Review Article

Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review

Caroline Santos Costa*, Bianca Del-Ponte, Maria Cecília Formoso Assunção and Iná Silva Santos
Postgraduate Program in Epidemiology, Federal University of Pelotas, Rua Marechal Deodoro 1160 – 3° andar, Pelotas, RS, CEP 96020-220, Brazil

Submitted 15 October 2016: Final revision received 8 May 2017: Accepted 18 May 2017: First published online 5 July 2017

Abstract
Objective: To review the available literature on the association between consumption of ultra-processed foods and body fat during childhood and adolescence.
Design: A systematic review was conducted in the PubMed, Web of Science and LILACS databases. Studies that evaluated the association between consumption of ultra-processed food (exposure) and body fat (outcome) during childhood and adolescence were eligible.
Subjects: Healthy children and adolescents.
Results: Twenty-six studies that evaluated groups of ultra-processed foods (such as snacks, fast foods, junk foods and convenience foods) or specific ultra-processed foods (soft drinks/sweetened beverages, sweets, chocolate and ready-to-eat cereals) were selected. Most of the studies (*n* 15) had a cohort design. Consumption was generally evaluated by means of FFQ or food records; and body composition, by means of double indirect methods (bioelectrical impedance analysis and skinfolds). Most of the studies that evaluated consumption of groups of ultra-processed foods and soft drinks/sweetened beverages found positive associations with body fat.
Conclusions: Our review showed that most studies have found positive associations between consumption of ultra-processed food and body fat during childhood and adolescence. There is a need to use a standardized classification that considers the level of food processing to promote comparability between studies.

Keywords
Ultra-processed foods
Body fat
Obesity
Childhood
Adolescence

Childhood and adolescent obesity has presented a growing prevalence over the last three decades[1]. Over the same period, modifications to how foods are produced and increasing availability of transportation facilities have been observed, characterizing an 'obesogenic' environment[2] with increasing prevalence of non-healthy eating habits[3] and decreasing prevalence of physical activity[4]. The dietary profile of populations within this scenario has become characterized by high energy density, in which foods rich in fibre have been replaced by products rich in fat and sugars, with a high level of processing[3,5].

A recent food classification (NOVA) based on the extent and purpose of industrial food processing has divided foods into four groups: unprocessed or minimally processed foods; processed culinary ingredients; processed foods; and ultra-processed foods. This last category comprises a group of industrial formulations that are manufactured using several ingredients and a series of processes[6–9]. Most of these products contain little or no whole food. They are ready-to-consume or ready-to-heat and thus require little or no culinary preparation, which makes them easily accessible and convenient. Typically, they are combined with sophisticated use of additives, to make them durable and hyper-palatable. However, they have very low nutritional quality and their consumption tends to limit consumption of unprocessed or minimally processed foods[6–9].

Consumption of ultra-processed foods has been pointed out as a risk factor for increasing obesity, as measured by BMI, among both adolescents and adults[10,11]. Moreover, it has been shown in the literature that individuals who are obese at an early age tend to remain obese throughout

*Corresponding author: Email carolinercosta@gmail.com

life[12]. Considering the growing prevalence of obesity and the consumption of ultra-processed foods worldwide, the objective of the present systematic review was to identify papers on the association between consumption of ultra-processed food and body fat during childhood and adolescence.

Methods

Search strategy

The search was performed in two worldwide electronic databases (PubMed and Web of Science) and in a Latin American and Caribbean database (LILACS). Terms relating to body composition and to consumption of ultra-processed foods were used. The search key was composed of combinations of the following terms: ('body composition' OR 'fat free mass' OR 'fat mass' OR 'dual-energy X-ray absorptiometry' OR 'bioelectrical impedance' OR 'plethysmography' OR 'DEXA scan' OR 'DXA scan' OR 'body fat' OR 'bodpod' OR 'lean mass' OR 'adiposity') AND ('ultra processed' OR 'ultraprocessed' OR 'ultra-processed' OR 'ready-to-eat' OR 'ready-to-consume' OR 'industrialized' OR 'fast-food' OR 'fast food' OR 'fastfood' OR 'junk food' OR 'prepared food' OR 'candy' OR 'ice cream' OR 'chocolate' OR 'carbonated beverage' OR 'soft drink' OR 'sweetened beverage' OR 'snacks' OR 'sausage' OR 'hot dog' OR 'burger' OR 'dietary patterns' OR 'dietary behaviors' OR 'dietary habits'). There were no restrictions to the search regarding topic. All papers needed to be original studies conducted on human subjects. The search was last updated on 15 July 2016.

In addition to the electronic search, the reviewers also undertook a hand search in the reference list of each study included, to identify potentially relevant studies that had not been reached in the initial search.

Eligibility criteria

To be eligible, the studies had to fulfil the following criteria. They needed to: evaluate the association between consumption of ultra-processed food and body fat; evaluate the exposure (consumption of ultra-processed food) and the outcome (body fat) during childhood or adolescence; and not solely include individuals with specific diseases or health conditions.

The exposure variable was the intake of any ultra-processed food, as defined in the NOVA classification (see online supplementary material, Supplemental Table 1)[6–9]. Studies that evaluated only BMI as the outcome were not included because BMI does not discriminate between fat mass and fat-free mass.

Selection of the studies

Two independent reviewers conducted an initial selection of the articles located in the electronic search, by means of reading the titles and abstracts. The papers selected at this stage were then read in full and were evaluated in accordance with the eligibility criteria. A third reviewer adjudicated regarding whether articles should be kept or excluded in situations in which the two reviewers disagreed.

Data analysis

From the full analysis on the articles thus selected, the following data were extracted: country and publication year; study design; sample size; age group evaluated; methods and instruments used to measure the exposure and outcome variables; variables used to control for confounding and in the mediation analysis (when present); and main findings.

The general and methodological quality of observational studies was evaluated in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) Statement[13]. The CONSORT (Consolidated Standards of Reporting Trials) Statement[14] was used to evaluate intervention studies. The maximum scores that can be attained is 22 points in the STROBE assessment and 25 points in CONSORT; of which 9 and 10 points, respectively, related to the Methods section of the studies.

Results

The electronic search resulted in 2243 titles (Fig. 1). After removing duplicates, 1553 titles/abstracts remained to be analysed. From reading the titles and abstracts, and in accordance with the eligibility criteria, Reviewer 1 and Reviewer 2 excluded 1498 and 1519 articles, respectively. After full readings of the articles, Reviewer 1 excluded another twenty-eight articles and Reviewer 2, nineteen, of which nine were coincident. The reasons for exclusion of the articles were that they presented:

- Investigation of ultra-processed food consumption and body fat, but not the association between these two variables (*n* 17);
- Investigation of food consumption by means of scores or dietary indices, from which it was not possible to discriminate the consumption of ultra-processed foods (*n* 5);
- Evaluation of food consumption according to dietary patterns or by means of specific questionnaires such as the 'Block' questionnaire, which asks not only about ultra-processed foods, but also about other food groups, such as unprocessed or minimally processed foods (*n* 4);
- Food consumption based on their components (macronutrients, sugar and energy density; *n* 4);
- No evaluation of the outcome or the exposure of interest (*n* 2);
- Use of behavioural clusters, including consumption of fruits and vegetables, consumption of soft drinks, sedentary behaviour and physically active behaviour (*n* 1);
- Evaluation of the frequency with which adolescents had meals in fast-food restaurants, without evaluation of the foods consumed (*n* 1);

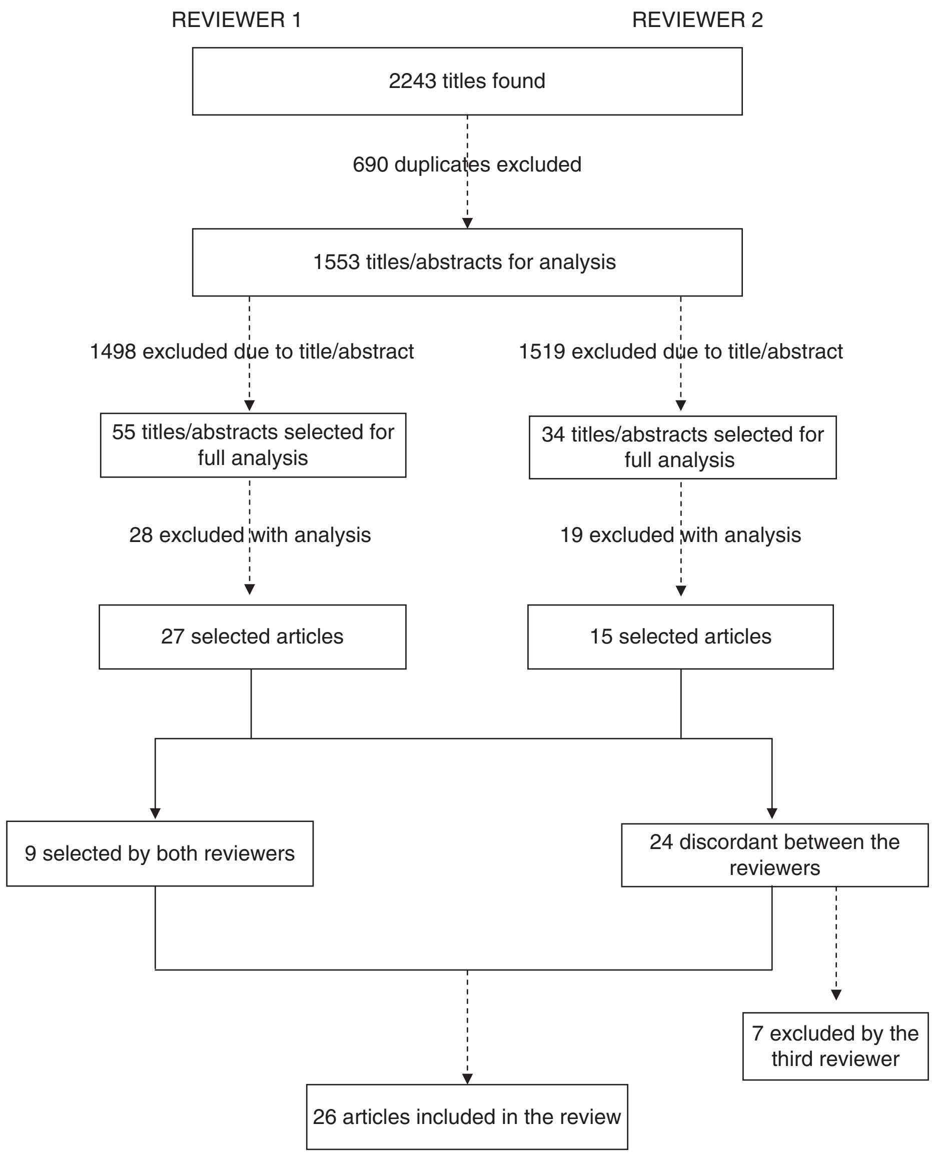

Fig. 1 Flowchart of article selection for the present systematic literature review on consumption of ultra-processed foods and body fat during childhood and adolescence

- Evaluation of Indigenous populations (*n* 1);
- Evaluation of fast-food consumption without discriminating which foods belong to this group (*n* 1);
- Evaluation of consumption of sugar that is not considered ultra-processed in the NOVA classification (*n* 1);
- Evaluation of an intervention composed of changes to physical activity, concomitant to consumption of ready-to-eat cereals, which hindered evaluation of the specific effect of ready-to-eat cereals (*n* 1).

After full readings of the articles, the two reviewers agreed regarding selection of nine studies and disagreed regarding twenty-four. The third reviewer judged the relevance of the twenty-four articles on which the two previous reviewers had disagreed and decided to exclude seven of them. The reasons for the seven exclusions at this stage were that they presented:

- Investigation of ultra-processed food consumption and body fat, but not the association between these two variables (*n* 4);
- Evaluation of food consumption according to dietary patterns or by means of specific questionnaires such as the 'Block' questionnaire, which asks not only about ultra-processed foods, but also about other food groups, such as unprocessed or minimally processed foods (*n* 2);
- Body fat analysed as the ratio of two skinfolds (subscapular to triceps skinfold), which only evaluates the fat distribution, and not the quantity of fat (*n* 1).

https://doi.org/10.1017/S1368980017001331 Published online by Cambridge University Press

No other papers were located through the hand search in the reference lists of the articles selected. A total of twenty-six studies were retained for the current review.

Among these twenty-six selected articles, twelve evaluated the association between consumption specifically of soft drinks or sweetened beverages and body fat[15–26], eleven explored the association between groups of ultra-processed foods and body fat[27–37] and three evaluated the association between consumption of specific ultra-processed foods (sweets, chocolate and ready-to-eat cereals) and body fat[38–40].

Seven studies were conducted in the USA[19,21,22,27–29,33], four in the UK[15,24,25,37], three in Germany[18,30,35], two in New Zealand[17,32] and one each in Australia[26], South Africa[31], Canada[36], Netherlands[34], Mexico[16], Spain[20] and Brazil[38]. Three were multicentre studies: one was carried out in four Oceania countries (New Zealand, Australia, Fiji and Tonga)[23]; and the other two were conducted in ten European cities in nine different countries (Austria, Belgium, France, Germany, Greece, Hungary, Italy, Spain and Sweden)[39,40]. The articles selected were published between 2004 and 2015.

Most of the studies were cohorts (*n* 15)[15,16,18,19,22,24,25,27–31,35–37], although two of these only presented cross-sectional analyses[16,36]; followed by cross-sectional studies (*n* 6)[17,20,32,38–40]; and intervention studies (*n* 5)[21,23,26,33,34], among which three only presented cross-sectional analyses[21,23,33] (Table 1). In four studies, only girls were evaluated[19,21,27,28]. The sample size ranged from 120 to 13 170 individuals. Twelve studies had sample sizes larger than 1000 individuals[16,17,20,23–25,28,31,34,37,39,40] (Table 1).

Regarding the age of the samples studied, in the longitudinal studies (cohort and intervention studies) the mean age at which the exposure was evaluated ranged from 7·8 (SD 3·6) to 8·49 (SD 4·0) years, and the mean age at which the outcome was assessed ranged from 13·5 (SD 3·3) to 14·1 (SD 3·6) years. In the studies with cross-sectional analysis, the mean age ranged from 11·2 (SD 3·3) to 15·8 (SD 3·0) years.

Food consumption was investigated using four different types of instrument. Eight studies used FFQ[16,17,27,31,32,37,38,40]; seven used food records (referring to three days: two weekdays and one day at the weekend)[15,18,24,28–30,35]; six applied 24 h recalls[19,20,22,26,36,39]; and five asked questions about the consumption of specific foods[21,23,25,33,34] with varying recall periods (last month, last week, last 5 d or the day before the interview; Table 1).

Except for the studies that evaluated the consumption of specific ultra-processed foods (*n* 15)[15–26,38–40], the analysis on food consumption in the remaining studies was performed by means of dietary patterns (*n* 6)[28,29,32,35–37]; or according to groups of specific foods (*n* 5) such as energy-dense snacks (soft drinks, sweets, crisps, bakery products and ice cream; *n* 2)[27,34], or through investigation of fast foods, bakery foods and soft drinks (*n* 1)[31], junk foods (sweetened beverages, French fries and crisps, frozen/baked desserts and chocolate sweets; *n* 1)[33] or convenience foods (pre-baked frozen products, canned or instantaneous products such as salads

Table 1 Description of the main characteristics observed in the studies selected for the present systematic literature review on consumption of ultra-processed foods and body fat during childhood and adolescence (*n* 26)

Characteristic	Groups of ultra-processed foods* (*n* 11)	Soft drinks/ sweetened beverages (*n* 12)	Other specific ultra-processed foods† (*n* 3)	Total (*n* 26)
Design				
Cohort	8	7	0	15
Cross-sectional	1	2	3	6
Intervention	2	3	0	5
Sample size				
<300	3	4	1	8
300–1000	4	2	0	6
>1000	4	6	2	12
Evaluation of food consumption				
FFQ‡	4	2	2	8
Food record	4	3	0	7
24 h recall	1	4	1	6
Specific question	2	3	0	5
Evaluation of body composition				
DXA	4	5	0	9
BIA	3	5	2	10
Skinfolds	4	2	1	7
Associations				
Direct	6	8	0	14
Inverse	0	0	2	2
No association	5	4	1	10

DXA, dual-energy X-ray absorptiometry; BIA, bioelectrical impedance analysis.
*Dietary patterns, snacks, fast foods, junk foods and convenience foods.
†Chocolate, sweets and ready-to-consume breakfast cereals.
‡Recall period: annual (*n* 2), weekly (*n* 2) and no available information (*n* 4).

https://doi.org/10.1017/S1368980017001331 Published online by Cambridge University Press

or soups, or ready-to-eat meals, like pizzas, except fast foods; *n* 1)[30].

In the studies that evaluated dietary patterns, the ultra-processed groups included snacks (like crisps or chocolates), sweets, convenience foods and fast foods[28]; snacks and convenience foods[35]; fast foods (sweetened beverages, French fries, fried chicken, salted snacks, hamburgers, hotdogs and pizzas)[36]; artificially sweetened beverages and manufactured sauces and butters[29]; bakery products, carbonated beverages, sweets, crisps, sausages, hamburgers, pizzas, cookies, instant noodles, ready-to-eat meals and aromatized milk[37]; and sweets, bakery products, crisps and natural or artificially sweetened beverages[32].

Three methods for evaluating body fat were used. Ten studies obtained body fat measurements by means of bioelectrical impedance analysis (BIA)[17,22,23,25–27,32,33,38,39]; followed by nine through dual-energy X-ray absorptiometry (DXA)[15,16,19,21,24,29,31,36,37]; and seven from skinfolds[18,20,28,30,34,35,40] (Table 1). Body fat was analysed as a percentage in sixteen articles[16–22,25–28,30,33,36,38,40] and in kilograms in four[24,29,31,37], while another three studies presented body fat both in kilograms and as a fat mass index (FMI)[15,32,35] and two, as both a percentage and in kilograms[23,39]. One study used the sum of the triceps, biceps, suprailiac and subscapular skinfolds (in millimetres) as a proxy for the body fat component[34].

Regarding study quality, the mean totals were 17·1 and 18·0 points, respectively, for the observational studies (*n* 24) and intervention studies (*n* 2)[26,34]. The mean score reached in the Methods section was 7 points for studies evaluated using both the STROBE Statement and the CONSORT Statement.

Among the studies that evaluated the association between consumption of groups of ultra-processed foods and body fat (*n* 11)[27–37], six found associations[29–31,35–37], which were all in a positive direction (i.e. higher consumption of ultra-processed foods was related to higher levels of body fat). All the studies that showed this association had a longitudinal design (cohort; Table 2).

Among the studies that evaluated the association between consumption of soft drinks/sweetened beverages and body fat (*n* 12)[15–26], eight found associations[16,17,19,22–26], which were all in a positive direction (i.e. higher consumption of soft drinks/sweetened beverages was followed by higher levels of body fat; Table 3). Laska *et al.*[22] found an association with a positive direction only in relation to consumption of sweetened beverages among boys, in a longitudinal analysis, and of diet soda among girls, in a cross-sectional analysis. However, the result for girls may have reflected reverse causality bias, given that those with excess body fat might have reported higher consumption of diet products because of their condition (Table 3). The studies that showed this association mostly had a longitudinal design (cohort or intervention; Table 3).

Among the studies that evaluated the association between consumption of other ultra-processed foods (sweets[38], chocolate[39] and ready-to-eat cereals[40]) and body fat, two found associations with a negative direction (i.e. increased consumption of chocolate[39] and ready-to-eat cereals[40] was associated with a lower percentage of body fat; Table 4).

The main variables used in the adjusted analyses were total energy intake, residual energy intake (energy intake from sources other than the foods evaluated), physical activity, age, sex, skin colour/ethnicity, parents' education and BMI, age at the menarche or at sexual maturation, birth weight and breast-feeding. In the present review, divergent opinions were observed regarding use of total energy intake as a possible confounding factor. Out of the twenty-six studies, nine adjusted for total energy intake[15,16,19,22,26,29,36,37,39] and five adjusted for residual energy intake[18,24,25,27,30]. None of the studies investigated whether total energy intake mediated the effect of consumption of ultra-processed foods or soft drinks on body fat. Two articles did not present adjusted analysis[20,38] and the remaining studies adjusted for variables other than energy intake.

Discussion

In summary, the present review showed that most of the studies that investigated consumption of groups of ultra-processed foods, as well as most of the studies that evaluated consumption of soft drinks/sweetened beverages, found positive associations with body fat. The lack of association in some of the studies may have been due to methodological issues. First, body fat was measured using three different methods (DXA, BIA and skinfolds). Among the studies that found associations, half used DXA[16,19,24,29,31,36,37], and among those that did not find any association, only two used this equipment[15,21]. Although the DXA method evaluates body composition indirectly, it has the capacity to derive measurements of greater validity than is possible using doubly indirect methods such as BIA and skinfolds.

Second, the instruments for the food consumption evaluation also varied among the studies (FFQ, food record, 24 h recall and specific questions). Although all these instruments generate information about consumption of certain groups of ultra-processed foods or about a specific ultra-processed food, a great variety of products were included, which could at least partly explain the divergence among the findings. For example, dietary patterns vary according to sex, socio-economic level, ethnic group and culture, such that specific dietary patterns are derived for each specific population[41]. This impairs the comparability of findings between studies[41]. Six of the studies analysed here derived dietary patterns[28,29,32,35–37].

https://doi.org/10.1017/S1368980017001331 Published online by Cambridge University Press

Table 2 Summary of the selected studies that investigated the association between consumption of groups of ultra-processed foods and body fat in children and adolescents

Authors, year, reference; country	Design	Study population (*n*, age, follow-up)	Exposure	Outcome	Adjustment variables	Main results
Phillips *et al.* (2004)[27]; USA	Longitudinal	*n* 132 (only girls; 8–12 years old; 4 years of follow-up)	FFQ; snack groups of high energy density: soft drinks, sweets, crisps, bakery products and ice cream	BF% evaluated by BIA	Physical activity index, inactivity time, parental overweight, race/ethnicity, daily servings of fruits and vegetables, percentage of daily energy from protein, carbohydrates and fat. Age was expressed as chronological age and age at menarche was included as a fixed covariate	No association between daily portions of snacks and BF% (log = 0·20; $P = 0·49$)
Ritchie *et al.* (2007)[28]; USA	Longitudinal	*n* 2371 (only girls; 9–10 years old; 10 years of follow-up)	Food record; dietary patterns	BF% evaluated by skinfolds (triceps, subscapular and suprailiac)	Corresponding baseline measure of adiposity, age at menarche, ever pregnant over the course of the 10-year study, maximal parental education, perceived physical activity frequency and TV/video watching. Analyses were stratified by skin colour (blacks and whites)	Mean BF% did not differ according to the patterns that contained mostly ultra-processed foods
Wosje *et al.* (2010)[29]; USA	Longitudinal	*n* 292 (age ranges: 3·8–4·8, >4·8–5·8, >5·8–6·8 and >6·8–7·8 years; follow-up every 4 months)	Food record; dietary patterns	BF in kg evaluated by DXA	Race, sex, height, exact age, energy intake, Ca intake, accelerometer counts per minute, TV viewing time, outdoor playtime, other dietary pattern score	'Dietary pattern 1', that contained mostly ultra-processed foods, was positively related to BF (consumption quartile 4 presented higher fat mass than quartiles 1 and 2&3); effect measure was not presented
Alexy *et al.* (2011)[30]; Germany	Longitudinal	*n* 585 (3 years old; followed up until 18 years old)	Food record; convenience foods (CF)	BF% evaluated by skinfolds (triceps and subscapular)	Age, residual energy, maternal BMI, maternal education level and physical activity	No association among girls: $\beta = 0·012$; $P = 0·6953$ Among boys, CF consumption at baseline significantly predicted change in BF%: $\beta = 0·104$; $P = 0·0098$
Feeley *et al.* (2013)[31]; South Africa	Longitudinal	*n* 1298 (13 years old; 4 years of follow-up)	FFQ about specific foods; fast foods, bakery products and sweetened beverages	BF in kg evaluated by DXA	Height and household durable assets; stratified by sex	Only sweetened beverages consumption was positively associated with BF in boys ($\beta = 0·018$; $P < 0·05$)
Howe *et al.* (2013)[32]; New Zealand	Cross-sectional	*n* 681 (mean age 15·8 years old)	FFQ; dietary patterns	BF in kg evaluated by BIA (FMI was also presented)	Age, school decile and ethnicity; stratified by sex	'Treat foods' pattern was not associated with BF in the adjusted model: $\beta = -3·57$ (95 % CI −7·69, 0·74)

Table 2 *Continued*

Authors, year, reference; country	Design	Study population (*n*, age, follow-up)	Exposure	Outcome	Adjustment variables	Main results
Montoye *et al.* (2013)[33]; USA	Intervention with cross-sectional analysis of the baseline	*n* 214 (mean age 9·8 years old)	Specific question: junk food consumption (times/d): sweetened beverages, French fries and chips, frozen/baked desserts, sweets made of chocolate	BF% evaluated by BIA	Age, gender, ethnicity and self-reported physical activity	No association between junk food consumption and BF% ($\beta = -0{\cdot}106$; $P = 0{\cdot}444$)
Yildirim *et al.* (2013)[34]; Netherlands	Intervention	*n* 1108 (mean age 12·7 years old)	Specific questions: consumption of sweetened beverages (litres/d) and sweetened and salted snacks (number of snacks/d)	Skinfolds sum (in mm): triceps, biceps, suprailiac and subscapular	Gender and ethnicity	Consumption of sweetened beverages ($\beta = 0{\cdot}02$; 95 % CI −0·62, 0·77) and sweet ($\beta = -0{\cdot}19$; 95 % CI −0·53, 0·19) and salted ($\beta = -0{\cdot}250$; 95 % CI −1·42, 0·36) snacks was not associated with the skinfolds sum
Diethelm *et al.* (2014)[35]; Germany	Longitudinal	*n* 371 (6–7 years old; 4 years of follow-up)	Food record; dietary patterns	BF in kg evaluated by triceps, biceps, suprailiac and subscapular skinfolds (FMI was also presented)	Baseline body composition, sex, maternal overweight, paternal education, gestational age, birth weight and breast-feeding	Changing pattern by reduced rank regression (savoury foods) was associated with change in FMI; comparing subjects from the lowest consumption tertile, those in the highest tertile had 74 % more increase in FMI
Shang *et al.* (2013)[36]; Canada	Longitudinal, with cross-sectional analysis	*n* 613 (8–10 years old)	24 h recall; dietary patterns	BF% evaluated by DXA	Age, sex, daily energy intake, daily average steps (steps/d), screen time (h/d), sleep time (h/d), mother's obesity (BMI $\geq$ 30 kg/m^2) and family income	Children with fast food pattern score higher than P75 presented higher BF% than those with score < P25 (41·8 *v.* 40·1 %; $P < 0{\cdot}05$). The fast food pattern was positively associated with BF% ($\beta = 0{\cdot}08$; $P = 0{\cdot}04$)
Leary *et al.* (2015)[37]; England	Longitudinal	*n* 4750 (38 months; followed up until 15 years old)	FFQ; dietary patterns	BF in kg evaluated by DXA	Gender and age at the time of body composition measurement, energy intake at 38 months for the four dietary patterns, parental factors (maternal and paternal height, maternal and paternal BMI, maternal age, parity), social factors (social class, maternal education), birth weight, gestational age, pubertal status; stratified by sex	The junk food dietary pattern was associated with BF (greater score at 3 years of age was associated with an increase in BF at age 15 years): $\beta = 0{\cdot}06$; $P = 0{\cdot}002$; fussy or snack: $\beta = -0{\cdot}01$; $P = 0{\cdot}8$

BF%, body fat percentage; BIA, bioelectrical impedance analysis; BF, body fat; DXA, dual-energy X-ray absorptiometry; FMI, fat mass index; TV, television; P75, 75th percentile; P25, 25th percentile.

Table 3 Summary of the selected studies that investigated the association between soft drink/sweetened beverages consumption and body fat in children and adolescents

Authors, year, reference; country	Design	Study population (*n*, age, follow-up)	Exposure	Outcome	Adjustment variables	Main results
Johnson *et al.* (2007)[15]; England	Longitudinal	*n* 521 (at 5 years old) and *n* 682 (at 7 years old); followed up until 9 years old	Food record; sweetened beverages consumption evaluated by daily portion (1 portion = 180 ml)	BF in kg evaluated by DXA (FMI was also presented)	Sex, height at 9 years, child's BMI at baseline, TV watching, maternal education, paternal class, maternal and paternal BMI, misreporting of energy intake (energy intake per EER), dietary energy density, percentage of energy intake from fat and fibre density	No association between sweetened beverages consumption and fat mass ($\Delta = -0{\cdot}15$, $P = 0{\cdot}45$ at 5 years; $\Delta = -0{\cdot}11$, $P = 0{\cdot}41$ at 7 years)
Denova-Gutiérrez *et al.* (2009)[16]; Mexico	Longitudinal with cross-sectional analysis	*n* 1055 (10–19 years old; mean age 14·5 years)	FFQ; sweetened beverages consumption evaluated by daily portion (1 portion = 240 ml)	BF% evaluated by DXA (cut-off points for excess BF by age and sex)	Age, sex, sexual maturation, place of residence, physical activity, father's education, total energy intake, alcohol consumption and energy derived from total fat intake	To additional daily intake of sweetened beverages there was an increase of 0·8 in BF% ($P < 0{\cdot}001$) and OR for overweight was 1·18 ($P < 0{\cdot}001$); OR for >3 portions was 2·06 ($P = 0{\cdot}004$)
Duncan *et al.* (2008)[17]; New Zealand	Cross-sectional	*n* 1229 (5–11 years old)	FFQ; fast foods and soft drinks/sweetened beverages consumption	BF% evaluated by BIA (cut-off points for excess BF: 25 % for boys and 30 % for girls)	Sex, age, ethnicity, socio-economic status, physical activity, active transport, sports participation, breakfast, bought lunch, fast foods, sugary drinks, weekday sleep and weekend sleep	OR to have high BF in those who consumed 5+ fast food portions/week was 2·38 ($P \geq 0{\cdot}05$); in those who consumed 5+ portions sweetened beverages/week, 2·37 ($P < 0{\cdot}05$), compared with 0 portions (OR = 2·26; $P < 0{\cdot}05$ for 3–4 portions/week)
Libuda *et al.* (2008)[18]; Germany	Longitudinal	*n* 244 (9–13 years old; 5 years of follow-up)	Food record; sweetened beverages consumption evaluated by daily volume (ml)	BF% evaluated by skinfolds (triceps and subscapular)	Time in years after maximal growth velocity (equals years of adolescence) as an indicator for pubertal status, weight at birth, year of birth, maternal BMI and educational level, energy derived from other sources (residual energy) at the first assessment (total energy intake minus energy from each of the beverage groups), its interaction with time and the annual change in residual energy	No association between sweetened beverages consumption and BF
Fiorito *et al.* (2009)[19]; USA	Longitudinal	*n* 166 (only girls; 5 years old; 10 years of follow-up)	24 h recall; sweetened beverages consumption evaluated by daily portion (1 portion = 240 ml)	BF% evaluated by DXA and skinfolds (triceps and subscapular)	Sweetened beverage consumption at the age adiposity was measured, energy intake at age 5 years, and maternal BMI, parental education and family income at study entry	Sweetened beverages consumption at 5 years was a predictor of adiposity at 5, 7, 9, 11, 13 and 15 years Girls who consumed ≥ 2 portions of sweetened beverage at 5 years had higher BF% values at 5 and 15 years compared with girls with lower sweetened beverages consumption
Gomez-Martinez *et al.* (2009)[20]; Spain	Cross-sectional	*n* 1523 (mean age 15·4 years old)	24 h recall; sweetened beverages evaluated by daily portion (1 average portion = 336 ml)	BF% evaluated by skinfolds (triceps and subscapular)	Only crude analysis. Stratified by age and sex	No association between sweetened beverages consumption and BF
Bauer *et al.* (2011)[21]; USA	Intervention with cross-sectional analysis	*n* 253 (only girls; mean age 15·7 years old)	Specific question about parents' soft drink consumption (portions/week) and daughters' soft drink consumption (weekly frequency in the last month)	BF% evaluated by DXA	Age, race/ethnicity and parental education	No association between soft drinks consumption and BF % (data not shown in tables) No association between parents' soft drinks consumption and daughters' BF%
Laska *et al.* (2012)[22]; USA	Longitudinal	*n* 562 (mean age 14·6 years old; 2 years of follow-up)	24 h recall; sweetened beverages consumption evaluated by daily portion	BF% evaluated by BIA	Race, grade, parent education, school lunch, puberty, total physical activity measured at baseline, study (ECHO or IDEA) and total energy intake measured at baseline	Cross-sectional analysis: among girls, there was a positive association between diet soft drinks consumption and BF% ($\beta = 3{\cdot}64$; $P < 0{\cdot}001$) Longitudinal analysis: among boys, there was a positive association between sweetened beverages consumption and BF% ($\beta = 0{\cdot}73$; $P = 0{\cdot}001$)

Table 3 *Continued*

Authors, year, reference; country	Design	Study population (*n*, age, follow-up)	Exposure	Outcome	Adjustment variables	Main results
Sluyter *et al.* (2013)[23]; New Zealand, Australia, Fiji and Tonga	Intervention with cross-sectional analysis	*n* 5714 (12–22 years old)	Specific question: soft drink consumption (last 5 d); portion = number of glasses/cans (last day)	BF% evaluated by BIA (BF in kg was also presented)	Age, sex and ethnicity	Among the combined ethnic groups, sweetened beverages consumption presented a positive dose-dependent association with BF% and total BF; consistent direction of the effects through the ethnic groups: 7 of 8 positive associations
Bigornia *et al.* (2015)[24]; England	Longitudinal	*n* 2455 (10 years old; 3 years of follow-up)	Food record; sugar-sweetened beverages evaluated by daily portion (1 portion = 180 ml)	BF in kg evaluated by DXA	Model 1: change in sugar-sweetened beverages consumption, sugar-sweetened beverages consumption at age 10 years, sex, baseline age, height and adiposity, BMI at age 10 years; Model 2: model 1 plus physical activity and pubertal stage at age 13 years, maternal overweight/obesity status, maternal education, dieting at age 13 years, and change in fruit juice, fruit and vegetable, and total fat intakes from age 10 to 13 years; Model 3: model 2 plus dietary reporting errors at age 13 years; Model 4: model 2 among plausible dietary reporters at age 13 years only	Association between the change in sweetened beverages consumption and all adiposity measures (TBFM: $\beta = 0{\cdot}033$, $P = 0{\cdot}011$); in the models adjusted for total energy intake, the magnitude of the estimates for TBFM remained similar
Laverty *et al.* (2015)[25]; UK	Longitudinal	*n* 13 170 (7 years old; 4 years of follow-up)	Specific question: consumption of beverages natural and artificially (diet) sweetened; never/once per week; 1–6 times per week; at least once per day. Without definition of quantity per portion	BF% evaluated by BIA	Age, sex, ethnic group, family income, mother's highest educational qualification, country, portions of fruit consumed per day, breakfast consumption, days per week of sport/exercise, hours spent watching TV per weekday, mode of transport to school, being on a controlled diet at age 7 and snacking at age 7. Models of change in adiposity adjusted for adiposity at age 7	Weekly (+0·37 %; 95 % CI 0·05, 0·70 %) and daily (+0·54 %; 95 % CI 0·17, 0·92 %) consumption of naturally sweetened beverages was associated with increased BF% at 11 years Weekly (+0·88 %; 95 % CI 0·49, 1·27 %) and daily (+1·18 %, 95 % CI 0·81, 1·54 %) consumption of artificially sweetened beverages was associated with increased BF% at 11 years
Zheng *et al.* (2015)[26]; Australia	Intervention	*n* 158 (8 years old; 3·5 years of follow-up)	24 h recall; sweetened beverages consumption evaluated by daily portion (1 portion = 100 ml)	BF% evaluated by BIA	Baseline age, gender, BMI *Z*-score, SEIFA score, maternal age at birth, parental education level, parental countries of birth, maternal age at birth, presence of gestational diabetes, breast-feeding characteristics, pubertal status, randomization group and total energy intake	For each increase of 100 ml in the daily intake of sweetened beverages at 9 years, there was an increase of 0·9 percentage points in BF ($P = 0{\cdot}004$) Trend of dose–response was found for quartiles of sweetened beverages consumption and BF% (*P* trend = 0·005)

BF, body fat; DXA, dual-energy X-ray absorptiometry; FMI, fat mass index; BF%, body fat percentage; BIA, bioelectrical impedance analysis; TV, television; EER, estimated energy requirement; ECHO, Etiology of Childhood Obesity; IDEA, Identifying Determinants of Eating and Activity; SEIFA, Socio-Economic Index for Areas; TBFM, total body fat mass.

Table 4 Summary of the selected studies that investigated the association between the consumption of specific ultra-processed foods and body fat

Authors, year, reference; country	Design	Study population (*n*, age, follow-up)	Exposure	Outcome	Adjustment variables	Main results
Chaves *et al.* (2013)[38]; Brazil	Cross-sectional	*n* 120 (10–13 years old)	FFQ; daily consumption of sweets	BF% evaluated by BIA (excess BF by cut-off points proposed by Lohman)	Only crude analysis	No association between daily consumption of sweets and BF excess (OR = 2·19; 95 % CI 0·57, 8·37; $P = 0·1$)
Cuenca-García *et al.* (2014)[39]; 10 European cities of 9 different countries	Multicentre cross-sectional	*n* 1458 (12·5–17·5 years old)	24 h recall; consumption of chocolate in grams	BF% evaluated by BIA and skinfolds (triceps and subscapular)	Height, sex, age, sexual maturation, total energy, saturated fat, fruit and vegetable intakes and physical activity	Chocolate consumption was associated with a lower BF%, estimated by skinfolds ($\beta = -0·008$; $P = 0·011$) and BIA ($\beta = -0·011$; $P = 0·012$)
Michels *et al.* (2015)[40]; 10 European cities of 9 different countries	Multicentre cross-sectional	*n* 1215 (12·5–17·5 years old)	FFQ; daily consumption of ready-to-eat cereals	BF% evaluated by BIA and skinfolds (triceps and subscapular)	Age, sex, socio-economic status, city and breakfast skipping	Daily consumption of ready-to-eat cereals was associated with lower BF% (22·9 % for daily consumers *v*. 25·0 % for non-consumers; $P < 0·001$)

BF%, body fat percentage; BF, body fat; BIA, bioelectrical impedance analysis.

Among the studies that evaluated other specific ultra-processed foods, two of them found associations in a negative direction, such that they showed that higher consumption of chocolate and ready-to-eat cereals was related to a lower percentage of body fat. These findings may reflect residual confounding. Michels *et al.*[40] did not adjust for consumption of milk (that was added to ready-to-eat cereals) or for physical activity, although these variables might have a correlation with body fat. Cuenca-García *et al.*[39] evaluated chocolate consumption from a 24 h recall, an instrument that does not measure dietary habits. Additionally, because of the cross-sectional design of the study by Cuenca-García *et al.*[39], it is possible that individuals with lower percentages of body fat had higher consumption of chocolate only over the 24 h preceding the interview.

It is important to emphasize that only one of the studies selected for the present review reported the parameters that were used for sample size calculation[38] and none presented a statistical power calculation. Nevertheless, the scores relating to study quality, as evaluated through the STROBE and CONSORT Statements, were considered good. There was no difference in the mean scores for quality between studies that did or did not find an association (data not shown).

Although ultra-processed foods are a major source of energy intake, they are just one group of foods among all the possible sources of energy intake in the diet. Therefore, to assess the effect of the energy provided by ultra-processed foods on body fat levels, it is important to disentangle the effect of ultra-processed foods from the effect of other sources of energy. Consequently, studies that adjusted for total energy intake (including energy provided by ultra-processed foods) may in fact have over-adjusted for the exposure, thus decreasing the magnitude of the association between consumption of ultra-processed foods and body fat. For this reason, we take the view that the adjustment should be limited to residual energy solely from other sources. Nevertheless, seven of the nine studies examined here that adjusted for total energy intake found positive associations[16,19,22,26,29,36,37].

Regarding the strategies used by the authors of the studies selected for the current analysis to decrease the occurrence of bias, self-reporting errors were considered in five studies[15,16,18,24,26]. One study evaluated under-reporting and over-reporting of energy intake (daily intakes <79 % and >121 % of the estimated energy requirement, respectively). However, they did not exclude these cases from the analysis, under the argument that in doing so, the children who were of greatest interest for the study (those with highest percentages of body fat) would probably be excluded[15]. Therefore, the implausible reports were used as a covariate in the adjusted analysis. Individuals with implausible energy intake (under-reported or over-reported) were excluded in two studies[27,33]. Cuenca-García *et al.*[39] performed additional analyses in which obese adolescents were excluded, to prevent underestimated reporting of chocolate intake. However, after these analyses, the results did not change. Some of the studies reported using standardized protocols for anthropometric measurements[16,23,25,28,32,34–36], to decrease occurrences of measurement errors.

Among the limitations of the present review, the great variability of methods used to investigate food consumption can be highlighted, along with the great variability of the instruments used to assess body composition. These factors hindered evaluation of the data by means of meta-analysis. The articles included in the review looked only at specific products and did not apply the NOVA classification. In fact, so far, only two studies have applied the NOVA classification to assess associations: not with body fat but with obesity and weight gain. Louzada *et al.*[10] were the first to use this indicator in a cross-sectional study to evaluate the association with obesity. Mendonça *et al.*[11] applied this indicator in the first cohort study that was planned to evaluate the effect of ultra-processed food consumption on weight gain.

On the other hand, to the best of our knowledge, the present systematic review is the first addressing the association between consumption of ultra-processed foods and body fat levels among children and adolescents. Investigations on consumption of ultra-processed foods during childhood have gained importance because the dietary habits acquired over this period tend to be kept throughout life, which can influence the prevalence of obesity in this population[42,43].

Conclusion

It is evident that the great majority of the literature on the association between consumption of ultra-processed foods and body fat levels presents positive directions (i.e. increased consumption ends up increasing body fat levels). Most of the studies with designs of greater robustness, and which used DXA to evaluate body composition, showed positive associations between consumption of ultra-processed foods and body fat levels.

Despite the large number of studies on the association between dietary habits and body fat levels that are available in the literature, there is a lack of studies exploring the association between consumption of ultra-processed foods and obesity among children and adolescents. Use of a standardized food classification, such as NOVA, which makes it possible to consider the level of food processing, is much needed to uncover the role of such foods in obesity epidemics and to enable comparability between the findings of upcoming studies.

Acknowledgements

Acknowledgements: The authors thank the National Support Program for Centers of Excellence (PRONEX-CAPES) and Brazilian National Research Council (CNPq). *Financial support:* This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. *Conflict of interest:* None. *Authorship:* All authors contributed substantially to the conception and design, data acquisition, analysis and/or interpretation. C.S.C. drafted the article and B.D.-P., M.C.F.A. and I.S.S. reviewed it critically for important intellectual content. All authors approved the final version to be published. *Ethics of human subject participation:* Not applicable.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980017001331

References

1. Ng M, Fleming T, Robinson M *et al.* (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **384**, 766–781.
2. Popkin BM (2006) Technology, transport, globalization and the nutrition transition food policy. *Food Policy* **31**, 554–569.
3. Popkin BM (2006) Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr* **84**, 289–298.
4. Owen N, Sparling PB, Healy GN *et al.* (2010) Sedentary behavior: emerging evidence for a new health risk. *Mayo Clin Proc* **85**, 1138–1141.
5. Martins APB, Levy RB, Claro RM *et al.* (2013) Participação crescente de produtos ultraprocessados na dieta brasileira (1987–2009). *Rev Saude Publica* **47**, 656–665.
6. Monteiro CA, Cannon G, Moubarac J-C *et al.* (2017) The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr* (Epublication ahead of print version).
7. Pan American Health Organization (2015) *Ultra-Processed Food and Drink Products in Latin America: Trends, Impact on Obesity, Policy Implications*. Washington DC: PAHO.
8. Food and Agriculture Organization of the United Nations (2015) *Guidelines on the Collection of Information on Food Processing Through Food Consumption Surveys*. Rome: FAO.
9. Monteiro CA, Levy RB, Claro RM *et al.* (2010) A new classification of foods based on the extent and purpose of their processing. *Cad Saude Publica* **26**, 2039–2049.
10. Louzada MLdC, Baraldi LG, Steele EM *et al.* (2015) Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med* **81**, 9–15.
11. Mendonça RdD, Pimenta AM, Gea A *et al.* (2016) Ultra-processed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr* **104**, 1433–1440.
12. Singh AS, Mulder C, Twisk JW *et al.* (2008) Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* **9**, 474–488.
13. Vandenbroucke JP, Von Elm E, Altman DG *et al.* (2007) Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *Ann Intern Med* **147**, W163–W194.
14. Moher D, Hopewell S, Schulz KF *et al.* (2010) CONSORT 2010 explanation and elaboration: updated guidelines for

reporting parallel group randomised trials. *J Clin Epidemiol* **63**, e1–e37.
15. Johnson L, Mander AP, Jones LR *et al.* (2007) Is sugar-sweetened beverage consumption associated with increased fatness in children? *Nutrition* **23**, 557–563.
16. Denova-Gutiérrez E, Jiménez-Aguilar A, Halley-Castillo E *et al.* (2009) Association between sweetened beverage consumption and body mass index, proportion of body fat and body fat distribution in Mexican adolescents. *Ann Nutr Metab* **53**, 245–251.
17. Duncan JS, Schofield G, Duncan EK *et al.* (2008) Risk factors for excess body fatness in New Zealand children. *Asia Pac J Clin Nutr* **17**, 138–147.
18. Libuda L, Alexy U, Sichert-Hellert W *et al.* (2008) Pattern of beverage consumption and long-term association with body-weight status in German adolescents – results from the DONALD study. *Br J Nutr* **99**, 1370–1379.
19. Fiorito LM, Marini M, Francis LA *et al.* (2009) Beverage intake of girls at age 5 y predicts adiposity and weight status in childhood and adolescence. *Am J Clin Nutr* **90**, 935–942.
20. Gómez-Martínez S, Martín A, Romeo J *et al.* (2009) Is soft drink consumption associated with body composition? A cross-sectional study in Spanish adolescents. *Nutr Hosp* **24**, 97–102.
21. Bauer KW, Neumark-Sztainer D, Fulkerson JA *et al.* (2011) Familial correlates of adolescent girls' physical activity, television use, dietary intake, weight, and body composition. *Int J Behav Nutr Phys Act* **8**, 25.
22. Laska MN, Murray DM, Lytle LA *et al.* (2012) Longitudinal associations between key dietary behaviors and weight gain over time: transitions through the adolescent years. *Obesity (Silver Spring)* **20**, 118–125.
23. Sluyter JD, Scragg RK, Plank LD *et al.* (2013) Sizing the association between lifestyle behaviours and fatness in a large, heterogeneous sample of youth of multiple ethnicities from 4 countries. *Int J Behav Nutr Phys Act* **10**, 115.
24. Bigornia SJ, LaValley MP, Noel SE *et al.* (2015) Sugar-sweetened beverage consumption and central and total adiposity in older children: a prospective study accounting for dietary reporting errors. *Public Health Nutr* **18**, 1155–1163.
25. Laverty AA, Magee L, Monteiro CA *et al.* (2015) Sugar and artificially sweetened beverage consumption and adiposity changes: national longitudinal study. *Int J Behav Nutr Phys Act* **12**, 137.
26. Zheng M, Allman-Farinelli M, Heitmann B *et al.* (2015) Liquid versus solid energy intake in relation to body composition among Australian children. *J Hum Nutr Diet* **28**, 70–79.
27. Phillips SM, Bandini LG, Naumova EN *et al.* (2004) Energy-dense snack food intake in adolescence: longitudinal relationship to weight and fatness. *Obes Res* **12**, 461–472.
28. Ritchie LD, Spector P, Stevens MJ *et al.* (2007) Dietary patterns in adolescence are related to adiposity in young adulthood in black and white females. *J Nutr* **137**, 399–406.
29. Wosje KS, Khoury PR, Claytor RP *et al.* (2010) Dietary patterns associated with fat and bone mass in young children. *Am J Clin Nutr* **92**, 294–303.
30. Alexy U, Libuda L, Mersmann S *et al.* (2011) Convenience foods in children's diet and association with dietary quality and body weight status. *Eur J Clin Nutr* **65**, 160–166.
31. Feeley AB, Musenge E, Pettifor JM *et al.* (2013) Investigation into longitudinal dietary behaviours and household socio-economic indicators and their association with BMI *Z*-score and fat mass in South African adolescents: the Birth to Twenty (Bt20) cohort. *Public Health Nutr* **16**, 693–703.
32. Howe AS, Black KE, Wong JE *et al.* (2013) Dieting status influences associations between dietary patterns and body composition in adolescents: a cross-sectional study. *Nutr J* **12**, 51.
33. Montoye AH, Pfeiffer KA, Alaimo K *et al.* (2013) Junk food consumption and screen time: association with childhood adiposity. *Am J Health Behav* **37**, 395–403.
34. Yildirim M, Singh AS, Velde SJ *et al.* (2013) Mediators of longitudinal changes in measures of adiposity in teenagers using parallel process latent growth modeling. *Obesity (Silver Spring)* **21**, 2387–2395.
35. Diethelm K, Günther AL, Schulze MB *et al.* (2014) Prospective relevance of dietary patterns at the beginning and during the course of primary school to the development of body composition. *Br J Nutr* **111**, 1488–1498.
36. Shang L, O'Loughlin J, Tremblay A *et al.* (2013) The association between food patterns and adiposity among Canadian children at risk of overweight. *Appl Physiol Nutr Metab* **39**, 195–201.
37. Leary S, Lawlor D, Smith GD *et al.* (2015) Behavioural early-life exposures and body composition at age 15 years. *Nutr Diabetes* **5**, e150.
38. Chaves OC, Franceschini Sdo C, Ribeiro SMR *et al.* (2013) Anthropometric and biochemical parameters in adolescents and their relationship with eating habits and household food availability. *Nutr Hosp* **28**, 1352–1356.
39. Cuenca-García M, Ruiz JR, Ortega FB *et al.* (2014) Association between chocolate consumption and fatness in European adolescents. *Nutrition* **30**, 236–239.
40. Michels N, De Henauw S, Breidenassel C *et al.* (2015) European adolescent ready-to-eat-cereal (RTEC) consumers have a healthier dietary intake and body composition compared with non-RTEC consumers. *Eur J Nutr* **54**, 653–664.
41. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**, 3–9.
42. Madruga SW, Araújo CLP, Bertoldi AD *et al.* (2012) Manutenção dos padrões alimentares da infância à adolescência. *Rev Saude Publica* **46**, 376–386.
43. Ventura AK & Worobey J (2013) Early influences on the development of food preferences. *Curr Biol* **23**, R401–R408.