European Journal of Nutrition (2019) 58:3267–3278
https://doi.org/10.1007/s00394-018-1870-3

ORIGINAL CONTRIBUTION

Consumption of ultra-processed food products and diet quality among children, adolescents and adults in Belgium

Stefanie Vandevijvere[1] · Karin De Ridder[1] · Thibault Fiolet[2] · Sarah Bel[1] · Jean Tafforeau[1]

Received: 30 September 2018 / Accepted: 23 November 2018 / Published online: 3 December 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract

Purpose To assess the dietary share of ultra-processed foods (UPF) among Belgian children, adolescents and adults and associations with diet quality.

Methods Data from the national Food Consumption Surveys 2004 ($N = 3083$; ≥ 15 years) and 2014–2015 ($N = 3146$; 3–64 years) were used. Two 24-h recalls (dietary records for children) were used for data collection. Foods consumed were classified by the level of processing using the NOVA classification. The usual proportion of daily energy intake from UPF was determined using SPADE (Statistical Program to assess dietary exposure).

Results In 2014/2015, 36.4% of foods consumed were ultra-processed, while 42.4% were unprocessed/minimally processed. The usual proportion of daily energy intake from UPF was 33.3% (95% CI 32.1–35.0%) for children, 29.2% (95% CI 27.7–30.3%) for adolescents and 29.6% (95% CI 28.5–30.7%) for adults. There were no differences in UPF consumption between 2004 and 2014/2015. The products contributing most to UPF consumption were processed meat (14.3%), cakes, pies, pastries (8.9%), sweet biscuits (7.7%) and soft drinks (6.7%). The UPF dietary share was significantly lower during consumption days when participants met the WHO salt intake recommendation (≤ 5 g/day) and when saturated fat was ≤ 10% of their total energy intake. The dietary share of unprocessed/minimally processed foods was significantly higher during consumption days when participants met the WHO salt and fruit/vegetable intake (≥ 400 g/day) recommendations and when saturated fat was ≤ 10% of their total energy intake.

Conclusions The UPF dietary share is substantial and associated with lower diet quality. Internationally recommended policies to limit UPF accessibility and marketing need to be implemented to reduce UPF consumption.

Keywords Ultra-processed foods · Diet quality · Food consumption surveys · Belgium

Introduction

Malnutrition in all its forms, including obesity, is a major cause of death and disease globally, as documented in the latest Global Burden of Disease Study (GBD) 2016 [1]. Available food energy per capita has increased in most regions of the world, and this increase was previously found to be sufficient to explain concurrent increases in average population body weight in many countries [2]. Globally, between 1990 and 2010, the consumption of healthy food items improved, while at the same time consumption of unhealthy food items worsened, with heterogeneity across regions and countries [3].

In Belgium, dietary risks are the top third contributor to the burden of disease (2016), following tobacco and high blood pressure [4]. Belgians are generally not meeting food-based dietary guidelines [5, 6], in particular for fruits and vegetables and for restricting energy-dense, nutrient-poor foods. Fruit and vegetable intakes among the Belgian population aged 15–64 years slightly decreased between 2004 and 2014, but the difference was not significant [5, 6]. Consumption of energy-dense, nutrient-poor foods among individuals 15–64 year old was excessive in 2004 (730 kcal/day) and

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00394-018-1870-3) contains supplementary material, which is available to authorized users.

✉ Stefanie Vandevijvere
stefanie.vandevijvere@sciensano.be

[1] Scientific Institute of Public Health (Sciensano), J. Wytsmanstraat 14, 1050 Brussels, Belgium

[2] Federal Public Service of Health, Food Chain Safety and Environment, Place Victor Horta, 40/10, 1060 Brussels, Belgium

decreased to 674 kcal/day in 2014. This decrease was also not statistically significant [5, 6]. In 2014, only about 2.1% of children (3–9 years), 2.4% of adolescents (10–17 years) and 6.6% of adults complied with the recommendations limiting the consumption of energy-dense nutrient-poor foods [6].

Recently, it has been suggested that food processing, more specifically the type, intensity and purpose of food processing may be linked to human health [7], and a new method of food classification has been proposed [8]: the NOVA classification (with NOVA being a name, not an acronym), which is increasingly applied by researchers to investigate the link between nutrition and human health. The NOVA classification divides foods into four groups according to their degree of processing:

1. unprocessed or minimally processed foods,
2. processed culinary ingredients,
3. processed foods and
4. ultra-processed foods.

Ultra-processed foods (UPF) are products made mostly or entirely from substances extracted from foods or derived from food constituents with little if any intact food, which often contain flavours, colours and other additives that mimic or intensify the sensory qualities of foods or culinary preparations made from foods [9].

UPF are designed to be convenient, attractive and accessible and they are highly profitable and heavily marketed [7, 9]. Minimally processed foods are more satiating and less hyperglycemic than UPF [10]. In addition, it has been shown that the environment created in the gut by UPF could be an evolutionarily unique selection ground for microbes with behaviours that promote diverse forms of inflammation-related diseases [11].

UPF represent already more than 50% of total daily energy intake in some high-income countries, such as the United States [12, 13] and Canada [14]. Consumption of UPF has been associated with unhealthy dietary patterns [15–22] and with overweight and obesity in studies conducted in the US [23], Canada [24], France [25], Brazil [26, 27] and both across Latin American [28] and European [29] countries. A recent cohort study from Spain found that participants in the highest quartile of UPF consumption were at a higher risk of developing overweight or obesity than those in the lowest quartile of consumption [30]. Other recent cohort studies from Spain and France found a link between consumption of UPF and hypertension [31] and between consumption of UPF and cancer [32], respectively.

However, to date, the dietary share of UPF, meaning the proportion of daily energy consumed from UPF, has not been determined for the Belgian population. The aim of this study was therefore to assess the dietary share of UPF in a representative sample of children, adolescents and adults in Belgium and its association with dietary quality using the data from the Belgian national Food Consumption Surveys 2004 and 2014–2015.

Methods

National food consumption survey data

The Belgian food consumption surveys 2004 and 2014/2015 were conducted according to the guidelines published by The European Food Safety Authority in view of the EU Menu project [33]. The surveys were approved by the Ethical Committee of the University of Ghent and the Commission for the Protection of Privacy. Participants signed a written informed consent form. The study design and methodology of both surveys have been explained in detail elsewhere [5, 34].

In brief, a representative sample of the Belgian population ($N = 3083$, individuals ≥ 15 years in 2004 and $N = 3146$, individuals 3–64 years in 2014–2015) was randomly selected from the National Population Register according to a multistage stratified sampling procedure.

Dietary intake in adolescents and adults [10–64 years old (or 15 years and older in 2004)] was assessed using the 24-h dietary recall method, carried out on two non-consecutive days. GloboDiet © (formerly EPIC-SOFT), a computerised 24-h recall program designed for the standardized collection of dietary data within a pan-European survey, was used and adapted to the Belgian situation [35]. GloboDiet involves a structured and standardized approach to collect very detailed descriptions and quantities of consumed foods, recipes and dietary supplements. Food portion sizes were quantified using household measures (e.g., glasses, cups, spoons, etc.), food portions (obtained from manufacturer's information) and a picture book including a selection of country-specific dishes in different portion sizes.

Dietary assessment in children (3–9 years old) was done using two self-administered non-consecutive 1-day food diaries (open-ended without pre-coded food lists) followed by a GloboDiet completion interview with the proxy respondent (parent or legal guardian).

The collected food consumption data was afterwards linked with detailed information on the nutrient composition of each specific food item, using the Belgian Food Composition Data NUBEL (including branded foods) and the Dutch Food Composition data (NEVO).

The plausibility of reported energy intake was estimated by comparing the reported energy intakes with the presumed energy requirements using the Goldberg cutoff method, which has been revised by Black [36]. Misreporters included individuals with a ratio below the lower cutoff

(under-reporters) and individuals with a ratio above the upper cutoff (over-reporters) [36].

Classification of foods according to the NOVA classification

All foods and ingredients consumed were classified as 'ultra-processed', 'processed', 'unprocessed or minimally processed' or 'processed culinary ingredient' according to the NOVA classification [8, 37], which is to date the most commonly used system to classify foods by level of processing. NOVA is now recognised as a valid tool for nutrition and public health research, policy and action, in reports from the Food and Agriculture Organization [38] of the United Nations and the Pan American Health Organization [39].

UPF are products made mostly or entirely from substances extracted from foods or derived from food constituents with little if any intact food, which often contain flavours, colours and other additives that mimic or intensify the sensory qualities of foods or culinary preparations made from foods [9]. Ingredients of UPF include versions of oils and fats, flours and starches, sugar, and proteins, including those resulting from further processing, such as hydrogenated oils and fats, modified starches, hydrolysed proteins, and crushed or extruded 'mixes' of meat offals or remnants [8].

Some food descriptors, used within the GloboDiet recall program, were particularly useful to classify foods consumed according to the NOVA classification [8, 37] (Supplementary material 1), such as sugar content (sweetened with sugar, sweetened with artificial sweeteners or unsweetened), conservation method (canned, frozen, dried, salted, marinated, candied, fresh/untreated, etc.), medium (in oil, in water, in own juice, in syrup, etc.), production method (home prepared, industrially prepared, artisanal, catering, etc.), and ingredient (salted or unsalted).

Home-prepared dishes and recipes were disaggregated into ingredients and those ingredients were classified according to the NOVA classification. However, some composite foods that were home prepared could not be disaggregated into core ingredients (e.g., some milk-based desserts, cakes, pies and pastries, some soups and sauces) and represented about 0.9% of all foods consumed in 2014 and 2.6% of all food items consumed in 2004. In such cases, these home-prepared composite foods were classified as processed. Alcoholic beverages were not classified using the NOVA classification and were kept as a separate group.

Other variables

Height was accurately measured to 0.5 cm using a stadiometer (type SECA 213) and weight to 0.1 kg using an electronic scale (type SECA 815 and 804). Height and weight were measured during the second home visit (same day as the second 24-h dietary recall). Data on sex, region, educational level (higher education long type, higher education short type, secondary education or lower), self-perceived health (very good, good, fair, bad, very bad), frequency of breakfast consumption (never, less than 1 day a month, 1–3 days a month, 1 day a month, 2–4 days a week, 5–6 days a week, every day), smoking (every day, once in a while, no) and frequency of consumption of meal with family (two or more meals a day, one meal a day, only in the weekend, only on days of celebration, never) were retrieved from a CAPI (computer-assisted personal interview) conducted during the first home visit (same day as first 24-h dietary recall). In children (3–9 years), a parent or legal guardian was used as a proxy respondent. Smoking and frequency of consumption of meal with family were only collected for adults and adolescents.

Data analysis

Analyses were conducted in SAS 9.3. All analyses took the survey design into account. The comparison of the proportions of foods/ingredients consumed classified into the different NOVA groups between 2004 and 2014/2015 was done using χ^2 test.

The repeated 24-h recall data were used to estimate the usual intake distribution of the proportion of daily energy consumed from UPF and unprocessed/minimally processed foods, overall and by population group, in both 2004 and 2014/15. A correction for within-subject variation [40, 41] was applied using the Statistical Program to Assess Dietary Exposure (SPADE) [42]. The usual intake distribution was modelled as a function of age. Uncertainty in the habitual intake distribution was quantified with ready for use bootstrap which provided confidence intervals with the required confidence level [42]. The association between the usual proportion of daily energy consumed from UPF and the usual proportion of daily energy consumed from unprocessed/minimally processed foods was assessed trough Spearman rank correlation.

The mean energy contribution of food subgroups to the dietary share of UPF and unprocessed/minimally processed foods for different age groups and by sex was analysed using data from the first 24-h recall of the 2014/2015 survey.

The hypothesis that people meeting dietary recommendations consume lower proportions of daily energy intake from UPF and higher proportions of daily energy intake from unprocessed/minimally processed foods was tested. To do so, using the first interview day, the proportion of daily energy intake consumed from UPF and unprocessed/minimally processed foods was compared between consumption days on which the World Health Organization (WHO) recommendations for fruit and vegetables ($\geq$ 400 g/day), salt

(≤ 5 g/day), saturated fat (≤ 10% of daily energy intake), and trans-fatty acids (≤ 1% of daily energy intake) were met or not met (using Wilcoxon rank sum tests). Salt added at the table or during cooking was not collected in the surveys. Consumption data on added or free sugars were not available at the time of the study and therefore the WHO recommendation for intake of free sugars was not considered in this study.

Generalized linear models were used to investigate the association of proportion of daily energy intake from UPF and unprocessed/minimally processed foods with sex, age, educational level, body mass index class, region of residence, self-perceived health, frequency of breakfast consumption, smoking, and frequency of consumption of meal with family. The mean consumption over 2 days was used as the dependent variable. The models were adjusted for mean total daily energy intake and included an interaction term sex × BMI class. The analysis was repeated excluding misreporters. A p value of < 0.05 was considered statistically significant for all analyses conducted.

Results

In 2014/2015, among the Belgian population 3–64 years, the proportion of foods and ingredients consumed classified as ultra-processed was 36.4% and the proportion of foods and ingredients consumed classified as unprocessed/minimally processed was 42.4%. When comparing 2004 and 2014–2015 for the population group 15–64 years, the proportions of foods/ingredients consumed classified into the different NOVA groups were statistically significantly different ($p < 0.001$) (Table 1):

- The proportion of foods consumed classified as processed was lower in 2014
- The proportion of foods consumed classified as unprocessed or minimally processed was higher in 2014/2015
- There was only a small difference in the proportion of foods consumed classified as ultra-processed between the two survey periods: 33.6% in 2004 and 34.8% in 2014/2015.

Overall, in 2014–2015 in Belgium the average usual proportion of daily energy intake from UPF and unprocessed or minimally processed foods was 29.9% and 21.3%, respectively (Table 2). Consumption of UPF was negatively associated with consumption of unprocessed/minimally processed foods ($r = -0.17$, $p < 0.001$).

The consumption of daily energy from UPF was not significantly different between men and women. However, women consumed a significantly higher proportion of their daily energy from unprocessed or minimally processed foods, compared to men (Table 2). After excluding misreporters ($n = 818$), the average usual proportion of daily energy intake from UPF increased to 32.6% (95% CI 31.0–33.4%) for the total population 3–64 years with no difference between men and women (data not shown).

Young children (3–9 years) consumed a significantly higher proportion of their daily energy from UPF (33.3% on average) compared to adolescents and adults (29.2% and 29.6% on average, respectively) in 2014–2015. There were no differences in the consumption of UPF between different socio-economic population groups (secondary education or lower, short-term education, long-term education). However, individuals with long-term education (or parental education in the case of children) consumed a significantly higher proportion of their daily energy from minimally or unprocessed foods compared to those with secondary education or lower. There were no differences in consumption of either UPF or unprocessed/minimally processed foods between people with obesity, overweight or normal weight (Table 2).

For the population group 15–64 years, there was no significant difference for both men and women in regards to the consumption of UPF between 2004 and 2014–2015. There was an increase in the consumption of unprocessed/minimally processed foods between 2004 and 2014–2015,

Table 1 Proportion of foods and ingredients consumed in function of the extent of processing (according to the NOVA classification [8]), by survey year and by age group, Belgian national food consumption survey, 2004 and 2014–2015

	2004		2014–2015	
	≥ 15 years	15–64 years*	3–64 years	15–64 years*
	N (%)	*N* (%)	*N* (%)	*N* (%)
Unprocessed/minimally processed foods	58,586 (40.7)	41,290 (39.5)	66,948 (42.4)	56,746 (43.3)
Processed culinary ingredients	11,915 (8.3)	8085 (7.7)	9853 (6.2)	8480 (6.5)
Processed foods	23,839 (16.6)	17,148 (16.4)	20,747 (13.1)	17,371 (13.2)
Ultra-processed foods	45,599 (31.7)	35,135 (33.6)	57,394 (36.4)	45,619 (34.8)
Alcoholic beverages (excl from NOVA)	4034 (2.8)	2828 (2.7)	2917 (1.8)	2911 (2.2)
Total	143,972 (100)	104,486 (100)	157,858 (100)	131,127 (100)

*Difference between 2004 and 2014–2015 is statistically significant ($p < 0.001$)

Table 2 Usual dietary share of (% daily energy intake from) unprocessed/minimally processed and ultra-processed food products in the Belgian population (3–64 years) by population group (Belgian national food consumption survey 2014–2015)

Population group	*N*	*%E* from ultra-processed foods				*%E* from unprocessed/minimally processed foods			
		Mean	95% CI	P75	P95	Mean	95% CI	P75	P95
All	3146	29.9	29.0–30.8	38.9	53.3	21.3	20.7–21.9	26.9	38.7
By sex									
Females	1598	29.7	28.7–31.2	38.0	51.5	22.9	22.2–23.7	28.6	40.2
Males	1548	29.9	28.6–31.2	39.5	54.6	19.6	18.8–20.4	24.9	36.4
By age group (years)									
3–9	992	33.3	32.1–35.0	44.4	60.3	20.1	19.3–20.7	25.4	36.8
10–17	928	29.2	27.7–30.3	39.3	54.7	17.9	17.4–18.7	22.8	33.2
18–64	1226	29.6	28.5–30.7	38.2	51.8	22.0	21.2–22.7	27.7	39.5
By BMI class									
Normal weight	1970	30.7	29.1–31.9	39.3	52.4	21.0	19.9–21.6	26.5	37.7
Overweight	619	28.5	27.5–31.1	37.5	52.4	21.8	21.6–23.5	27.2	38.2
Obese	310	29.3	26.6–31.1	37.8	53.3	21.4	21.2–24.4	27.5	40.8
By education level									
Secondary education or lower	1290	30.5	28.6–31.5	39.0	52.0	19.9	19.2–20.9	25.4	37.9
Higher education, short type	885	29.9	28.0–31.4	40.2	56.4	21.4	20.2–22.5	27.1	39.1
Higher education, long type	916	30.5	28.9–31.9	38.8	52.0	22.8	21.8–23.8	28.1	38.2

but this was only significant for the total population (Table 3).

For the total population 3–64 years, processed meat products (14.3%), cakes, pies and pastries (8.9%) and dry cakes and sweet biscuits (7.7%) and carbonated soft drinks (6.7%) were the biggest contributors to the dietary share of UPF in 2014–2015 and pasta, rice and other grains (19.8%), fruits (18.5%), potatoes (9.4%) and chicken (7.8%) were the biggest contributors to the dietary share of unprocessed and minimally processed food products. There were some slight differences between age groups by gender in the contributions of food subgroups to UPF intakes (Table 4).

The UPF dietary share was significantly lower ($p = 0.0194$) and the dietary share of unprocessed/minimally processed foods was significantly higher ($p < 0.001$) during consumption days when the survey participants met the WHO salt intake recommendation (≤ 5 g/day); this was the case for all age groups (Figs. 1, 2). The UPF dietary share was significantly lower ($p = 0.0034$; most age groups) and the dietary share of unprocessed/minimally processed foods was significantly higher ($p < 0.001$; all age groups) during consumption days when saturated fat was ≤ 10% of energy intake.

For most age groups, the UPF dietary share was lower on consumption days during which the individuals were meeting the WHO guideline for fruit and vegetable consumption (≥ 400 g/day), however this was not significant in the overall population ($p = 0.0993$). The dietary share of unprocessed/

Table 3 Usual dietary share of (% daily energy intake from) unprocessed/minimally processed and ultra-processed food products in Belgium for the population group 15–64 years (Belgian national food consumption survey 2004 and 2014–2015)

Population group	*N*	*%E* from ultra-processed foods (2004)				*N*	*%E* from ultra-processed foods (2014–2015)			
		Mean	95% CI	P75	P95		Mean	95% CI	P75	P95
15–64 years	2043	30.3	29.3–31.5	38.6	51.8	1424	29.5	28.5–30.6	38.2	51.9
Females	931	28.9	27.1–30.2	37.5	50.8	715	29.2	28.0–30.9	37.2	50.0
Males	1110	32.3	30.9–34.3	40.1	53.0	709	29.6	28.0–31.0	38.8	53.1
Population group	*N*	*%E* from un/minimally processed foods (2004)				*N*	*%E* from un/minimally processed foods (2014–2015)			
		Mean	95% CI	P75	P95		Mean	95% CI	P75	P95
15–64 years	2043	20.2	19.8–21.0	24.9	33.8	1424	21.8	21.1–22.5	27.4	39.2
Females	931	22.3	21.5–23.3	27.3	36.6	715	23.7	22.9–24.7	29.5	41.1
Males	1110	18.5	17.5–19.1	22.9	31.1	709	19.7	18.7–20.6	25.0	36.4

Table 4 Top contributing food subgroups (results for the top contributing food sub groups are the same for interview day 1 and 2) to the consumption of unprocessed/minimally processed and ultra-processed foods in Belgium for the total population and specific age groups by sex (Belgian national food consumption survey 2014–2015)

Population group	Ultra-processed foods				Unprocessed and minimally processed foods			
All	Processed meat products (14.3%)	Cakes, pies, pastries (8.9%)	Dry cakes, sweet biscuits (7.7%)	Carbonated soft drinks (6.7%)	Pasta, rice, other grains (19.8%)	Fruits (18.5%)	Potatoes (9.4%)	Chicken (7.8%)
Males								
3–5 years	Milk beverages (14.8%)	Processed meat products (11.5%)	Dry cakes, sweet biscuits (11.3%)	Cakes, pies, pastries (8.6%)	Fruits (29.6%)	Pasta, rice, other grains (18.5%)	Fruit and vegetable juices (8.9%)	Potatoes (8.1%)
6–9 years	Processed meat products (12.9%)	Dry cakes, sweet biscuits (12.9%)	Milk beverages (10.3%)	Cakes, pies, pastries (8.5%)	Pasta, rice, other grains (23.7%)	Fruits (23.5%)	Potatoes (9.3%)	Fruit and vegetable juices (8.9%)
10–13 years	Processed meat products (13.5%)	Cakes, pies, pastries (10.8%)	Chocolate spreads (8.4%)	Dry cakes, sweet biscuits (8.4%)	Pasta, rice, other grains (27.6%)	Fruits (15.0%)	Potatoes (10.8%)	Chicken (8.8%)
14–17 years	Processed meat products (14.1%)	Dry cakes, sweet biscuits (8.9%)	Carbonated soft drinks (8.8%)	Cakes, pies, pastries (8.0%)	Pasta, rice, other grains (30.3%)	Potatoes (11.5%)	Fruits (9.8%)	Chicken (8.6%)
18–34 years	Processed meat products (14.4%)	Carbonated soft drinks (10.6%)	Cakes, pies, pastries (8.5%)	Mayonnaise and similar (6.0%)	Pasta, rice, other grains (26.6%)	Fruits (13.3%)	Potatoes (11.7%)	Chicken (8.6%)
35–50 years	Processed meat products (15.5%)	Carbonated soft drinks (8.1%)	Cakes, pies, pastries (7.2%)	Mayonnaise and similar (6.4%)	Pasta, rice, other grains (19.6%)	Fruits (18.6%)	Potatoes (10.3%)	Chicken (8.2%)
51–64 years	Processed meat products (18.0%)	Margarines (10.4%)	Cakes, pies, pastries (9.7%)	Mayonnaise and similar (8.3%)	Fruits (20.9%)	Pasta, rice, other grains (12.8%)	Potatoes (10.1%)	Beef (8.5%)
Females								
3–5 years	Milk beverages (15.5%)	Processed meat products (13.1%)	Dry cakes, sweet biscuits (11.3%)	Cakes, pies, pastries (8.9%)	Fruits (26.9%)	Pasta, rice, other grains (18.4%)	Fruit and vegetable juices (10.8%)	Potatoes (7.4%)
6–9 years	Processed meat products (12.0%)	Dry cakes, sweet biscuits (10.5%)	Cakes, pies, pastries (10.4%)	Milk beverages (9.1%)	Fruits (25.2%)	Pasta, rice, other grains (20.8%)	Potatoes (11.4%)	Fruit and vegetable juices (6.9%)
10–13 years	Processed meat products (11.9%)	Cakes, pies, pastries (10.2%)	Dry cakes, sweet biscuits (9.5%)	Chocolate spreads (8.0%)	Pasta, rice, other grains (23.8%)	Fruits (17.0%)	Potatoes (10.2%)	Chicken (10.1%)
14–17 years	Dry cakes, sweet biscuits (11.2%)	Processed meat products (10.9%)	Carbonated soft drinks (9.3%)	Cakes, pies, pastries (7.4%)	Pasta, rice, other grains (27.3%)	Fruits (15.0%)	Chicken (10.1%)	Potatoes (9.6%)
18–34 years	Processed meat products (13.7%)	Cakes, pies, pastries (8.2%)	Dry cakes, sweet biscuits (8.1%)	Milk beverages (7.1%)	Pasta, rice, other grains (25.0%)	Fruits (17.7%)	Chicken (11.2%)	Potatoes (6.6%)
35–50 years	Processed meat products (14.8%)	Dry cakes, sweet biscuits (8.5%)	Cakes, pies, pastries (8.4%)	Chocolate spreads (6.4%)	Pasta, rice, other grains (17.3%)	Fruits (17.1%)	Chicken (7.8%)	Potatoes (7.1%)
51–64 years	Processed meat products (13.7%)	Cakes, pies, pastries (13.0%)	Margarines (8.1%)	Dry cakes, sweet biscuits (7.1%)	Fruits (23.2%)	Pasta, rice, other grains (10.5%)	Potatoes (9.2%)	Beef (6.3%)

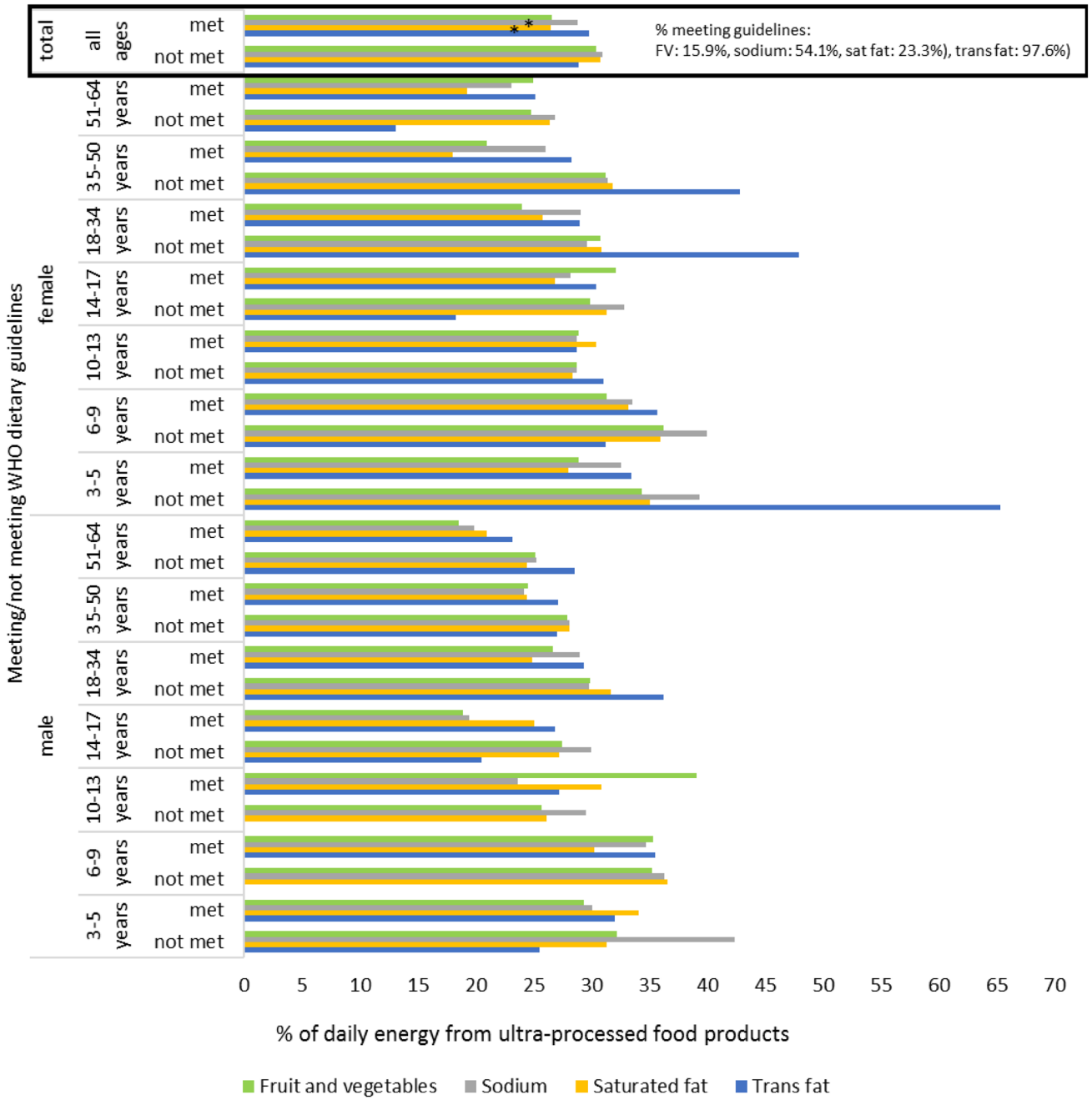

Fig. 1 Dietary share of ultra-processed food products comparing days when WHO guidelines for fruit and vegetables (FV), sodium, saturated fat and trans-fat are met/not met for different age groups by sex; Belgian national food consumption survey 2014/2015. *%E from UPF between meeting and not meeting the guidelines is significantly different for sodium and saturated fat; $p < 0.05$

minimally processed foods was significantly higher during consumption days when the participants met the WHO salt and fruit and vegetable intake (≥ 400 g/day) recommendations; this was the case for all age groups ($p < 0.001$). For trans-fatty acids, the differences are not statistically significant but the number of individuals not meeting the WHO guidelines is very low in Belgium (≤ 15 individuals for each of the age groups) (Figs. 1, 2).

For the total population, age, region, BMI class, total energy intake and frequency of breakfast consumption were significantly associated with UPF dietary share. Compared to the youngest age group (3–5 years), all but one age group (51–64 years) consumed a significantly lower proportion of daily energy from UPF. Compared to Flemish region residents, residents from Brussels and the Walloon region consumed a significantly higher proportion of energy from

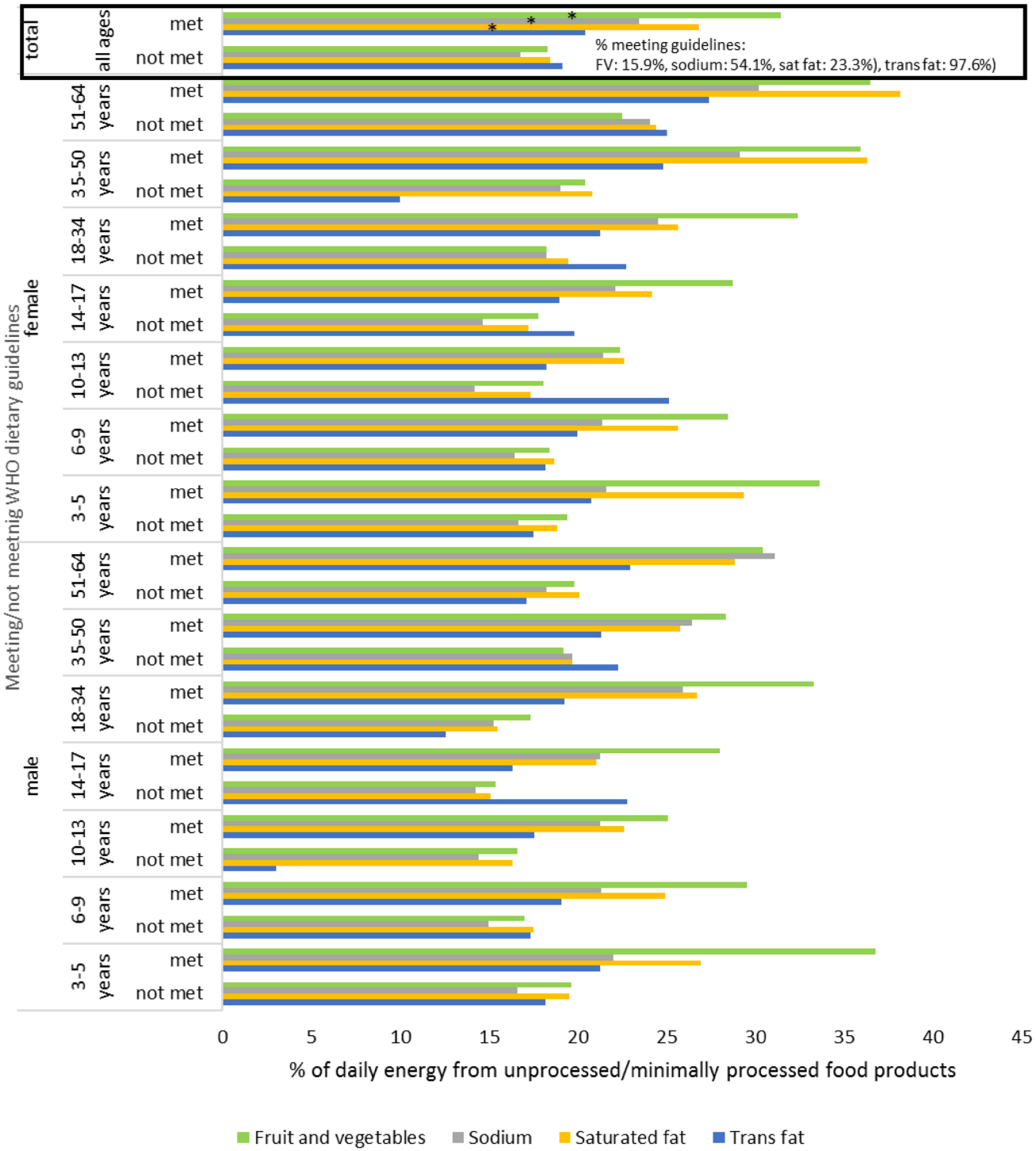

Fig. 2 Dietary share of unprocessed/minimally processed food products (MPF) comparing days when WHO guidelines for fruit and vegetables (FV), sodium, saturated fat and trans fat are met/not met for different age groups by sex; Belgian national food consumption survey 2014/2015. *%*E* from MPF between meeting and not meeting the guidelines is significantly different for fruit and vegetables, sodium and saturated fat; $p < 0.001$

UPF. Compared to normal weight individuals, individuals with obesity consumed a significantly lower proportion of their daily energy from UPF (Table 5). These differences between normal weight individuals and individuals with obesity became non-significant after exclusion of misreporters (data not shown). For the total population, age,

Table 5 Association of socio-demographic, socio-economic and health status factors with mean proportion of daily energy intake from unprocessed/minimally processed foods and ultra-processed foods over the two consumption days, all age groups (Belgian national food consumption survey 2014/2015)

Parameter	Mean % of daily energy from ultra-processed foods				Mean % of daily energy from unprocessed/minimally processed foods			
	Estimate	Standard error	*t* value	$Pr > \|t\|$	Estimate	Standard error	*t* value	$Pr > \|t\|$
Intercept	19.37	2.28	8.8	< 0.0001	21.01	1.57	13.37	< 0.0001
Sex								
Female					0.82	0.66	1.24	0.2151
Male					0.00			
Age group (years)								
51–64	0.47	2.10	0.22	0.8241	− 0.97	1.35	− 0.72	0.4713
35–50	− 8.56	2.11	− 4.05	< 0.0001	− 1.45	1.35	− 1.07	0.2850
18–34	− 7.27	2.10	− 3.45	0.0006	− 0.14	1.37	− 0.1	0.9197
14–17	− 6.23	1.80	− 3.45	0.0006	2.54	1.17	2.16	0.0307
10–13	− 6.58	1.79	− 3.68	0.0002	4.00	1.18	3.4	0.0007
6–9	− 6.98	1.83	− 3.81	0.0001	5.72	1.21	4.73	< 0.0001
3–5	0.00				0.00			
Education level of the household								
Other					7.67	2.71	2.83	0.0047
Higher education, short type					1.42	0.54	2.63	0.0085
Higher education, long type					1.94	0.57	3.39	0.0007
Secondary or lower					0.00			
Region								
Brussels capital region	6.13	1.17	5.26	< 0.0001	1.85	0.79	2.36	0.0185
Walloon region	8.09	0.78	10.37	< 0.0001	− 0.97	0.50	− 1.94	0.0523
Flanders	0.00				0.00			
BMI class								
Underweight	5.22	1.80	2.9	0.0037	− 2.29	1.81	− 1.27	0.2051
Overweight	− 1.67	0.86	− 1.94	0.0520	0.79	0.75	1.05	0.2950
Obese	− 3.28	1.04	− 3.15	0.0016	0.16	0.94	0.17	0.8648
Normal weight	0.00				0.00			
Self-perceived health								
Good					− 1.35	0.55	− 2.46	0.0140
Fair					− 1.58	0.76	− 2.09	0.0370
Bad					− 1.55	2.05	− 0.76	0.4498
Very bad					4.94	2.90	1.7	0.0886
Very good					0.00			
Breakfast consumption frequency								
Less than 1 day/month	9.054065	5.180901	1.75	0.0806	− 0.39	3.24	− 0.12	0.9040
1–3 days/month	9.641977	2.945608	3.27	0.0011	2.48	1.93	1.29	0.1982
1 day/month	5.767624	2.534473	2.28	0.0229	0.08	1.62	0.05	0.9629
2–4 days/week	0.698721	1.718837	0.41	0.6844	2.20	1.11	1.98	0.0477
5–6 days/week	3.898889	1.850637	2.11	0.0352	4.20	1.19	3.52	0.0004
Once a day	3.688198	1.436204	2.57	0.0103	3.72	0.95	3.93	< 0.0001
Never	0.00				0.00			
Mean total daily energy intake	0.004938	0.00053526	9.23	< 0.0001	− 0.00348	0.000383	− 9.07	< 0.0001
Sex × BMI class								
Female × underweight					− 0.28	2.37	− 0.12	0.9056
Female × overweight					0.17	1.04	0.17	0.8672
Female × obese					3.34	1.26	2.66	0.0079
Female × normal weight					0.00			

Table 5 (continued)

Parameter	Mean % of daily energy from ultra-processed foods				Mean % of daily energy from unprocessed/minimally processed foods			
	Estimate	Standard error	*t* value	*Pr* > |*t*|	Estimate	Standard error	*t* value	*Pr* > |*t*|
Male × underweight					0.00			
Male × overweight					0.00			
Male × obese					0.00			
Male × normal weight					0.00			

region, self-perceived health and frequency of breakfast consumption were significantly associated with dietary share of unprocessed/minimally processed foods (MPF). Total energy intake was significantly inversely associated with MPF dietary intake. We observed a significant effect modification in the relationship between BMI class and MPF consumption by sex.

Compared to men, women with obesity consumed a significantly higher proportion of daily energy from MPF than normal weight women. Compared to participants from low educated households, those from higher educated households consumed a significantly higher proportion of daily energy from MPF (Table 5). While individuals with good and fair self-perceived health consumed significantly less MPF than individuals with very good perceived health, consumption of MPF between individuals with very good and very bad self-perceived health was not significantly different. When excluding misreporters, there was no more association between consumption of MPF and self-perceived health (data not shown).

In the model with adolescents and adults only, individuals who consumed more than two meals a day with family compared to those who did never, consumed a significantly higher proportion of energy out of MPF and never-smokers also consumed a significantly higher proportion of energy out of MPF compared to those smoking every day (data not shown).

Discussion

About one-third of daily energy intake is contributed by ultra-processed foods (UPF) in the Belgian population, and young children consume the largest proportion of their daily energy intake from UPF. Other studies, such as from the US [43], Canada [21] and Chile [18] also found that children consume the most UPF compared to other population groups.

Higher consumption of UPF is associated with lower diet quality in Belgium (lower fruit and vegetable consumption for some age groups, higher salt and saturated fat intake); the opposite is observed for higher consumption of unprocessed/minimally processed foods. The association of intake of UPF with the intake of trans-fatty acids is mixed, but this is probably due to the fact that the average population intake of trans fatty acids has decreased since 2004 in Belgium and is below the WHO recommended intake of < 1% of total energy intake in 2014 [44].

Estimates of UPF purchases calculated from national household budget surveys (conducted in Europe between 1991 and 2008) showed that the average household availability of UPF ranged from 10% of total purchased dietary energy in Portugal to 50% in the UK. After adjustment for confounders, each percentage point increase in the household availability of UPF resulted in an increase of 0·25 percentage points in obesity prevalence [29]. In Belgium UPF were found to contribute about 46% to total purchased dietary energy, which is higher than the average usual proportion of daily energy intake from UPF (30%) found in this study. However, food consumption surveys usually provide more details on the foods consumed compared to household budget surveys which are based on purchases. The data of this study can thus be considered as more accurate.

Some countries like Brazil [45] and Uruguay [46] include the concept of UPF in their food-based dietary guidelines. France has recently set a target to reduce population consumption of ultra-processed foods with 20% by 2022 [47]. In addition, some countries, like Chile [48], are taking action to limit the marketing of UPF products to children, and other countries, like Mexico [49, 50] and Hungary [51], introduced fiscal measures, such as a tax on junk food. The tax in Mexico has already demonstrated a positive effect with significant declines in the purchases of both solid and liquid UPF observed in a national urban sample [49, 52].

In Belgium, the latest food consumption survey showed that about 64% of the Belgian population was in favour of regulating the restriction of unhealthy food marketing to children, 78% in favour of measures on food reformulation and 57% in favour of fiscal measures to increase taxes on unhealthy foods and simultaneously decrease taxes on healthy foods [44]. Such measures are likely needed to reduce UPF consumption since these products are considered highly palatable, cheap, conducive to excessive

consumption and aggressively marketed, making them highly profitable for food manufacturers [53].

In addition to policies, improving food preparatory skills is important, as a UK study found that better home food preparation skills and more frequent use of those skills was associated with lower consumption of UPF [54]. Interestingly in our study, sharing meals with family more often, was significantly associated with higher consumption of unprocessed/minimally processed foods.

Strengths of this study include the use of national food consumption survey data representative for the Belgian population and different population groups, the detailed descriptions on the foods consumed and the use of statistical modelling to calculate usual intakes (i.e., remove within-person day-to-day variability). In addition, this is the first study assessing UPF intake among the Belgian population.

The limitations include lack of data on the intake of added and free sugar and salt added at the table or during cooking and the fact that almost one-third of survey participants were identified as misreporters. In addition, it was not possible to disaggregate some of the home-prepared composite foods into ingredients.

Conclusion

About one-third of daily energy intake is contributed by UPF in Belgium and young children have the highest intakes of those food products. Internationally recommended policies to limit availability, affordability and marketing of UPF need to be implemented to reduce UPF consumption in Belgium.

Acknowledgements The authors want to thank the Ministry of Health to provide funding for the national food consumption surveys of 2004 and 2014/2015.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. GBD 2016 Causes of Death Collaborators (2017) Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet 390:1423–1459
2. Vandevijvere S, Chow CC, Hall K, Umali E, Swinburn B (2015) Increased food energy supply as a major driver of the obesity epidemic: a global analysis. Bull World Health Organ 93:446–456
3. Imamura F, Micha R, Khatibzadeh S et al (2015) Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob Health 3:e132–e142
4. Institute for Health Metrics and Evaluation (2018) Country Profile Belgium. http://www.healthdata.org/belgium. Accessed 10 Aug 2018
5. Vandevijvere S, De VS, Huybrechts I et al (2009) The gap between food-based dietary guidelines and usual food consumption in Belgium, 2004. Public Health Nutr 12:423–431
6. De Ridder K, Bel S, Brocatus L et al (2016) De consumptie van voedingsmiddelen en de inname van voedingsstoffen. In: Bel S, Tafforeau J (eds) Voedselconsumptiepeiling 2014–2015. Rapport 4. Wetenschappenlijk Instituut voor Volksgezondheid, Brussels
7. Monteiro CA (2009) Nutrition and health. The issue is not food, nor nutrients, so much as processing. Public Health Nutr 12:729–731
8. Monteiro CA, Cannon G, Moubarac JC et al (2018) The UN decade of nutrition, the NOVA food classification and the trouble with ultra-processing. Public Health Nutr 21:5–17
9. Monteiro C, Cannon G, Levy RB et al (2016) NOVA. The star shines bright. World Nutr 7(1–3):28–38
10. Fardet A (2016) Minimally processed foods are more satiating and less hyperglycemic than ultra-processed foods: a preliminary study with 98 ready-to-eat foods. Food Funct 7:2338–2346
11. Zinöcker MK, Lindseth IA (2018) The Western diet–microbiome–host interaction and its role in metabolic disease. Nutrients 10:365
12. Martinez SE, Baraldi LG, Louzada ML et al (2016) Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. BMJ Open 6:e009892
13. Poti JM, Mendez MA, Ng SW, Popkin BM (2015) Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? Am J Clin Nutr 101:1251–1262
14. Moubarac JC, Martins AP, Claro RM et al (2013) Consumption of ultra-processed foods and likely impact on human health. Evidence from Canada. Public Health Nutr 16:2240–2248
15. Adams J, White M (2015) Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). Int J Behav Nutr Phys Act 12:160
16. Batal M, Johnson-Down L, Moubarac JC et al (2018) Quantifying associations of the dietary share of ultra-processed foods with overall diet quality in First Nations peoples in the Canadian provinces of British Columbia, Alberta, Manitoba and Ontario. Public Health Nutr 21:103–113
17. Bielemann RM, Motta JV, Minten GC, Horta BL, Gigante DP (2015) Consumption of ultra-processed foods and their impact on the diet of young adults. Revista de Saude Publica 49:28
18. Cediel G, Reyes M, da Costa Louzada ML et al (2018) Ultra-processed foods and added sugars in the Chilean diet (2010). Public Health Nutr 21:125–133
19. Cornwell B, Villamor E, Mora-Plazas M et al (2018) Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. Public Health Nutr 21:142–147
20. Martinez SE, Popkin BM, Swinburn B, Monteiro CA (2017) The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. Popul Health Metr 15:6
21. Moubarac JC, Batal M, Louzada ML, Martinez SE, Monteiro CA (2017) Consumption of ultra-processed foods predicts diet quality in Canada. Appetite 108:512–520
22. Louzada MLDC, Ricardo CZ, Steele EM et al (2018) The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. Public Health Nutr 21:94–102
23. Juul F, Martinez-Steele E, Parekh N, Monteiro CA, Chang VW (2018) Ultra-processed food consumption and excess weight among US adults. Br J Nutr 120:90–100

24. Nardocci M, Leclerc BS, Louzada ML et al (2018) Consumption of ultra-processed foods and obesity in Canada. Can J Public Health. https://doi.org/10.17269/s41997-018-0130-x
25. Julia C, Martinez L, Alles B et al (2018) Contribution of ultra-processed foods in the diet of adults from the French NutriNet-Sante study. Public Health Nutr 21:27–37
26. Canella DS, Levy RB, Martins AP et al (2014) Ultra-processed food products and obesity in Brazilian households (2008–2009). PLoS One 9:e92752
27. Louzada ML, Baraldi LG, Steele EM et al (2015) Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. Prev Med 81:9–15
28. Pan American Health Organization (2015) Ultra-processed food and drink products in Latin America: trends, impact on obesity, policy implications. Pan American Health Organization, Washington, D.C.
29. Monteiro CA, Moubarac JC, Levy RB et al (2018) Household availability of ultra-processed foods and obesity in nineteen European countries. Public Health Nutr 21:18–26
30. Mendonca RD, Pimenta AM, Gea A et al (2016) Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. Am J Clin Nutr 104:1433–1440
31. Mendonca RD, Lopes AC, Pimenta AM et al (2017) Ultra-processed food consumption and the incidence of hypertension in a mediterranean cohort: the Seguimiento Universidad de Navarra Project. Am J Hypertens 30:358–366
32. Fiolet T, Srour B, Sellem L et al (2018) Consumption of ultra-processed foods and cancer risk: results from NutriNet-Santé prospective cohort. BMJ 360:k322
33. European Food Safety Authority (2009) General principles for the collection of national food consumption data in the view of a pan-European dietary survey. EFSA J 17:1435
34. Bel S, Van den Abeele S, Lebacq T et al (2016) Protocol of the Belgian food consumption survey 2014: objectives, design and methods. Arch Public Health 74:20
35. Park MK, Freisling H, Huseinovic E et al (2018) Comparison of meal patterns across five European countries using standardized 24-h recall (GloboDiet) data from the EFCOVAL project. Eur J Nutr 57:1045–1057
36. Black AE (2000) The sensitivity and specificity of the Goldberg cut-off for EI:BMR for identifying diet reports of poor validity. Eur J Clin Nutr 54:395–404
37. Monteiro CA, Levy RB, Claro RM, Castro IR, Cannon G (2010) A new classification of foods based on the extent and purpose of their processing. Cadernos de Saude Publica 26:2039–2049
38. FAO (2015) Guidelines on the collection of information on food processing through food consumption surveys. FAO, Rome
39. Pan American Health Organization (2016) PAHO nutrient profile model. Pan American Health Organization, Washington, D.C.
40. Souverein OW, Dekkers AL, Geelen A et al (2011) Comparing four methods to estimate usual intake distributions. Eur J Clin Nutr 65(Suppl 1):S92–S101
41. Dodd KW, Guenther PM, Freedman LS et al (2006) Statistical methods for estimating usual intake of nutrients and foods: a review of the theory. J Am Diet Assoc 106:1640–1650
42. Dekkers AL, Verkaik-Kloosterman J, van Rossum CT, Ocke MC (2014) SPADE, a new statistical program to estimate habitual dietary intake from multiple food sources and dietary supplements. J Nutr 144:2083–2091
43. Baraldi LG, Martinez SE, Canella DS, Monteiro CA (2018) Consumption of ultra-processed foods and associated sociodemographic factors in the USA between 2007 and 2012: evidence from a nationally representative cross-sectional study. BMJ Open 8:e020574
44. Wetenschappenlijk Instituut voor Volksgezondheid (2016) Voedselconsumptiepeiling 2014–2015. Rapport 1: Voedingsgewoonten, antropometrie en voedingsbeleid. Wetenschappenlijk Instituut voor Volksgezondheid, Brussels
45. Monteiro CA, Cannon G, Moubarac JC et al (2015) Dietary guidelines to nourish humanity and the planet in the twenty-first century. A blueprint from Brazil. Public Health Nutr 18:2311–2322
46. Ministerio de Salud (2016) Guia alimentaria para la poblacion uruguaya. Para una alimentacion saludable, compartida y placentera. http://msp.gub.uy/sites/default/files/archivos_adjuntos/MS_guia_web.pdf. Accessed 10 Oct 2018
47. Fiolet T (2018) Quoi dans mon assiette: Objectifs du PNNS 2018–2022. https://quoidansmonassiette.fr/objectifs-pnns-2018-2022-pour-politique-nutritionnelle-et-sante-en-france/. Accessed 10 Oct 2018
48. New York Times (2018) In sweeping war on obesity, Chile slays tony the tiger. https://www.nytimes.com/2018/02/07/health/obesity-chile-sugar-regulations.html. Accessed 10 Oct 2018
49. Batis C, Rivera JA, Popkin BM, Taillie LS (2016) First-year evaluation of Mexico's tax on nonessential energy-dense foods: an observational study. PLoS Med 13:e1002057
50. Hernandez F, Batis C, Rivera JA, Colchero MA (2018) Reduction in purchases of energy-dense nutrient-poor foods in Mexico associated with the introduction of a tax in 2014. Prev Med 118:16–22
51. Biro A (2015) Did the junk food tax make the Hungarians eat healthier? Food Policy 54:107–115
52. Colchero MA, Popkin BM, Rivera JA, Ng SW (2016) Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. BMJ 352:h6704
53. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B (2013) Ultra-processed products are becoming dominant in the global food system. Obes Rev 14(Suppl 2):21–28
54. Lam MCL, Adams J (2017) Association between home food preparation skills and behaviour, and consumption of ultra-processed foods: cross-sectional analysis of the UK National diet and nutrition survey (2008–2009). Int J Behav Nutr Phys Act 14:68