have been naturally found in an extensive variety of plant species (Hagel et al., 2019; Nowak et al., 2018). In fact, it has been reported that some plants such as blueberries, carrots, olives and strawberries synthesize parabens, mainly MeP (Calvo-Flores et al., 2018). In another study, MeP and PrP were detected in 43% and 28% of analyzed radish stem samples (Abril et al., 2021), whilst MeP has also been detected in leafy vegetables (lettuce, spinach and chard) and root vegetables (carrot, turnip and potato) (Aparicio et al., 2018). Parabens have even been located in drinking water leading to their absorption by aquatic animals (Nowak et al., 2018). This is shown by one study in which more than 90% of analyzed fish was to contain at least 70% of MeP, PrP, BuP and EtP (Błędzka et al., 2014).

Despite the fact that estimated dietary paraben intake is below recommended levels for tolerable daily intake (TDI), other routes of exposure such as cosmetics, household dust and air must also be considered. The cumulative effect of parabens together with other endocrine disruptors present in food such as bisphenols, heavy metals, pesticides and polybrominated diphenyl ethers could pose a risk to human health and should be further investigated.

Interestingly, the present analysis showed differences between adolescent boys and girls regarding the factors predicting high paraben intake. In general, boys were at a greater risk of high dietary exposure to total parabens and PrP. This may be explained by the fact that boys consume more foods with high PrP concentrations than girls. Indeed, boys consumed more canned tuna, ham, pineapple and bakery and baked goods than girls, as can be seen in Table 2. These outcomes cannot be compared with other studies that measured PrP in urine (Calafat et al., 2010; Engel et al., 2014; Feizabadi et al., 2020a; Kang et al., 2016; Yu et al., 2019). Indeed, paraben concentrations in these studies were higher in women with respect to men, probably due to the presence of parabens in cosmetics and other personal care products which are used

more frequently by women (Calafat et al., 2010; Engel et al., 2014). As shown in Table 2, boys consumed more bakery and baked goods products than girls, with this being associated with higher daily BuP and PrP exposure. Additionally, girls aged 14 or below had higher odds of having a high total paraben intake. This may be explained by the increased energy intake seen to occur in girls at between 10 and 14 years of age, which in turn increases their dietary exposure to parabens. In contrast, energy intake in 14–16 year old girls decreases as a result of reaching the end of the growing process, usually around 16 years of age (Deheeger et al., 2002). Moreover, lifestyle and dietary changes will, in turn, affect dietary exposure to parabens throughout life. The association found between age and higher exposure may also be due to an increased consumption of foods with higher paraben concentrations, such as processed food, by the adolescent population (Soni et al., 2005). In this respect, a cross-sectional study conducted in Spain, the ANIBES study, revealed that food choices change with age and 9–12 year old girls consumed more processed food than 13–17 year old girls (Partearroyo et al., 2019). Studies such as this support the idea that adolescence is a crucial stage for exposure to endocrine-disrupting compounds.

The odds of having a high PrP intake were lower in adolescent boys who did not come from a large family. This finding could be attributed to the fact that larger households tend to cook at home as it is cheaper than buying ultra-processed food or fast food. In fact, one study found that households with more than one child consumed less fast food in comparison to those that had one child or none (Akbay et al., 2007).

Additionally, smoking was positively associated with high PrP intake in boys. This may be explained by the fact that adolescent smokers are more likely to have an unhealthy lifestyle, engage in less physical activity, consume more alcohol and follow an unhealthy diet (Cho et al., 2011; Patino-Alonso et al., 2014). In fact, two studies including 373 and 4372 adolescents from Mexico and Thailand, respectively, reported associations between an unhealthy diet and smoking habits (Boonchooduang et al., 2019; Gutiérrez-Pliego et al., 2016).

Moreover, present results also showed that a lower paternal occupational ranking was associated with lower odds of having a high BuP intake in girls. A low paternal educational level has been reported to be associated with a lower family socioeconomic status (Guillaume et al., 1999). This may suggest that families with a higher socioeconomic status have more access to ultra-processed foods since they possess the necessary economic capital to be able to afford them. If fact, several studies have suggested that households with a lower socioeconomic status tend to consume more culinary preparations (unprocessed or minimally processed foods and processed culinary ingredients) (Araujo et al., 2017). This, together with the fact that girls generally eat healthier food, could explain their lower risk of dietary exposure to parabens.

Several studies have assessed the relationship between paraben exposure and obesity in children. In this regard, as mentioned above, only the study conducted by Xue et al. (2015) found a non-significant association between postnatal exposure to parabens and childhood obesity (Xue et al., 2015). In contrast, another report found positive associations between urinary parabens and height z scores but only in 3-year-old boys (Guo et al., 2017). Another study conducted with 6–8 year old girls found null associations between adiposity measurements and paraben exposure (Deierlein et al., 2017). Recently, the Canadian Health Measures Survey failed to find an association of paraben concentration in urine with obesity and metabolic syndrome (Kim and Chevrier, 2020).

Although no previous studies have specifically investigated the associations between exposure to parabens and overweight and obesity in adolescents, the null association found in the present study within male adolescents is consistent with findings reported by a Czech study (Kolátorová et al., 2018) conducted with a small group of participants. In contrast, present outcomes are not in agreement with those reported by the National Health and Nutrition Examination Survey (NHANES), which observed inverse associations between these same parameters in men (Quirós-Alcalá et al., 2018). Another interesting point is that the positive association found in the present study between dietary paraben exposure in adolescent girls and overweight/obesity differs with results reported by NHANES and the Czech study. Other studies that investigated the association between BMI and paraben exposure have reported inverse associations overall (Den Hond et al., 2013; Kang et al., 2016; Smith et al., 2012), inverse associations in men (Meeker et al., 2011) and null associations in women (Meeker et al., 2013). However, such studies were not designed to specifically evaluate the association between overweight and paraben exposure and so did not adjust for important confounders.

Present findings in adolescent girls are consistent with the anti-androgenic and estrogenic properties of parabens. In this regard, many studies have discussed the sexual dimorphism of endocrine disrupting chemical (EDC). In addition, the effects of parabens may be modified by the presence of natural hormones and other EDCs. It has been reported that estrogens protect against obesity in adult humans through a number of mechanisms including appetite suppression (Clegg et al., 2007), increased basal energy expenditure (Musatov et al., 2007; Xu et al., 2011), transformation of white fat into healthier brown fat (Palmer and Clegg, 2015; Rosen and Spiegelman, 2014) and promotion of subcutaneous fat depots (Palmer and Clegg, 2015). Visceral and white fat are related with insulin resistance, high blood triglyceride levels, high low-density lipoprotein (LDL) cholesterol, and low blood levels of high-density lipoprotein (HDL) cholesterol (Ebbert and Jensen, 2013). Testosterone also exerts a protective role against the development of obesity and metabolic disease in men through the transformation of testosterone into estradiol (Cheng et al., 2017; Ding et al., 2006). However, the effects of sex hormones may differ between children, adolescents and adults. In boys, the interaction between testosterone and growth hormone reduces fat deposition (Veldhuis et al., 2005), whilst in girls, estrogens reduce the lipolytic activity of growth hormone resulting in increased fat deposition (Loomba-Albrecht and Styne, 2009). This is consistent with the present outcomes in girls as the estrogenic effect of parabens contributes to higher overweight/obesity incidence.

To our knowledge, this is the first study to investigate the association between dietary exposure to parabens and their influencing factors, such as BMI, in adolescents. Moreover, our study is one of the biggest studies to date on this topic and included large number of participants. In addition, as mentioned previously, paraben concentration in the food used to estimate intake was measured directly by the present research group itself.

The present study has some limitations. The first limitation is that diet alone is not the only source of parabens exposure in humans and that other sources, such as personal care products and pharmaceuticals, were not considered. Dietary exposure to parabens in humans has been previously reported, however, the main food sources of parabens are still unknown (Liao et al, 2013a, 2013b; Maher et al., 2020) and the daily cumulative effect of parabens through food warrant further investigation (Maher et al., 2020). The second limitation is that, for obvious reasons, not all food products could be included in the questionnaire. This can result in an underestimation of dietary exposure. Nevertheless, included food products were those most highly consumed by the study population and provided more than 95% of energy intake and macronutrients. Another limitation was the difficultly of obtaining accurate data with regards to dietary paraben intake. In order to overcome this limitation, the FFQ was used. This includes 96 food items and specifies consumption frequency and type of food packaging. This FFQ has been validated relative to 24h recall methods (Figures S1 and S2, Supplementary material). Data collected through the present study can only be used to form an estimation of dietary exposure to these compounds and cannot give real measurements. Lastly, in the present study, paraben concentration was not measured in biological samples, which would provide a more accurate estimation of actual exposure in the population studied. However, studies employing these methods are currently being conducted by the present research group.

## 5. Conclusion

Outcomes of the present study showed positive associations between dietary exposure to parabens and overweight/obesity in girls in a large sample of adolescents. These findings represent an important public health concern given the ubiquity of paraben exposure in this population. However, given the small number of available studies addressing the relation between paraben intake and obesity, present findings need to be confirmed within other populations. Ideally, future studies will use a longitudinal design and include measurements of parabens in biological samples during relevant developmental time periods.

## Funding sources

This work was carried out in line with 'GP/EFSA/ENCO/380 2018/03/G04: OBEMIRISK: Knowledge platform for assessing the risk of Bisphenols on gut microbiota and its role in obesogenic phenotype: looking for biomarkers'. This research was also funded by Plan Estatal de I + D + I 2013–2016 and co-funded by FEDER-ISCIII PI17/01758, FEDER-Consejería de Salud y Familias, Junta de Andalucía PE-0250-2019, FEDER/Junta de Andalucía-Consejería de Transformación Económica, Industria, Conocimiento y Universidades/Proyecto P18-RT-4247. All individuals participating in this research signed an informed consent form and the study protocol was approved by the Ethics Committee of the University of Granada.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

The results presented in this article are part of a doctoral thesis carried out by Virginia Robles Aguilera, Nutrition and Food Sciences Doctorate Program of the University of Granada.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2021.111548.

## References

Abril, C., Santos, J.L., Martín, J., Aparicio, I., Alonso, E., 2021. Uptake and translocation of multiresidue industrial and household contaminants in radish grown under controlled conditions. Chemosphere 268, 128823. https://doi.org/10.1016/j.chemosphere.2020.128823.

Akbay, C., Tiryaki, G.Y., Gul, A., 2007. Consumer characteristics influencing fast food consumption in Turkey. Food Contr. 18 (8), 904–913. https://doi.org/10.1016/j.foodcont.2006.05.007.

Álvarez-Muñoz, D., Rodríguez-Mozaz, S., Jacobs, S., Serra-Compte, A., Cáceres, N., Sioen, I., Verbeke, W., Barbosa, V., Ferrari, F., Fernández-Tejedor, M., Cunha, S., Granby, K., Robbens, J., Kotterman, M., Marques, A., Barceló, D., 2018. Pharmaceuticals and endocrine disruptors in raw and cooked seafood from European market: concentrations and human exposure levels. Environ. Int. 119, 570–581. https://doi.org/10.1016/j.envint.2018.07.006.

Aparicio, I., Martín, J., Abril, C., Santos, J.L., Alonso, E., 2018. Determination of household and industrial chemicals, personal care products and hormones in leafy and root vegetables by liquid chromatography-tandem mass spectrometry. J. Chromatogr. A 1533, 49–56. https://doi.org/10.1016/j.chroma.2017.12.011.

Araujo, M.C., Cunha, D.B., Bezerra, I.N., Castro, M.B.T. de, Sichieri, R., 2017. Quality of food choices of Brazilian adolescents according to individual earnings. Publ. Health Nutr. 20 (17), 3145–3150. https://doi.org/10.1017/S1368980017002099.

Azzouz, A., Colón, L.P., Hejji, L., Ballesteros, E., 2020. Determination of alkylphenols, phenylphenols, bisphenol A, parabens, organophosphorus pesticides and triclosan in different cereal-based foodstuffs by gas chromatography-mass spectrometry. Anal. Bioanal. Chem. 412 (11), 2621–2631. https://doi.org/10.1007/s00216-020-02491-1.

Azzouz, A., Colón, L.P., Souhail, B., Ballesteros, E., 2019. A multi-residue method for GC-MS determination of selected endocrine disrupting chemicals in fish and seafood from European and North African markets. Environ. Res. 178, 108727. https://doi.org/10.1016/j.envres.2019.108727.

Bemrah, N., Jean, J., Rivière, G., Sanaa, M., Leconte, S., Bachelot, M., Deceuninck, Y., Bizec, B.L., Dauchy, X., Roudot, A.-C., Camel, V., Grob, K., Feidt, C., Picard-Hagen, N., Badot, P.-M., Foures, F., Leblanc, J.-C., 2014. Assessment of dietary exposure to bisphenol A in the French population with a special focus on risk characterisation for pregnant French women. Food Chem. Toxicol. Int. J. Publ. Br. Ind. Biol. Res. Assoc. 72, 90–97. https://doi.org/10.1016/j.fct.2014.07.005.

Benítez-Villalba, J.C., Zafra-Gómez, A., Dorival-García, N., Camino-Sánchez, F.J., Cantarero, S., Vílchez, J.L., 2013. Ultra-performance liquid chromatography MS/MS method for the determination of parabens in compost from sewage sludge: comparison of the efficiency of two extraction techniques. J. Separ. Sci. 36 (16), 2635–2645. https://doi.org/10.1002/jssc.201300318.

Blazević, I., Radonić, A., Mastelić, J., Zekić, M., Skocibusić, M., Maravić, A., 2010. Hedge mustard (Sisymbrium officinale): chemical diversity of volatiles and their antimicrobial activity. Chem. Biodivers. 7 (2), 2023–2034. https://doi.org/10.1002/cbdv.200900234.

Błędzka, D., Gromadzińska, J., Wąsowicz, W., 2014. Parabens. From environmental studies to human health. Environ. Int. 67, 27–42. https://doi.org/10.1016/j.envint.2014.02.007.

Boberg, J., Taxvig, C., Christiansen, S., Hass, U., 2010. Possible endocrine disrupting effects of parabens and their metabolites. Reprod. Toxicol. 30 (2), 301–312. https://doi.org/10.1016/j.reprotox.2010.03.011.

Boonchooduang, N., Likhitweerawong, N., Louthrenoo, O., 2019. Association between smoking, alcohol consumption, and dietary habits in Northern Thai adolescents in Thailand, 2016 - 2017. J. Compr. Pediatr. 10 (3) https://doi.org/10.5812/compreped.68342.

Calafat, A.M., Ye, X., Wong, L.-Y., Bishop, A.M., Needham, L.L., 2010. Urinary concentrations of four parabens in the U.S. population: NHANES 2005-2006. Environ. Health Perspect. 118 (5), 679–685. https://doi.org/10.1289/ehp.0901560.

Calvo-Flores, F.G., Isac-Garcéa, J., Dobado, J.A., 2018. Personal-care products. In: Emerging Pollutants: Origin, Structure and Properties. Wiley-VCH Verlag GmbH & Co. KGaA, Germany, pp. 385–422.

Charles, A.K., Darbre, P.D., 2013. Combinations of parabens at concentrations measured in human breast tissue can increase proliferation of MCF-7 human breast cancer cells. J. Appl. Toxicol. 33 (5), 390–398. https://doi.org/10.1002/jat.2850.

Chen, J., Ahn, K.C., Gee, N.A., Gee, S.J., Hammock, B.D., Lasley, B.L., 2007. Antiandrogenic properties of parabens and other phenolic containing small molecules in personal care products. Toxicol. Appl. Pharmacol. 221 (3), 278–284. https://doi.org/10.1016/j.taap.2007.03.015.

Cheng, J., Han, B., Li, Q., Xia, F., Zhai, H., Wang, N., Jensen, M., Lu, Y., 2017. Testosterone: relationships with metabolic disorders in men-an observational study from SPECT-China. Internet J. Endocrinol. 4547658. https://doi.org/10.1155/2017/4547658, 2017.

Cho, E.R., Shin, A., Lim, S.-Y., Kim, J., 2011. Dietary patterns and their associations with health behaviours in Korea. Publ. Health Nutr. 14 (2), 356–364. https://doi.org/10.1017/S1368980010002685.

Clegg, D.J., Brown, L.M., Zigman, J.M., Kemp, C.J., Strader, A.D., Benoit, S.C., Woods, S.C., Mangiaracina, M., Geary, N., 2007. Estradiol-dependent decrease in the orexigenic potency of ghrelin in female rats. Diabetes 56 (4), 1051–1058. https://doi.org/10.2337/db06-0015.

Cole, T.J., Bellizzi, M.C., Flegal, K.M., Dietz, W.H., 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 320 (7244), 1240–1243. https://doi.org/10.1136/bmj.320.7244.1240.

Cole, T.J., Flegal, K.M., Nicholls, D., Jackson, A.A., 2007. Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ 335 (7612), 194–197. https://doi.org/10.1136/bmj.39238.399444.55.

Deheeger, M., Bellisle, F., Rolland-Cachera, M.F., 2002. The French longitudinal study of growth and nutrition: data in adolescent males and females. J. Hum. Nutr. Diet. Off. J. Br. Diet. Assoc. 15 (6), 429–438. https://doi.org/10.1046/j.1365-277x.2002.00396.x.

Deierlein, A.L., Rock, S., Park, S., 2017. Persistent endocrine-disrupting chemicals and fatty liver disease. Curr. Environ. Health Rep. 4 (4), 439–449. https://doi.org/10.1007/s40572-017-0166-8.

Den Hond, E., Paulussen, M., Geens, T., Bruckers, L., Baeyens, W., David, F., Dumont, E., Loots, I., Morrens, B., de Bellevaux, B.N., Nelen, V., Schoeters, G., Van Larebeke, N., Covaci, A., 2013. Biomarkers of human exposure to personal care products: results from the Flemish Environment and Health Study (FLEHS 2007-2011). Sci. Total Environ. 463–464, 102–110. https://doi.org/10.1016/j.scitotenv.2013.05.087.

Ding, E.L., Song, Y., Malik, V.S., Liu, S., 2006. Sex differences of endogenous sex hormones and risk of type 2 diabetes: a systematic review and meta-analysis. J. Am. Med. Assoc. 295 (11), 1288–1299. https://doi.org/10.1001/jama.295.11.1288.

Ebbert, J.O., Jensen, M.D., 2013. Fat depots, free fatty acids, and dyslipidemia. Nutrients 5 (2), 498–508. https://doi.org/10.3390/nu5020498.

EFSA (The European Food Safety Authority), 2004. EFSA Advises on the Safety of Paraben Usage in Food. European Union. Available at: https://www.efsa.europa.eu/en/press/news/040929. (Accessed 23 March 2021).

Engel, L.S., Buckley, J.P., Yang, G., Liao, L.M., Satagopan, J., Calafat, A.M., Matthews, C.E., Cai, Q., Ji, B.-T., Cai, H., Engel, S.M., Wolff, M.S., Rothman, N., Zheng, W., Xiang, Y.-B., Shu, X.-O., Gao, Y.-T., Chow, W.-H., 2014. Predictors and variability of repeat measurements of urinary phenols and parabens in a cohort of Shanghai women and men. Environ. Health Perspect. 122 (7), 733–740. https://doi.org/10.1289/ehp.1306830.

European Public MRL Assessment Report (EPMAR), 2015. Propyl 4-Hydroxybenzoate and its Sodium Salt (All Food Producing Species). EMA/CVMP/632934/2014 Available at: https://www.ema.europa.eu/en/documents/mrl-report/propyl-4-hydr

oxybenzoate-its-sodium-salt-all-food-producing-species-european-public-mrl-assessment_en.pdf. (Accessed 23 March 2021).
Feizabadi, K.G., Hajizadeh, Y., Feizi, A., Ebrahimpour, K., 2020a. Urinary concentrations of parabens in a population of iranian adolescent and their association with sociodemographic indicators. Arch. Environ. Contam. Toxicol. 79 (2), 195–207. https://doi.org/10.1007/s00244-020-00746-7.
Feizabadi, K.G., Hajizadeh, Y., Feizi, A., Ebrahimpour, K., 2020b. Urinary concentrations of parabens amongst Iranian adults and their associations with socio-demographic factors. J. Environ. Health Sci. Eng. 18 (2), 1227–1238. https://doi.org/10.1007/s40201-020-00540-6.
Gálvez-Ontiveros, Y., Moscoso-Ruiz, I., Rodrigo, L., Aguilera, M., Rivas, A., Zafra-Gómez, A., 2021. Presence of parabens and bisphenols in food commonly consumed in Spain. Foods 10 (1), 92. https://doi.org/10.3390/foods10010092.
García-Córcoles, M.T., Cipa, M., Rodríguez-Gómez, R., Rivas, A., Olea-Serrano, F., Vílchez, J.L., Zafra-Gómez, A., 2018. Determination of bisphenols with estrogenic activity in plastic packaged baby food samples using solid-liquid extraction and clean-up with dispersive sorbents followed by gas chromatography tandem mass spectrometry analysis. Talanta 178, 441–448. https://doi.org/10.1016/j.talanta.2017.09.067.
Garrido-Miguel, M., Cavero-Redondo, I., Álvarez-Bueno, C., Rodríguez-Artalejo, F., Moreno, L.A., Ruiz, J.R., Ahrens, W., Martínez-Vizcaíno, V., 2019. Prevalence and trends of overweight and obesity in European children from 1999 to 2016: a systematic review and meta-analysis. JAMA Pediatr 173 (10), e192430. https://doi.org/10.1001/jamapediatrics.2019.2430.
Geer, L.A., Pycke, B.F.G., Waxenbaum, J., Sherer, D.M., Abulafia, O., Halden, R.U., 2017. Association of birth outcomes with fetal exposure to parabens, triclosan and triclocarban in an immigrant population in Brooklyn, New York. J. Hazard Mater. 323, 177–183. https://doi.org/10.1016/j.jhazmat.2016.03.028.
Giulivo, M., Lopez de Alda, M., Capri, E., Barceló, D., 2016. Human exposure to endocrine disrupting compounds: their role in reproductive systems, metabolic syndrome and breast cancer. A review. Environ. Res. 151, 251–264. https://doi.org/10.1016/j.envres.2016.07.011.
Guillaume, M., Lapidus, L., Lambert, A., Björntorp, P., 1999. Socioeconomic and psychosocial conditions of parents and cardiovascular risk factors in their children: the Belgian Luxembourg Child Study III. Acta Paediatr. Oslo Nor 88 (8), 866–873. https://doi.org/10.1080/08035259950168801, 1992.
Guo, J., Wu, C., Lu, D., Jiang, S., Liang, W., Chang, X., Xu, H., Wang, G., Zhou, Z., 2017. Urinary paraben concentrations and their associations with anthropometric measures of children aged 3 years. Environ. Pollut. 222, 307–314. https://doi.org/10.1016/j.envpol.2016.12.040.
Gutiérrez-Pliego, L.E., Camarillo-Romero, E., del, S., Montenegro-Morales, L.P., Garduño-García, J. de J., 2016. Dietary patterns associated with body mass index (BMI) and lifestyle in Mexican adolescents. BMC Publ. Health 16 (1), 850. https://doi.org/10.1186/s12889-016-3527-6.
Hagel, J.M., Chen, X., Facchini, P.J., 2019. Production of methylparaben in Escherichia coli. J. Ind. Microbiol. Biotechnol. 46 (1), 91–99. https://doi.org/10.1007/s10295-018-2102-9.
Hajizadeh, Y., Kiani Feizabadi, G., Ebrahimpour, K., Shoshtari-Yeganeh, B., Fadaei, S., Darvishmotevalli, M., Karimi, H., 2020. Urinary paraben concentrations and their implications for human exposure in Iranian pregnant women. Environ. Sci. Pollut. Res. Int. 27 (3), 14723–14734. https://doi.org/10.1007/s11356-020-07991-2.
Halla, N., Fernandes, I.P., Heleno, S.A., Costa, P., Boucherit-Otmani, Z., Boucherit, K., Rodrigues, A.E., Ferreira, I.C.F.R., Barreiro, M.F., 2018. Cosmetics preservation: a review on present strategies. Mol. Basel Switz. 23 (7), 1571. https://doi.org/10.3390/molecules23071571.
Hu, K., Zhao, D., Wu, G., Ma, J., 2017. Aromatic poly(ether ester)s derived from a naturally occurring building block nipagin and linear aliphatic α,ω-diols. RSC Adv. 7 (52), 32989–33000. https://doi.org/10.1039/C7RA01810J.
Huang, H., Liu, C., Wei, S., Wang, J., Zhang, C., 2015. Dynamic root exudation of phenolic allelochemicals from Johnson grass (Sorghum halepense). Weed Biol. Manag. 15 (4), 133–137. https://doi.org/10.1111/wbm.12076.
International Labour Office, 2012. International Standard Classification of Occupations. ISCO-08. Volume 1. Structure, Group Definitions and Correspondece Tables. Available at: https://www.ilo.org/wcmsp5/groups/public/—dgreports/—dcomm/—publ/documents/publication/wcms_172572.pdf. (Accessed 23 March 2021).
Iribarne-Durán, L.M., Domingo-Piñar, S., Peinado, F., Vela-Soria, F., Jiménez-Díaz, I., Barranco, E., Olea, N., Freire, C., Artacho-Cordón, F., Ocón-Hernández, O., 2020. Menstrual blood concentrations of parabens and benzophenones and related factors in a sample of Spanish women: an exploratory study. Environ. Res. 183, 109228. https://doi.org/10.1016/j.envres.2020.109228.
JECFA (the Joint FAO/WHO Expert Committee on Food Additives), 2006. Evaluation of Certain Food Additives and Contaminants. Sixty-Seventh Report of the Joint FAO/WHO Expert Committee on Food Additives, WHO Technical Report Series No. 940, Rome, Italy. Eur. Food Saf. Auth. Available at: https://www.efsa.europa.eu/en/news/efsa-advises-safety-paraben-usage-food. (Accessed 1 May 2021).
Jiménez-Díaz, I., Artacho-Cordón, F., Vela-Soria, F., Belhassen, H., Arrebola, J.P., Fernández, M.F., Ghali, R., Hedhili, A., Olea, N., 2016. Urinary levels of bisphenol A, benzophenones and parabens in Tunisian women: a pilot study. Sci. Total Environ. 562, 81–88. https://doi.org/10.1016/j.scitotenv.2016.03.203.
Jiménez-Díaz, I., Vela-Soria, F., Zafra-Gómez, A., Navalón, A., Ballesteros, O., Navea, N., Fernández, M.F., Olea, N., Vílchez, J.L., 2011. A new liquid chromatography-tandem mass spectrometry method for determination of parabens in human placental tissue samples. Talanta 84 (3), 702–709. https://doi.org/10.1016/j.talanta.2011.01.075.
Jo, A., Kim, S., Ji, K., Kho, Y., Choi, K., 2020. Influence of vegetarian dietary intervention on urinary paraben concentrations: a pilot study with "Temple Stay" Participants. Toxics 8 (1). https://doi.org/10.3390/toxics8010003.
Kang, H.-S., Kyung, M.-S., Ko, A., Park, J.-H., Hwang, M.-S., Kwon, J.-E., Suh, J.-H., Lee, H.-S., Moon, G.I., Hong, J.-H., Hwang, I.G., 2016. Urinary concentrations of parabens and their association with demographic factors: a population-based cross-sectional study. Environ. Res. 146, 245–251. https://doi.org/10.1016/j.envres.2015.12.032.
Kim, J., Chevrier, J., 2020. Exposure to parabens and prevalence of obesity and metabolic syndrome: an analysis of the Canadian Health Measures. Survey. Sci. Total Environ. 713, 135116. https://doi.org/10.1016/j.scitotenv.2019.135116.
Kolátorová, L., Lapčík, O., Stárka, L., 2018. Phytoestrogens and the intestinal microbiome. Physiol. Res. 67, S401–S408. https://doi.org/10.33549/physiolres.934022.
Lemini, C., Hernández, A., Jaimez, R., Franco, Y., Avila, M.E., Castell, A., 2004. Morphometric analysis of mice uteri treated with the preservatives methyl, ethyl, propyl, and butylparaben. Toxicol. Ind. Health 20 (6–10), 123–132. https://doi.org/10.1191/0748233704th202oa.
Liao, C., Chen, L., Kannan, K., 2013a. Occurrence of parabens in foodstuffs from China and its implications for human dietary exposure. Environ. Int. 57–58, 68–74. https://doi.org/10.1016/j.envint.2013.04.001.
Liao, C., Liu, F., Kannan, K., 2013b. Occurrence of and dietary exposure to parabens in foodstuffs from the United States. Environ. Sci. Technol. 47 (8), 3918–3925. https://doi.org/10.1021/es400724s.
Liu, Y., Zhang, C., Wei, S., Cui, H., Huang, H., 2011. Compounds from the subterranean part of Johnsongrass and their allelopathic potential. Weed Biol. Manag. 11 (3), 160–166. https://doi.org/10.1111/j.1445-6664.2011.00416.x.
Loomba-Albrecht, L.A., Styne, D.M., 2009. Effect of puberty on body composition. Curr. Opin. Endocrinol. Diabetes Obes. 16 (1), 10–15. https://doi.org/10.1097/med.0b013e328320d54c.
Luque-Muñoz, A., Vílchez, J.L., Zafra-Gómez, A., 2017. Multiclass method for the determination of pharmaceuticals and personal care products in compost from sewage sludge using ultrasound and salt-assisted liquid-liquid extraction followed by ultrahigh performance liquid chromatography-tandem mass spectrometry analysis. J. Chromatogr. A 1507, 72–83. https://doi.org/10.1016/j.chroma.2017.05.051.
Maher, H.M., Alzoman, N.Z., Almeshal, M.A., Alotaibi, H.A., Alotaibi, N.N., Al-Showiman, H., 2020. Quantitative screening of parabens in Ready-to-eat foodstuffs available in the Saudi market using high performance liquid chromatography with photodiode array detection. Arab. J. Chem. 13 (1), 2897–2911. https://doi.org/10.1016/j.arabjc.2018.07.019.
Martín, J., Zafra-Gómez, A., Hidalgo, F., Ibáñez-Yuste, A.J., Alonso, E., Vilchez, J.L., 2017. Multi-residue analysis of 36 priority and emerging pollutants in marine echinoderms (Holothuria tubulosa) and marine sediments by solid-liquid extraction followed by dispersive solid phase extraction and liquid chromatography-tandem mass spectrometry analysis. Talanta 166, 336–348. https://doi.org/10.1016/j.talanta.2017.01.062.
Martínez, J.A., 2012. Natural Fungicides Obtained from Plants. InTechOpen Access Publisher, London, UK, pp. 3–28.
Martín-Pozo, L., Cantarero-Malagón, S., Hidalgo, F., Navalón, A., Zafra-Gómez, A., 2020. Determination of endocrine disrupting chemicals in human nails using an alkaline digestion prior to ultra-high performance liquid chromatography–tandem mass spectrometry. Talanta 208, 120429. https://doi.org/10.1016/j.talanta.2019.120429.
Meeker, J.D., Cantonwine, D.E., Rivera-González, L.O., Ferguson, K.K., Mukherjee, B., Calafat, A.M., Ye, X., Anzalota Del Toro, L.V., Crespo-Hernández, N., Jiménez-Vélez, B., Alshawabkeh, A.N., Cordero, J.F., 2013. Distribution, variability, and predictors of urinary concentrations of phenols and parabens among pregnant women in Puerto Rico. Environ. Sci. Technol. 47 (7), 3439–3447. https://doi.org/10.1021/es400510g.
Meeker, J.D., Yang, T., Ye, X., Calafat, A.M., Hauser, R., 2011. Urinary concentrations of parabens and serum hormone levels, semen quality parameters, and sperm DNA damage. Environ. Health Perspect. 119 (2), 252–257. https://doi.org/10.1289/ehp.1002238.
Ministry of Health of the People's Republic of China, 2011. National Standards of the People's Republic of China GB 2760–2011. Available at: https://www.svscr.cz/wp-content/files/zivocisne-produkty/GB_2760-2011_Food-Additives.pdf. (Accessed 1 May 2021).
Moreiras, O., Carbajal, Á., Cabrera, L., Cuadrado, C., 2018. In: Pirámide (Grupo Anaya, S. A. (Ed.), Tablas de composición de alimentos. Guía de prácticas, 19ª.
Musatov, S., Chen, W., Pfaff, D.W., Mobbs, C.V., Yang, X.-J., Clegg, D.J., Kaplitt, M.G., Ogawa, S., 2007. Silencing of estrogen receptor alpha in the ventromedial nucleus of hypothalamus leads to metabolic syndrome. Proc. Natl. Acad. Sci. U.S.A. 104 (7), 2501–2506. https://doi.org/10.1073/pnas.0610787104.
Nowak, K., Ratajczak–Wrona, W., Górska, M., Jabłońska, E., 2018. Parabens and their effects on the endocrine system. Mol. Cell. Endocrinol. 474, 238–251. https://doi.org/10.1016/j.mce.2018.03.014.
Oishi, S., 2002. Effects of propyl paraben on the male reproductive system. Food Chem. Toxicol. Int. J. Publ. Br. Ind. Biol. Res. Assoc. 40 (12), 1807–1813. https://doi.org/10.1016/s0278-6915(02)00204-1.
Pajurek, M., Pietron, W., Maszewski, S., Mikolajczyk, S., Piskorska-Pliszczynska, J., 2019. Poultry eggs as a source of PCDD/Fs, PCBs, PBDEs and PBDD/Fs. Chemosphere 223, 651–658. https://doi.org/10.1016/j.chemosphere.2019.02.023.
Palmer, B.F., Clegg, D.J., 2015. The sexual dimorphism of obesity. Mol. Cell. Endocrinol. 402, 113–119. https://doi.org/10.1016/j.mce.2014.11.029.
Partearroyo, T., Samaniego-Vaesken, M. de L., Ruiz, E., Aranceta-Bartrina, J., Gil, Á., González-Gross, M., Ortega, R.M., Serra-Majem, L., Varela-Moreiras, G., 2019.

Current food consumption amongst the Spanish ANIBES study population. Nutrients 11 (11), 2663. https://doi.org/10.3390/nu11112663.

Patino-Alonso, M.C., Recio-Rodríguez, J.I., Belio, J.F.M., Colominas-Garrido, R., Lema-Bartolomé, J., Arranz, A.G., Agudo-Conde, C., Gomez-Marcos, M.A., García-Ortiz, L., EVIDENT Group, 2014. Factors associated with adherence to the Mediterranean diet in the adult population. J. Acad. Nutr. Diet. 114 (4), 583–589. https://doi.org/10.1016/j.jand.2013.07.038.

Pereira-Fernandes, A., Demaegdt, H., Vandermeiren, K., Hectors, T.L.M., Jorens, P.G., Blust, R., Vanparys, C., 2013. Evaluation of a screening system for obesogenic compounds: screening of endocrine disrupting compounds and evaluation of the PPAR dependency of the effect. PloS One 8 (10), e77481. https://doi.org/10.1371/journal.pone.0077481.

Philippat, C., Botton, J., Calafat, A.M., Ye, X., Charles, M.-A., Slama, R., 2014. Prenatal exposure to phenols and growth in boys. Epidemiol. Camb. Mass 25 (5), 625–635. https://doi.org/10.1097/EDE.0000000000000132.

Pollock, T., Weaver, R.E., Ghasemi, R., deCatanzaro, D., 2017. Butyl paraben and propyl paraben modulate bisphenol A and estradiol concentrations in female and male mice. Toxicol. Appl. Pharmacol. 325, 18–24. https://doi.org/10.1016/j.taap.2017.04.001.

Quirós-Alcalá, L., Buckley, J.P., Boyle, M., 2018. Parabens and measures of adiposity among adults and children from the U.S. general population: NHANES 2007-2014. Int. J. Hyg Environ. Health 221 (4), 652–660. https://doi.org/10.1016/j.ijheh.2018.03.006.

Rodríguez-Gómez, R., Dorival-García, N., Zafra-Gómez, A., Camino-Sánchez, F.J., Ballesteros, O., Navalón, A., 2015. New method for the determination of parabens and bisphenol A in human milk samples using ultrasound-assisted extraction and clean-up with dispersive sorbents prior to UHPLC-MS/MS analysis. J. Chromatogr. B Analyt. Technol. Biomed. Life. Sci. 992, 47–55. https://doi.org/10.1016/j.jchromb.2015.04.022.

Rodríguez-Gómez, R., Martín, J., Zafra-Gómez, A., Alonso, E., Vílchez, J.L., Navalón, A., 2017. Biomonitoring of 21 endocrine disrupting chemicals in human hair samples using ultra-high performance liquid chromatography-tandem mass spectrometry. Chemosphere 168, 676–684. https://doi.org/10.1016/j.chemosphere.2016.11.008.

Rosen, E.D., Spiegelman, B.M., 2014. What we talk about when we talk about fat. Cell 156 (1–2), 20–44. https://doi.org/10.1016/j.cell.2013.12.012.

Roth, C.L., Jain, V., 2018. Rising obesity in children: a serious public health concern. Indian J. Pediatr. 85 (6), 461–462. https://doi.org/10.1007/s12098-018-2639-7.

Smith, K.W., Braun, J.M., Williams, P.L., Ehrlich, S., Correia, K.F., Calafat, A.M., Ye, X., Ford, J., Keller, M., Meeker, J.D., Hauser, R., 2012. Predictors and variability of urinary paraben concentrations in men and women, including before and during pregnancy. Environ. Health Perspect. 120 (11), 1538–1543. https://doi.org/10.1289/ehp.1104614.

Soni, M.G., Carabin, I.G., Burdock, G.A., 2005. Safety assessment of esters of p-hydroxybenzoic acid (parabens). Food Chem. Toxicol. Int. J. Publ. Br. Ind. Biol. Res. Assoc. 43 (7), 985–1015. https://doi.org/10.1016/j.fct.2005.01.020.

Ursino, M.G., Poluzzi, E., Caramella, C., De Ponti, F., 2011. Excipients in medicinal products used in gastroenterology as a possible cause of side effects. Regul. Toxicol. Pharmacol. 60 (1), 93–105. https://doi.org/10.1016/j.yrtph.2011.02.010.

Vela-Soria, F., Ballesteros, O., Camino-Sánchez, F.J., Zafra-Gómez, A., Ballesteros, L., Navalón, A., 2015. Matrix solid phase dispersion for the extraction of selected endocrine disrupting chemicals from human placental tissue prior to UHPLC-MS/MS analysis. Microchem. J. 118, 32–39. https://doi.org/10.1016/j.microc.2014.07.018.

Vela-Soria, F., Ballesteros, O., Rodríguez, I., Zafra-Gómez, A., Ballesteros, L., Cela, R., Navalón, A., 2013. A new treatment by dispersive liquid-liquid microextraction for the determination of parabens in human serum samples. Anal. Bioanal. Chem. 405 (23), 7259–7267. https://doi.org/10.1007/s00216-013-7181-x.

Vela-Soria, F., Ballesteros, O., Zafra-Gómez, A., Ballesteros, L., Navalón, A., 2014. A multiclass method for the analysis of endocrine disrupting chemicals in human urine samples. Sample treatment by dispersive liquid-liquid microextraction. Talanta 129, 209–218. https://doi.org/10.1016/j.talanta.2014.05.016.

Veldhuis, J.D., Erickson, D., Iranmanesh, A., Miles, J.M., Bowers, C.Y., 2005. Sex-steroid control of the aging somatotropic axis. Endocrinol Metab. Clin. N. Am. 34 (4), 877–893. https://doi.org/10.1016/j.ecl.2005.07.006.

Xu, Y., Nedungadi, T.P., Zhu, L., Sobhani, N., Irani, B.G., Davis, K.E., Zhang, X., Zou, F., Gent, L.M., Hahner, L.D., Khan, S.A., Elias, C.F., Elmquist, J.K., Clegg, D.J., 2011. Distinct hypothalamic neurons mediate estrogenic effects on energy homeostasis and reproduction. Cell Metabol. 14 (4), 453–465. https://doi.org/10.1016/j.cmet.2011.08.009.

Xue, J., Wu, Q., Sakthivel, S., Pavithran, P.V., Vasukutty, J.R., Kannan, K., 2015. Urinary levels of endocrine-disrupting chemicals, including bisphenols, bisphenol A diglycidyl ethers, benzophenones, parabens, and triclosan in obese and non-obese Indian children. Environ. Res. 137, 120–128. https://doi.org/10.1016/j.envres.2014.12.007.

Yu, Y., Li, W., Lu, S., Wu, S., Wang, F., Tse, L.A., Kang, L., Ma, S., 2019. Urinary parabens in adults from South China: implications for human exposure and health risks. Ecotoxicol. Environ. Saf. 182, 109419. https://doi.org/10.1016/j.ecoenv.2019.109419.

Zhang, Linyuan, Ding, S., Qiao, P., Dong, L., Yu, M., Wang, C., Zhang, M., Zhang, Lixia, Li, Y., Tang, N., Chang, B., 2016. n-butylparaben induces male reproductive disorders via regulation of estradiol and estrogen receptors. J. Appl. Toxicol. JAT 36 (9), 1223–1234. https://doi.org/10.1002/jat.3291.