Global trends in ultra-processed food and drink product sales and

their association with adult body mass index trajectories

Abstract

Objective

To evaluate global trends in ultra-processed food and drink (UPFD) volume sales/capita and associations with adult body-mass-index (BMI) trajectories.

Methods

Total food/drink volume sales/capita from *Euromonitor* for 80 countries (2002-2016) were matched to mean adult BMI from the NCD-Risk-Factor-Collaboration (2002-2014). Products were classified as UPFD/non-UPFD according to the *NOVA* classification system. Mixed models for repeated measures were used to analyse associations between UPFD volume sales/capita and adult BMI trajectories, controlling for confounding factors.

Results

The increase in UPF volume sales was highest for South-and-South-East-Asia (67·3%) and North-Africa and the Middle-East (57·6%), while for UPD the increase was highest for South-and–South-East-Asia (120.0%) and Africa (70·7%). In 2016 baked goods were the biggest contributor to UPF volume sales (13·1%-44·5%), while carbonated drinks were the biggest contributor to UPD volume sales (40·2%-86·0%). For every standard deviation increase (51 kg/capita, 2002) in UPD volume sales, mean BMI increased by 0.195 kg/m^2 for men (p<0.001) and 0.072 kg/m^2 for women (p=0.003). For every standard deviation (40 kg/capita, 2002) increase in UPF volume sales, mean BMI increased by 0.316 kg/m² for men (p<0.001), while the association was not significant for women.

Conclusion

Increases in UPFD volume sales/capita were positively associated with population-level BMI trajectories.

Introduction

Global age-standardised mean body-mass index (BMI) increased from 21·7 kg/m² in 1975 to 24·2 kg/m² in 2014 in men, and from 22·1 kg/m² in 1975 to 24·4 kg/m² in 2014 in women. [1] Malnutrition, including obesity, is a major cause of death and disease globally as documented in the latest Global Burden of Disease Study (GBD) 2016. [2] Available food energy per capita has increased in most regions of the world, and these increases are sufficient to explain concurrent increases in average population body weight in many countries. [3]

In addition to increased food energy availability worldwide, population diets have shifted towards increased consumption of highly processed foods. [4,5] Recently it has been suggested that food processing, more specifically the type, intensity and purpose of food processing may be linked to human health. [6] A new method of food classification has therefore been proposed [7] : the NOVA classification, categorizing foods and drinks into unprocessed or minimally processed, processed culinary ingredients, processed and ultra-processed. Ultra-processed foods and drinks (UPFD) are defined as "not modified foods but formulations made mostly or entirely from substances derived from foods and additives with little if any intact food". [7] Ingredients of UPFD 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. [7] UPFD have been characterized as "hyper-palatable, quasi-addictive, and socially and environmentally destructive", and are often found to be aggressively marketed to children. [7,11-14]

The classification of foods by level of processing [15] has increasingly been used by researchers to investigate the link between nutrition and human health. In addition the Pan-American Health Organization (PAHO) [16,17] developed a nutrient profile model using the classification of foods by their level of processing [17] as a basis and encourages countries to apply this model when developing and implementing national nutrition guidelines and policies. Brazil was the first country to use the concept of UPFD in the development and implementation of its novel food-based dietary guidelines. [18]

UPFD already correspond to more than 50% of total energy intake in high income countries, such as the US [19,20] and Canada [21] and their consumption is increasing rapidly in middle-income countries. [22-25] Consumption of UPFD has been associated with unhealthy dietary patterns [26-33] and with overweight and obesity in studies conducted in the UK, US, Canada, Chile, Colombia, and Brazil. [16,34-39] A longitudinal study in Latin America, that included 13 countries, found a positive, strong and statistically significant association between annual changes in sales per capita of UPFD and annual changes in mean BMI after controlling for confounding factors. [16] A study across 19 European countries found a significant positive association between national household availability of UPFD and national prevalence of obesity among adults. [39] However, to date, no global analysis of the association between the consumption of UPFD and population obesity indicators has been conducted.

The aims of this study were to: (1) evaluate global trends in total volume sales/capita of UPFD, called hereafter UPF (foods) and UPD (drinks), (2) determine the contribution of food groups to UPF and UPD volume sales/capita, and (3) assess the statistical associations between UPF and UPD volume

sales/capita and adult BMI trajectories in 80 countries across eight geographic regions.

Methods

This is an ecological study that used repeated cross-sectional data on food and drink volume sales/capita and mean population BMI.

Ultra-processed food and drink sales data

Data on total volume sales of foods and drinks per capita were sourced from *Euromonitor International Passport Global Market Information Database* at the most fine-grained level (212 food subgroups in total) for 80 countries (*Supplementary Table 1*) over the period 2002-2016. [40] Euromonitor is the world's leading independent provider of strategic market research. Euromonitor collects volume sales data from various sources including trade associations, industry bodies, company financial reports, and official government statistics. These data are validated by food industry representatives. [40] Total volume sales (i.e. off-trade and on-trade sales) include sales through retail outlets and service outlets, such as bars, restaurants and cafes. For liquids (e.g. carbonated drinks), all data were extracted from Euromonitor into kilograms (instead of litres).

About 47.5% (N=38) of countries included were high-income, 32·5% (N=26) were upper-middle-income and 20·0% (N=16) were lower-middle-income countries based on Gross National Income per capita according to the World Bank Classification.

Food subgroups were classified as ultra-processed or non-ultra-processed according to the NOVA classification system [7,15], which is the most commonly used system to classify foods by level of processing.

The classification was conducted by two researchers independently (MG and SV) and checked by a third researcher (JM). The details of the Euromonitor food subgroups included in this study as ultra-processed (n=137, 64·3%) are listed in *Supplementary Table 2*. Baby foods were excluded as this study focused on adults.

UPFD were further divided into drinks (UPD) and foods (UPF) as the physical form of food (liquid vs solid) has been shown to influence energy balance and body weight. [41] UPD included flavoured bottled water, low calorie and regular cola carbonates, lemonade/lime, ginger ale, seltzer, tonic water/other bitters, orange carbonates, other non-cola carbonates, flavoured milk and soy drinks and shelf-stable, chilled and frozen soups. The category of carbonated drinks included naturally as well as artificially-sweetened drinks. The other subgroups were considered UPF (*Supplementary Table 2*). Instant and dehydrated soups and soft drink concentrates were excluded from the study due to the lack of reliable conversion factors.

Total volume sales of UPD and UPF per capita were summed by country and year. In order to calculate contributions of food groups to UPD and UPF volume sales, total volume sales of UPD and UPF per capita were summed for all countries by region, giving equal weight to each country. We used the Global Burden of Disease 2015 classification of eight regions: Western Europe, North America and Australasia, Central and Eastern Europe, North Africa and Middle East, Latin America and Caribbean, Africa, Central and East Asia and South and South East Asia. [42]

Body mass index data

Adult mean BMI data for men and women aged 18 years and older were obtained for all countries over a 40-year period, as published in a previous paper by the NCD-RisC group. [1] NCD-RisC applied a Bayesian hierarchical model to measured height and weight data from population-based studies in adults aged 18 years and older to estimate trends in mean population BMI from 1975 to 2014. Since no combined BMI estimates for the total population including both men and women are available, the analyses in the present study are conducted for men and women separately. Since the Euromonitor sales data are available for the period 2002-2016 and the obesity data for the period 1975-2014, the specific analyses of linking UPF volume sales per capita with BMI trajectories were done for the period 2002-2014.

Covariate data

Data on national income 2002-2014 (natural logarithm of per-person gross domestic product adjusted for inflation and purchasing power) were obtained from The World Bank. [43] The mean number of years of education were retrieved from the Institute of Health Metrics and Evaluation and the proportion of population living in urban areas for the years 2002-2014 were obtained from the UN Urbanization Prospects. Mean fruit and vegetable consumption for men and women (for the year 2005) for all countries was derived from the Global Dietary Database. [44]

As previous studies showed that obesity and the availability of energy-dense foods tend to be higher in countries with greater income inequality, [45,46] we adjusted for the GINI-index, a measure of inequality in household disposable income.

The GINI-index was derived from the "all the GINIs" dataset [47], but due to the lack of data for several years, the mean GINI over the time period 2002-2014 was calculated for each country and then tertiles were created. Data on the age-standardized proportion of male and female adults not engaging in sufficient physical activity (i.e. less than 150 minutes of moderate-intensity physical activity per week, or equivalent) for the latest available year by country were retrieved from the WHO global status report on NCDs (2014). [48]

Statistical analysis

The analyses were conducted using SAS 9·4 (Cary, USA, 2018). Time trends in volume sales of UPD and UPF per capita were calculated and contributions of food groups to volume sales of UPD and UPF per capita determined. Mixed models for repeated measures using spatial power covariance structure and the Kenward-Roger degrees of freedom method were used to analyse associations of total volume sales per capita of UPFD with adult BMI trajectories. Analyses were conducted by sex (as NCD-RisC only generates BMI trajectories for men and women separately) and for total volume sales of UPFD and UPD and UPF separately.

The natural logarithm of national income per capita, the mean number of years of education (by sex), the proportion of population living in urban areas, mean fruit and vegetable consumption in 2005 (by sex) and the tertile of the mean GINI-index were added in the model as covariates. Hong Kong, Taiwan, Saudi Arabia and United Arab Emirates were excluded from the analysis due to missing data for some of the covariates.

A model including the proportion of the population not engaging in sufficient physical activity as a covariate was run separately since only 68 out of the 80 countries had data available for this covariate.

All analyses were weighted by the inverse of half of the confidence intervals around the mean population BMI to give higher weight to countries/regions with more accurate estimates.

The analyses tested for non-linear time trends and for the interaction between year and UPFD volume sales; both were non-significant and therefore not included in the final model.

Results

Volume sales per capita of UPD and UPF by region

In 2016, volume sales of UPF per capita were highest in North America and Australasia (113·3 kg/capita/year) and lowest in Africa (14·4 kg/capita/year) and South and South East Asia (14·6 kg/capita/year) (Figure 1). Among specific countries, volume sales of UPF per capita were highest in the Netherlands (143·8 kg/capita/year), Germany (141·8 kg/capita/year) and the United Kingdom (140·7 kg/capita/year) (*Supplementary Table 1*).

The volume sales of UPD in 2016 were highest in North America and Australasia (157·6 kg/capita/year) and lowest in Africa (37·4 kg/capita/year) (Figure 1). Among specific countries, volume sales of UPD per capita were highest in the United States (238·8 kg/capita/year), Mexico (188·5 kg/capita/year) and Argentina (184·5 kg/capita/year) (*Supplementary Table 1*).

UPFD volume sales per capita increased in all regions over the period 2002-2016, except in Western Europe, North America and Australasia.

The percent increase in total volume sales per capita of UPF was highest for the regions of South and South East Asia (67·3%) and Africa and the Middle East (57·6%) and for UPD the percent increase was highest for the regions of South and South East Asia (120·0%) and Africa (70·7%).

Volume sales of UPFD decreased slightly for the regions of Western Europe (-3·8% for UPD) and North America and Australasia (-2·2% for UPF and -10·2% for UPD). Volume sales of UPD increased by 30·0 kg/capita in Latin America and the Caribbean and 20·0 kg/capita in Central and Eastern Europe; Central and East Asia and South and South East Asia. Volume sales of UPF increased by about 10·0 kg/capita for the regions Central and Eastern Europe, North Africa and the Middle East and Central and East Asia (Figure 2).

The minimum and maximum annual changes in volume sales of UPD and UPF were 0.25-2.82 kg/capita and 0.22-1.48 kg/capita for Western Europe, 0.20-3.10 kg/capita and 0.00-1.20 kg/capita for North America and Australasia, 0.18-5.26 kg/capita and 0.04-2.36 kg/capita for Central and Eastern Europe, 0.04-2.19 kg/capita and 0.01-1.31 kg/capita for North Africa and the Middle East, 0.03-4.78 kg/capita and 0.07-1.10 kg/capita for Latin America and the Caribbean, 0.40-1.90 kg/capita and 0.08-0.40 kg/capita for Africa, 0.48-2.91 kg/capita and 0.34-1.01 kg/capita for Central and East Asia and 0.47-3.03 kg/capita and 0.29-0.56 kg/capita for South and South East Asia respectively (data not shown).

Contribution of food groups to the volume sales of UPD and UPF

For 5 out of 8 regions in 2002 and 5 out of 8 regions in 2016, baked goods (e.g., cakes, pastries and industrial breads) were the most important contributor to volume sales of UPF (14·5%-49·6% in 2002 and 13·1%-44·5% in 2016).

The second most important contributing food group was, dependent on the region, dairy products, processed fruits and vegetables, or baked goods.

In all regions, carbonated drinks were the most important contributor to volume sales UPD (41·4%-89·4% in 2002 and 40·2%-86·0% in 2016) (Figures 3 and 4).

There were no major shifts over time in contributions of food groups to the volume sales of UPF. However, even though carbonated drinks were the most important contributor to volume sales of UPD, the percent contribution decreased from 2002 to 2016 in all regions; the least in Africa and Central and East Asia.

The contribution of ready-to-drink teas to volume sales of UPD increased especially in the Asian regions, and the contribution of sport and energy drinks increased in all regions except Central and East Asia (Figures 3 and 4).

UPD and UPF volume sales/capita and their associations with adult BMI trajectories

The final models for men and women are presented in Table 1. There was a significant positive association between total UPFD volume sales and mean population BMI for both men and women. For every standard deviation increase (51 kg/capita, year 2002) in volume sales of UPD, mean population BMI increased by 0·195 kg/m^2 for men (p<0·001) and 0·072 kg/m^2 for women (p=0·003) (Table 1). For every standard deviation (40 kg/capita, year 2002) increase in volume sales of UPF, mean population BMI increased by 0·316 kg/m² for men (p<0·001). There was no significant association between volume sales of UPF and mean population BMI in women (Table 1). When adding the proportion of the population not engaging in sufficient physical inactivity as covariate in the model, coefficients for the association between mean population

BMI and volume sales of total UPFD, UPD and UPF remained similar (data not shown).

Discussion

As in 2002, UPFD volume sales/capita remained highest in Western Europe and North America and Australasia in 2016 despite having decreased since 2002 in these regions. In all other world regions, particularly in South and South East Asia, sales of these products increased over the period 2002-2016. Baked goods, including cakes, pastries and industrial breads, were the most important contributor to sales of UPF while carbonated drinks were the most important contributor to sales of UPD.

An increase in volume sales per capita of UPD was linked to an increase in mean population BMI for both men and women, while an increase in volume sales per capita of UPF was only linked to mean population BMI for men. Some previous studies have been conducted on trends in UPFD consumption in different regions. Estimates of UPFD acquisition calculated from national household budget surveys in Europe conducted between 1991 and 2008 showed that the average household availability of UPFD ranged from 10·2% of total purchased dietary energy in Portugal to 50·4% in the UK. After adjustment for confounders each percentage point increase in the household availability of UPFD resulted in an increase of 0·25 percentage points in obesity prevalence. [39] Sales of UPFD have also been found to be associated with weight gain and obesity in Latin America. [16] Each 20 kg increase in average annual sales per capita of UPFD was associated with an increase of 0·28 kg/m^2 in age-standardized BMI scores. [16]

There are several plausible mechanisms that could explain the observed positive associations between UPFD and BMI.

UPFD provide excessive nutrients of concern including added sugar, sodium and saturated fats, and are low in fibre, protein, and micronutrients. Accordingly, studies conducted in several countries show that, when compared to people with lower consumption of UPFD, those with higher consumption have a higher risk of having diets that do not comply with one or more dietary goals recommended for the prevention of obesity. [26-33] A diet based on UPFD may promote obesity also through high energy density, high glycaemic load, large portion sizes, and low content of phytochemicals. [8]

UPFD high-intensity flavouring, often further enhanced with artificial ingredients, may override endogenous satiety mechanisms and produce behaviour akin to addiction. [8] UPFD are also typically packaged in plastics, and several plasticizers (e.g. bisphenol A) have been shown to be associated with obesity. [9,10]

Some countries like Brazil [18], Uruguay [49] and Canada [50] include the concept of UPFD in their food-based dietary guidelines. France has recently set a target to reduce consumption of UPFD with 20% by 2022. [51] However, so far there has been no uptake yet of the concept of UPFD in specific national government policies. Some countries are taking action to reduce consumption of certain categories of UPFD. For example Chile limits the marketing of products high in salt, energy, sugar and/or saturated fat to children. Other countries, like Mexico and Hungary, 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 sugar-sweetened beverages and junk food observed in a national urban sample. [52,53] 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 UPFD. [54]

The NOVA system for classifying foods and drinks according to level and purpose of processing has also been criticized [55], as it remains unclear whether the associations between UPFD consumption and weight status can be attributed to processing or the content of nutrients of concern in UPFD. As indicated by a recent study [56], the vast majority of criticism is from authors who have relationships with the UPFD industry and thus conflicts of interest. However, more research is needed to investigate the relative effect of various aspects of UPFD (nutritional quality, food additives and flavouring, convenience, energy density, packaging material) on weight status.

Strengths of the study include the use of population BMI estimates based on a large dataset with measured BMI data for almost every country, and modelled estimates for countries and years that fit well to the data. Limitations include the use of UPFD volume sales/capita, rather than dietary share of energy from ultra-processed foods. Additionally, we used sales data, rather than individual-level consumption data, which did not allow us to look at different consumption patterns for men and women. Finally, this is an ecological analysis, and while we adjusted for important confounders (e.g. socio-economic status, inequality, urbanisation and fruit and vegetable intake), we cannot rule out residual confounding. In particular, the development of markets for UPFD is associated with other changes that countries may undergo. These changes in turn may have obesogenic consequences, for example, among others, the percentage of women in the non-agricultural work force.

Conclusion

Volume sales per capita of ultra-processed foods and drinks are increasing globally, and are positively associated with adult BMI trajectories.

In order to address the growing obesity epidemic, governments should adopt nutrition guidelines that emphasize minimally processed foods-based diets and develop and implement among others taxation and marketing policies to reduce consumption of ultra-processed foods and drinks. Further research is needed to investigate the relative effect of various aspects of ultra-processed foods and drinks on weight status.

References

(1) NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *Lancet* 2016;**387**:1377-96.

(2) GBD 2016 Causes of Death Collaborators. 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* 2017;**390**:1423-59.

(3) Vandevijvere S, Chow CC, Hall K, Umali E, Swinburn B. Increased food energy supply as a major driver of the obesity epidemic: a global analysis. *Bulletin of the World Health Organization* 2015;**93**(7):446-56.

(4) Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. *Obes Rev* 2013;**14** Suppl 2:21-8.

(5) Moodie R, Stuckler D, Monteiro C, et al. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet* 2013;**381**(9867):670-9.

(6) Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutr* 2009;**12**(5):729-31.

(7) Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada MLC, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr* 2018;**21**(1):5-17.

(8) Ludwig DS. Technology, Diet, and the Burden of Chronic Disease. *JAMA* 2011;**305**(13):1352-3.

(9) Thayer KA, Heindel JJ, Bucher JR, Gallo MA. Role of Environmental Chemicals in Diabetes and Obesity: A National Toxicology Program Workshop Review. *Environ Health Perspect* 2012;**120**(6):779-89.

(10) Heindel JJ, Newbold R, Schug TT. Endocrine disruptors and obesity. *Nature Reviews Endocrinology* 2015;**11**:653-61.

(11) Allemandi L, Castronuovo L, Tiscornia MV, Ponce M, Schoj V. Food advertising on Argentinean television: are ultra-processed foods in the lead? *Public Health Nutr* 2018;**21**(1):238-46.

(12) Leite FH, Oliveira MA, Cremm EC, Abreu DS, Maron LR, Martins PA. Availability of processed foods in the perimeter of public schools in urban areas. *J Pediatr (Rio J)* 2012;**88**(4):328-34.

(13) Mallarino C, Gomez LF, Gonzalez-Zapata L, Cadena Y, Parra DC. Advertising of ultra-processed foods and beverages: children as a vulnerable population. *Rev Saude Publica* 2013;**47**(5):1006-10.

(14) Pulker CE, Scott JA, Pollard CM. Ultra-processed family foods in Australia: nutrition claims, health claims and marketing techniques. *Public Health Nutr* 2018;**21**(1):38-48.

(15) Monteiro CA, Levy RB, Claro RM, Castro IR, Cannon G. A new classification of foods based on the extent and purpose of their processing. *Cad Saude Publica* 2010;**26**(11):2039-49.

(16) Pan American Health Organization. Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications. Washington D.C.: Pan American Health Organization; 2015.

(17) Pan American Health Organization. PAHO Nutrient Profile Model. Washington D.C.: Pan American Health Organization; 2016.

(18) Monteiro CA, Cannon G, Moubarac JC, et al. Dietary guidelines to nourish humanity and the planet in the twenty-first century. A blueprint from Brazil. *Public Health Nutr* 2015;**18**(13):2311-22.

(19) Martinez SE, Baraldi LG, Louzada ML, Moubarac JC, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open* 2016;**6**(3):e009892.

(20) Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr* 2015;**101**(6):1251-62.

(21) Moubarac JC, Martins AP, Claro RM, Levy RB, Cannon G, Monteiro CA. Consumption of ultra-processed foods and likely impact on human health. Evidence from Canada. *Public Health Nutr* 2013;**16**(12):2240-8.

(22) Marron-Ponce JA, Sanchez-Pimienta TG, Louzada MLDC, Batis C. Energy contribution of NOVA food groups and sociodemographic determinants of ultra-processed food consumption in the Mexican population. *Public Health Nutr* 2018;**21**(1):87-93.

(23) Martins AP, Levy RB, Claro RM, Moubarac JC, Monteiro CA. Increased contribution of ultra-processed food products in the Brazilian diet (1987-2009). *Rev Saude Publica* 2013;**47**(4):656-65.

(24) Baker P, Friel S. Food systems transformations, ultra-processed food markets and the nutrition transition in Asia. *Global Health* 2016;**12**(1):80.

(25) Zhou J, Du S, Su C, Zhang B, Wang H, Popkin B. The food retail revolution in China and its association with diet and health. *Food Policy* 2015;**55**:92-100.

(26) Adams J, White M. Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008-12). *Int J Behav Nutr Phys Act* 2015;**12**:160.

(27) Batal M, Johnson-Down L, Moubarac JC, et al. 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* 2018;**21**(1):103-13.

(28) Bielemann RM, Motta JV, Minten GC, Horta BL, Gigante DP. Consumption of ultra-processed foods and their impact on the diet of young adults. *Rev Saude Publica* 2015;**49**:28.

(29) Cediel G, Reyes M, da Costa Louzada ML, et al. Ultra-processed foods and added sugars in the Chilean diet (2010). *Public Health Nutr* 2018;**21**(1):125-33.

(30) Cornwell B, Villamor E, Mora-Plazas M, Marin C, Monteiro CA, Baylin A. Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia. *Public Health Nutr* 2018;**21**(1):142-7.

(31) Martinez SE, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. *Popul Health Metr* 2017;**15**(1):6.

(32) Moubarac JC, Batal M, Louzada ML, Martinez SE, Monteiro CA. Consumption of ultra-processed foods predicts diet quality in Canada. *Appetite* 2017;**108**:512-20.

(33) Louzada MLDC, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr* 2018;**21**(1):94-102.

(34) Canella DS, Levy RB, Martins AP, et al. Ultra-processed food products and obesity in Brazilian households (2008-2009). *PLoS One* 2014;**9**(3):e92752.

(35) Costa CS, Del-Ponte B, Assuncao MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr* 2018;**21**(1):148-59.

(36) Julia C, Martinez L, Alles B, et al. Contribution of ultra-processed foods in the diet of adults from the French NutriNet-Sante study. *Public Health Nutr* 2018;**21**(1):27-37.

(37) Louzada ML, Baraldi LG, Steele EM, et al. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med* 2015;**81**:9-15.

(38) Mendonca RD, Pimenta AM, Gea A, et al. Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr* 2016;**104**(5):1433-40.

(39) Monteiro CA, Moubarac JC, Levy RB, Canella DS, Louzada MLDC, Cannon G. Household availability of ultra-processed foods and obesity in nineteen European countries. *Public Health Nutr* 2018;**21**(1):18-26.

(40) Euromonitor International. Passport Global Market Information Database. 2017. Available at http://www.portal.euromonitor.com. Accessed 15/07/2017

(41) Pan A, Hu FB. Effects of carbohydrates on satiety: differences between liquid and solid food. *Curr Opin Clin Nutr Metab Care* 2011;**14**(4):385-90.

(42) Institute for Health Metrics and Evaluation. Protocol for the global burden of diseases, injuries and risk factors. Available at http://www.healthdata.org/sites/default/files/files/Projects/GBD/GBD_Protocol.pdf. Accessed 23/01/2019

(43) James SL, Gubbins P, Murray C, Gakidou E. Developing a comprehensive
      time series of GDP per capita for 210 countries from 1950 to 2015.
      Population Health Metrics 2012;**10**(1):12.

(44) Global dietary database: measuring diet in countries worldwide. 2018.
Available at http://www.globaldietarydatabase.org/the-global-dietary-database-
      measuring-diet-worldwide.html. Accessed 15/07/2017.

(45) Pickett KE, Kelly S, Brunner E, Lobstein T, Wilkinson RG. Wider income
      gaps, wider waistbands? An ecological study of obesity and income
      inequality. *J Epidemiol Community Health* 2005;**59**(8):670-4.

(46) Wilkinson RG, Pickett KE. The spirit level: why greater equality makes
      societies stronger. New York: Bloomsbury Press; 2009.

(47) World Bank. All the GINIs Dataset. 2018. Available at
      https://datacatalog.worldbank.org/dataset/all-ginis-dataset. Accessed
      15/07/2017.

(48) World Health Organization. Global status report on noncommunicable
      diseases 2014. Geneva: World Health Organization; 2014.

(49) Ministerio de Salud. Guia alimentaria para la poblacion uruguaya. Para
      una alimentacion saludable, compartida y placentera. 2016.

(50) Government of Canada. Canada's food guide. 2019.
Available at https://food-guide.canada.ca/en/. Accessed 23/01/2019.

(51) Fiolet T. Quoi dans mon assiette: Objectifs du PNNS 2018-2022. 2018.
      Available at https://quoidansmonassiette.fr/objectifs-pnns-2018-2022-
      pour-politique-nutritionnelle-et-sante-en-france/. Accessed 23/01/2019.

(52)   Batis C, Rivera JA, Popkin BM, Taillie LS. First-Year Evaluation of Mexico's

Tax on Nonessential Energy-Dense Foods: An Observational Study. *PLoS*

Med 2016;**13**(7):e1002057.

(53)   Colchero MA, Popkin BM, Rivera JA, Ng SW. Beverage purchases from

stores in Mexico under the excise tax on sugar sweetened beverages:

observational study. *BMJ* 2016;**352**:h6704.

(54)   Lam MCL, Adams J. 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 2017;**14**(1):68.

(55) Poti J, Braga B, Qin B. Ultra-processed food intake and obesity: what really

matters for health—processing or nutrient content? *Curr Obes Rep*.

2017;**6**:420-431.

(56)   Mialon M, Serodio P, Scagliusi FB. Criticism of the NOVA classification:

who are the protagonists? *World Nutrition* 2018;**9**(3):176-240.

Tables and Figures

Figure 1 Change in annual total volume sales (kg/capita/year) of ultra-processed food products (UPF) and ultra-processed drink products (UPD) by major region (2002-2016)

Figure 2 Change in total volume sales of ultra-processed food products (UPF) and ultra-processed drink products (UPD) over the period 2002-2016

Figure 3 Contribution of food groups to total volume sales of ultra-processed food products (UPF) per capita by region in 2002 and 2016

Figure 4 Contribution of food groups to total volume sales of ultra-processed drink products (UPD) per capita by region in 2002 and 2016

Table 1 Solution for fixed effects from mixed models for repeated measures for total volume sales of ultra-processed food and drink (UPFD) products and UPF and UPD products as a determinant of male and female adult obesity trajectories (2002-2014)

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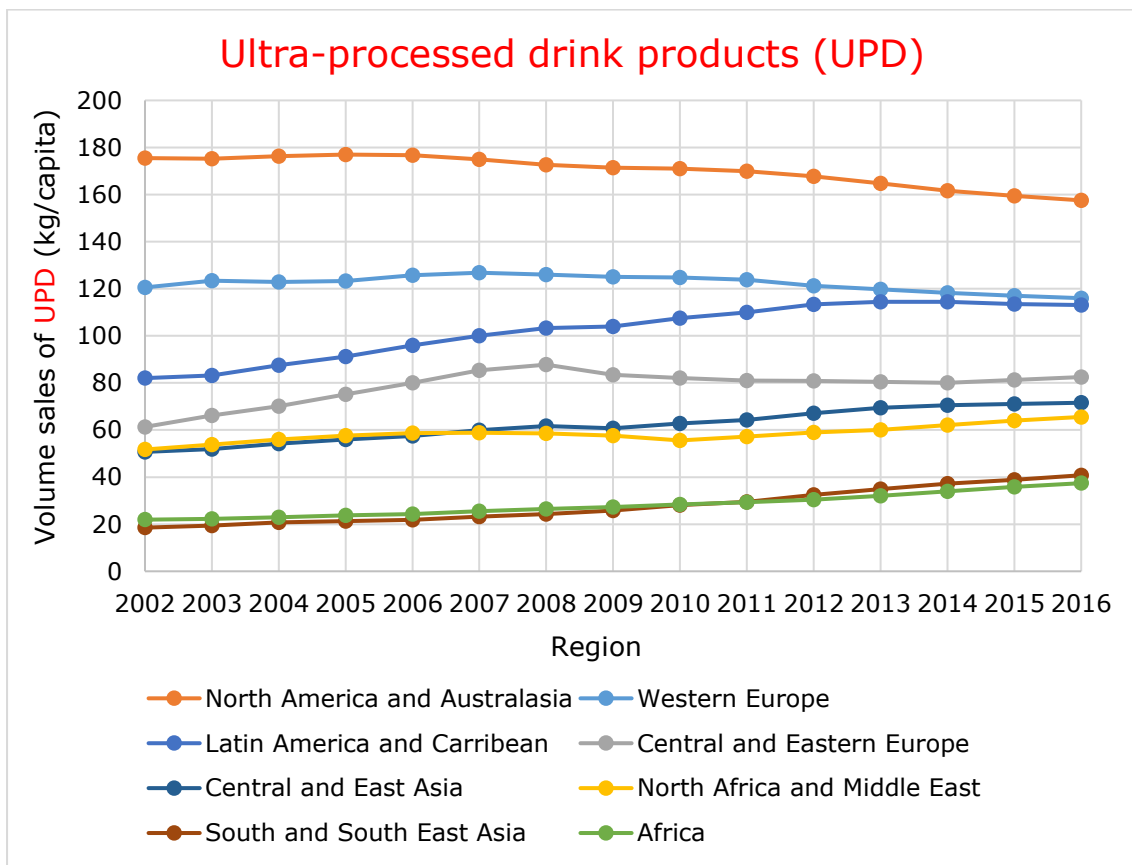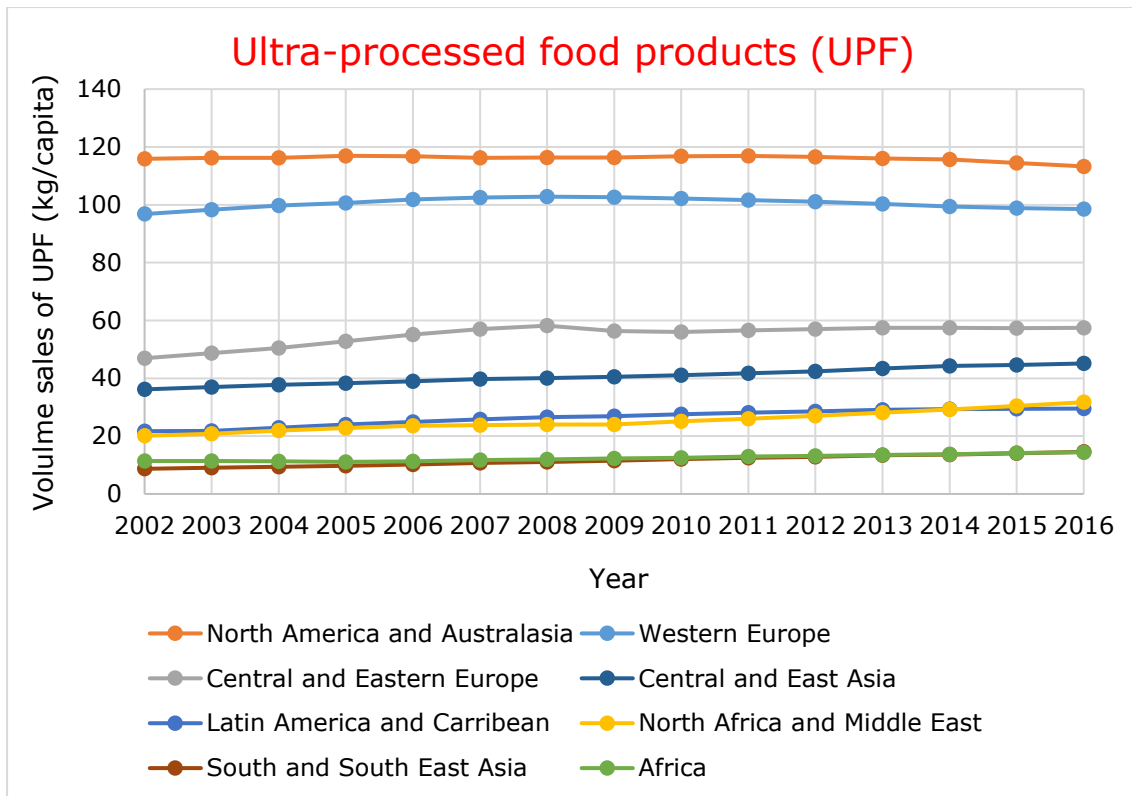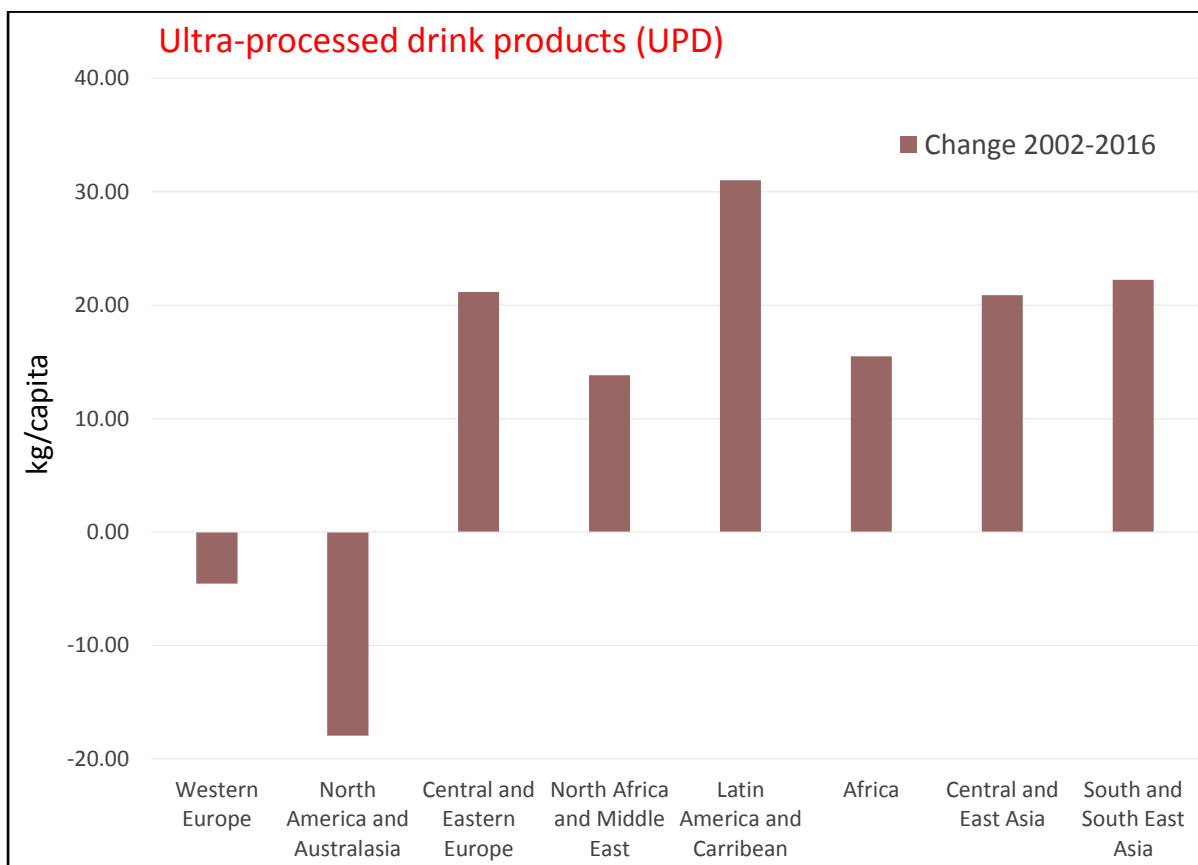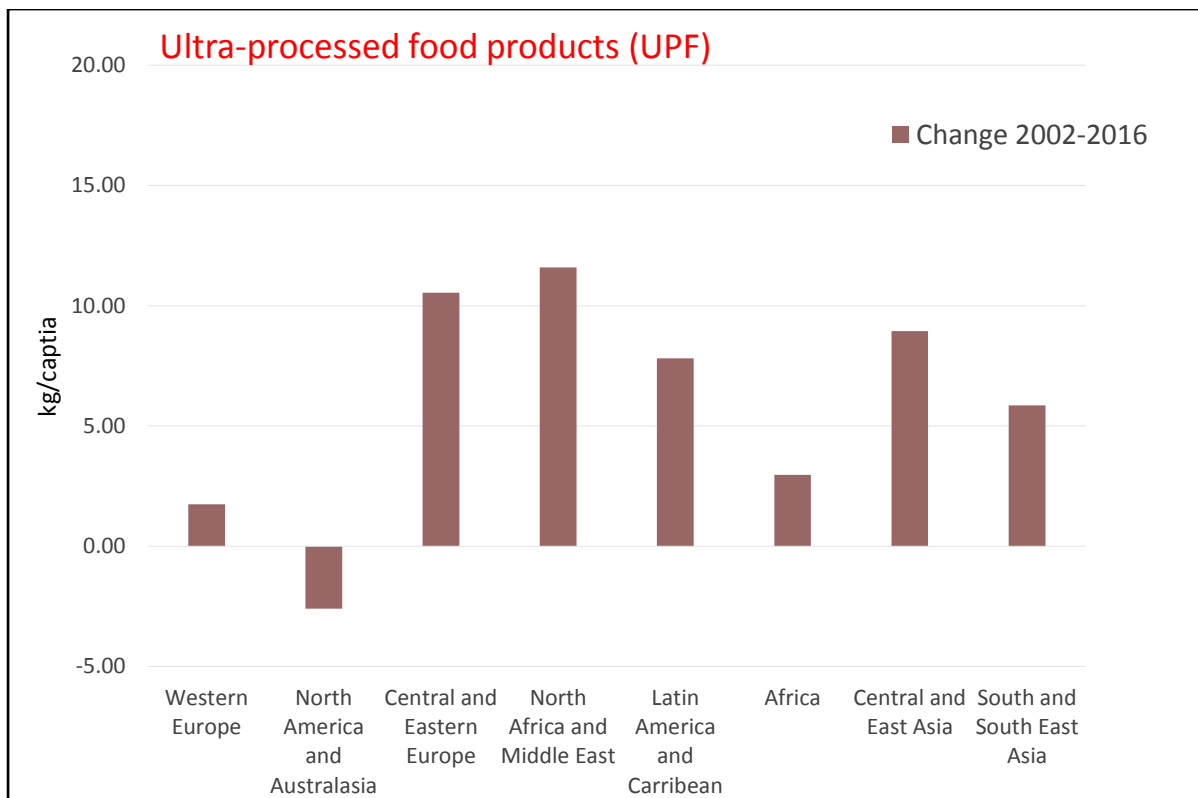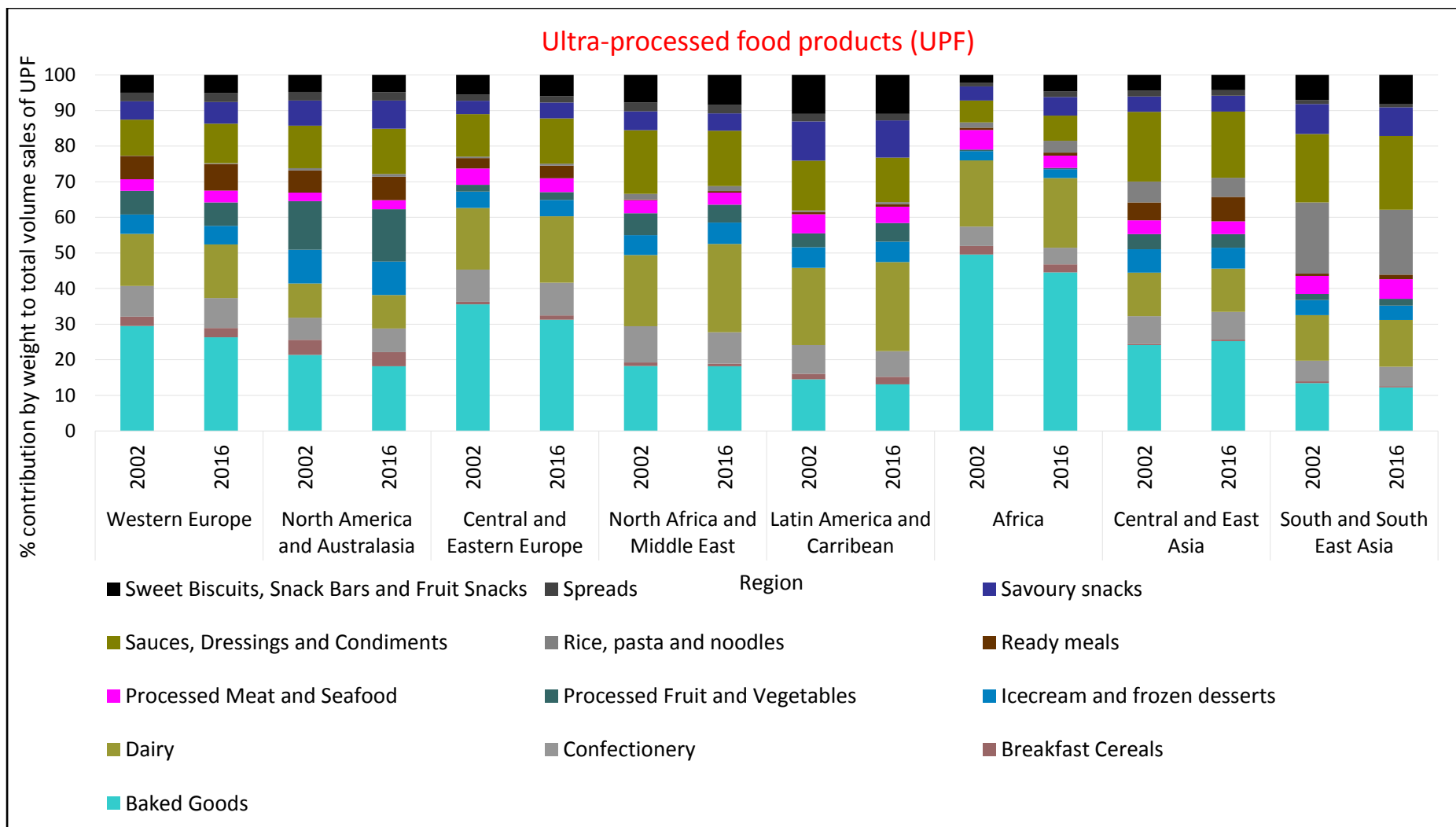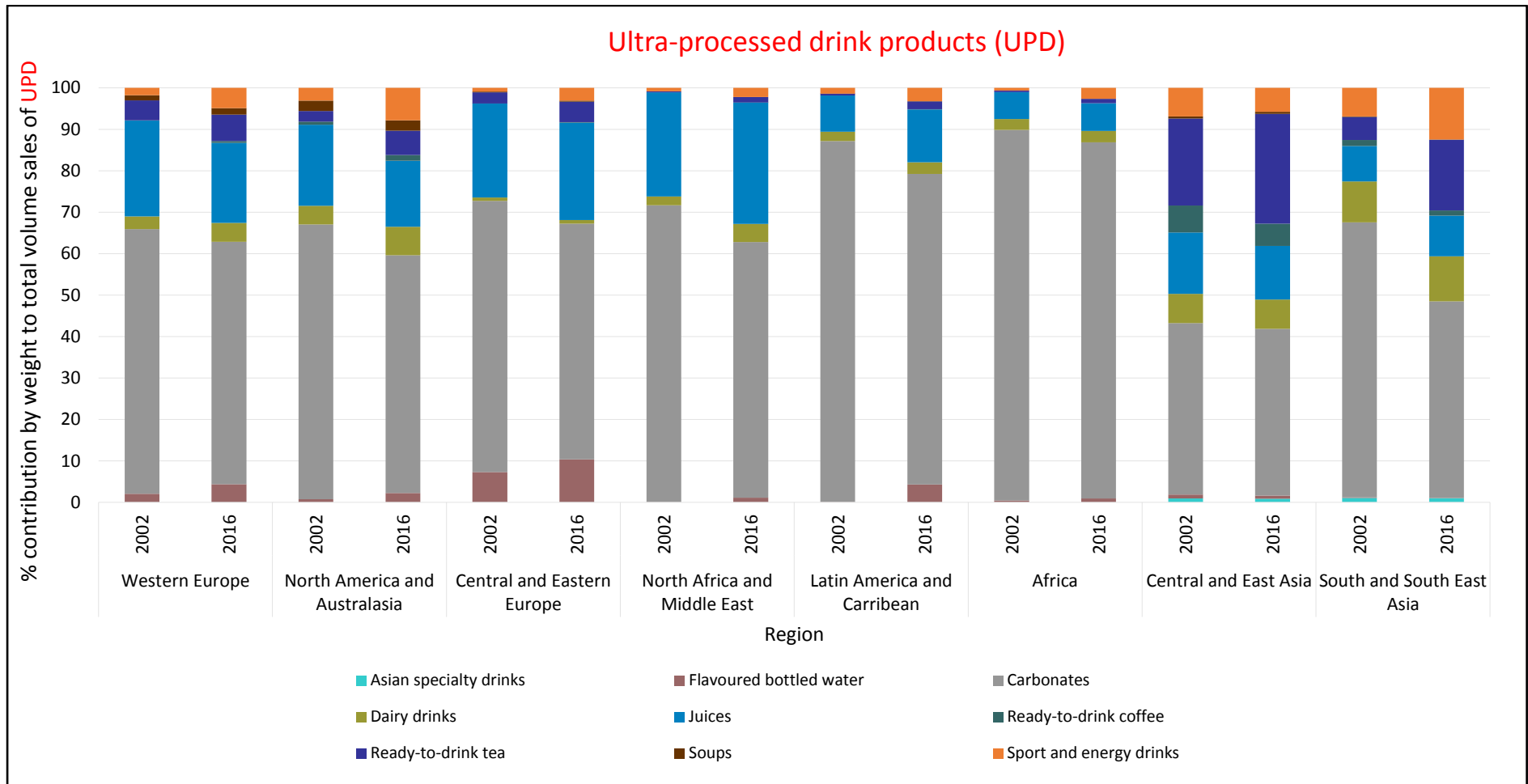
	MEN									WOMEN								
	Total UPFD			UPF			UPD			Total UPFD			UPF			UPD		
Effect	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Intercept	19.7723	0.3547	<.0001	19.8301	0.3696	<.0001	19.585	0.3614	<.0001	20.6613	0.3987	<.0001	20.472	0.4093	<.0001	20.5538	0.4039	<.0001
Total volume sales of UPFD (kg/capita)	**0.0037**	**0.0003**	**<.0001**	**0.0079***	**0.0011**	**<.0001**	**0.0038§**	**0.0004**	**<.0001**	**0.0012**	**0.0004**	**0.001**	**-0.0001**	**0.0012**	**0.9631**	**0.0014§**	**0.0005**	**0.003**
Year	0.0391	0.0033	<.0001	0.0433	0.0037	<.0001	0.0367	0.0035	<.0001	0.0442	0.0037	<.0001	0.0425	0.0041	<.0001	0.0436	0.0039	<.0001
Mean years of education	0.1101	0.0226	<.0001	0.0592	0.0260	0.0228	0.1135	0.0240	<.0001	0.0053	0.0239	0.823	0.0199	0.0266	0.4547	0.0103	0.0246	0.6768
Proportion of pop in urban areas	0.0539	0.0047	<.0001	0.0566	0.0049	<.0001	0.0558	0.0049	<.0001	0.0657	0.0050	<.0001	0.0667	0.0051	<.0001	0.0672	0.0050	<.0001
Ln GDP	0.1750	0.0388	<.0001	0.1932	0.0403	<.0001	0.1980	0.0399	<.0001	0.1907	0.0423	<.0001	0.2171	0.0434	<.0001	0.2119	0.0430	<.0001
GINI Tertile 1	-0.2635	0.1256	0.0362	-0.1383	0.1423	0.3311	-0.0471	0.1392	0.735	-0.3625	0.1544	0.019	-0.2647	0.1706	0.1211	-0.2969	0.1667	0.0752
GINI Tertile 2	-0.1198	0.1033	0.2466	-0.0028	0.1153	0.9804	0.0784	0.1128	0.4869	-0.6975	0.1313	<.0001	-0.5950	0.1428	<.0001	-0.6261	0.1399	<.0001
GINI Tertile 3	0.0000	.	.	0.0000	.	.	0.0000	.	.	0.0000	.	.	0.0000	.	.	0.0000	.	.
Mean fruit & vegetable consumption (g/day)	0.0007	0.0005	0.164	0.0006	0.0005	0.2902	0.0001	0.0005	0.8864	0.0019	0.0007	0.006	0.0015	0.0007	0.0281	0.0015	0.0007	0.0196
lnGDP * Proportion of pop in urban areas	-0.0027	0.0006	<.0001	-0.0025	0.0006	<.0001	-0.0026	0.0006	<.0001	-0.0029	0.0006	<.0001	-0.0030	0.0006	<.0001	-0.0032	0.0006	<.0001

*For every standard deviation (40 kg/capita, year 2002) increase in volume sales of UPF, mean population BMI increased by 0·316 kg/m² for men (p<0·001).
§For every standard deviation increase (51 kg/capita, year 2002) in volume sales ofUPD, mean population BMI increased by 0·195 kg/m^2 for men (p<0·001) and 0·072 kg/m^2 for women (p=0·003) (Table 1).

Supplementary material 1 Countries and regions included in the analysis

Region	Country	Income level	UPD(kg/capita /yr)		UPF (kg/capita/yr)	
			2002	2016	2002	2016
Latin America and Caribbean	Argentina	Upper middle-income	136.2	184.5	34.6	45.4
	Bolivia	Lower middle-income	47.7	116.5	10.3	17.4
	Brazil	Upper middle-income	71.7	83.8	26.2	36.5
	Chile	High income	116.5	174.2	41.2	60.6
	Colombia	Upper middle-income	67.5	84.8	15.0	20.5
	Costa Rica	Upper middle-income	97.2	108.0	22.2	30.5
	Dominican Republic	Upper middle-income	71.4	92.6	10.5	12.2
	Ecuador	Upper middle-income	63.9	62.2	13.2	14.4
	Guatemala	Lower middle-income	86.1	110.5	16.6	19.8
	Mexico	Upper middle-income	148.4	188.5	32.4	37.1
	Peru	Upper middle-income	42.0	84.4	7.3	15.9
	Uruguay	High income	34.6	123.0	29.9	55.7
	Venezuela	Upper middle-income	83.4	56.9	22.8	17.8
Western Europe	Austria	High income	140.1	129.3	73.7	80.9
	Belgium	High income	143.5	160.4	93.4	92.0
	Denmark	High income	119.4	127.0	100.2	92.8
	Finland	High income	131.4	114.3	123.8	124.6
	France	High income	78.2	78.1	77.6	79.0
	Germany	High income	153.6	161.6	134.8	141.8
	Greece	High income	84.1	52.2	46.2	46.8
	Ireland	High income	154.4	119.4	138.0	124.2
	Israel	High income	123.7	114.9	56.6	62.3
	Italy	High income	75.8	66.6	57.4	63.2
	Netherlands	High income	117.1	133.3	144.5	143.8
	Norway	High income	147.1	139.2	115.0	128.8
	Portugal	High income	83.9	77.3	51.4	67.4
	Spain	High income	124.9	115.3	70.8	85.4
	Sweden	High income	121.8	112.3	119.4	114.1
	Switzerland	High income	138.9	146.5	86.9	87.6
	UK	High income	111.6	124.4	156.1	140.7
Australasia and North America	Australia	High income	156.9	141.2	109.4	108.5
	Canada	High income	194.0	162.0	110.9	113.0
	New Zealand	High income	87.1	88.2	106.3	115.9
	United States	High income	264.0	238.8	137.0	115.8
Central and Eastern Europe	Belarus	Upper middle-income	34.1	52.8	60.9	63.0
	Bosnia Herzegovina	Upper middle-income	35.5	62.4	26.9	36.6
	Bulgaria	Upper middle-income	72.2	114.0	24.4	44.8
	Croatia	Upper middle-income	83.7	79.0	50.0	57.6
	Czech Republic	High income	132.6	122.4	65.9	73.2
	Estonia	High income	64.5	88.7	87.2	84.7
	Hungary	High income	76.8	93.8	33.3	42.3
	Latvia	High income	40.7	59.6	77.6	79.5
	Lithuania	High income	30.0	54.5	73.7	82.1
	Macedonia	Upper middle-income	63.0	91.0	39.9	54.9
	Poland	High income	69.1	113.9	42.1	63.4
	Romania	Upper middle-income	52.1	98.6	13.2	37.3
	Russia	Upper middle-income	31.8	53.1	39.3	57.8
	Serbia	Upper middle-income	59.5	88.7	43.4	60.0
	Slovakia	High income	93.0	116.4	53.3	58.9
	Slovenia	High income	76.9	76.1	40.8	46.5
	Ukraine	Lower middle-income	27.2	37.7	26.1	34.5
North Africa and the Middle East	Algeria	Upper middle-income	26.2	48.3	7.4	21.5
	Egypt	Lower middle-income	28.5	40.0	9.9	14.7
	Iran	Upper middle-income	37.3	52.7	15.7	23.6
	Morocco	Lower middle-income	17.4	28.9	13.8	23.4
	Saudi Arabia	High income	121.7	143.2	22.8	36.5

	Tunisia	Lower middle-income	27.0	35.2	27.1	44.6
	Turkey	Upper middl- income	30.8	67.2	26.9	49.4
	United Arab Emirates	High income	125.0	109.0	37.4	40.1
Africa	Cameroon	Lower middle-income	12.7	23.0	1.5	1.9
	Kenya	Lower middle-income	7.0	9.9	4.7	6.4
	Nigeria	Lower middle-incomemiddle-income	9.8	14.0	4.6	6.2
	South Africa	Upper middle-incomemiddle-income	58.2	102.8	35.0	43.2
Central and East Asia	Azerbaijan	Upper middle-incomemiddle-income	19.1	33.7	22.4	35.4
	China	Upper middle-income	11.8	39.9	11.0	23.6
	Georgia	Lower middle-income	18.1	66.2	36.0	67.8
	Hong Kong	High income	77.7	104.2	40.6	51.9
	Japan	High income	130.1	151.2	88.4	89.9
	Kazakhstan	Upper middle-income	36.6	74.1	38.9	39.2
	Singapore	High income	67.8	82.1	40.6	41.7
	South Korea	High income	56.6	56.9	44.2	49.1
	Taiwan	High income	81.4	89.7	30.9	40.0
	Uzbekistan	Lower middle-income	7.9	17.9	8.7	12.6
South and South East Asia	India	Lower middle-income	1.8	5.7	1.5	3.8
	Indonesia	Lower middle-income	8.1	22.1	10.0	16.7
	Malaysia	Upper middle-income	28.8	57.4	20.3	26.2
	Pakistan	Lower middle-income	4.5	10.0	1.5	3.6
	Philippines	Lower middle-income	40.5	61.5	10.6	15.9
	Thailand	Upper middle-income	39.7	81.9	12.3	20.2
	Vietnam	Lower middle-income	6.4	46.9	4.7	15.5

Countries were classified into regions according to the Global Burden of Disease Study 2015
Income level of countries was classified based on Gross National Income per capita according to the World Bank Classification.
UPD and UPF were calculated from volume sales per capita for foods and drinks in Euromonitor

Supplementary material 2 Euromonitor food and drink subgroups classified as _ultra-processed_*

Category	Food Group Level 1	Food Group Level 2	Food Group Level 3	Food Group Level 4	Food Group Level 5
PACKAGED FOOD	Baked Goods	Bread	Leavened Bread	_Packaged Leavened Bread_	
		Cakes	_Packaged Cakes_		
		Dessert Mixes			
		Frozen Baked Goods			
		Pastries	_Packaged Pastries_		
	Breakfast Cereals	RTE Cereals	_Children's Cereals_		
			Family Breakfast Cereals	_Flakes_	
				Muesli and Granola	
				Other RTE Cereals	
	Confectionary	Chocolate Confectionary	_Chocolate Pouches & Bags_		
			Boxed Assortments		
			Chocolate with Toys		
			Countlines		
			Seasonal Chocolate		
			Tablets		
			Other Chocolate Confectionary		
		Gum	_Bubble Gum_		
			Chewing Gum		
		Sugar Confectionary	_Boiled Sweets_		
			Liquorice		
			Lollipops		
			Medicated Confectionary		
			Mints	_Powder Mints_	
				Standard Mints	
			Pastilles, Gums, Jellies, Chews		
			Toffees, Caramel and Nougat		
			Other Sugar Confectionary		

Dairy	Butter and Margarine	Margarine and Spreads		
	Cheese	Processed Cheese	Spreadable Processed Cheese	
			Other Processed Cheese	
	Drinking Milk Products	Flavoured Milk Drinks	Dairy Only Flavoured Milk Drinks	
			Flavoured Milk Drinks with Fruit Juice	
		Milk Alternatives	Soy Drinks	
			Soy Milk	
			Other Milk Alternatives	
	Yoghurt and Sour Milk Products	Yoghurt	Drinking Yoghurt	
			Flavoured Yoghurt	
	Other Dairy	Chilled and Shelf Stable Desserts	Dairy Desserts	Chilled Dairy Desserts
				Shelf Stable Dairy Desserts
			Soy Desserts	Chilled Soy Desserts
				Shelf Stable Soy Desserts
		Chilled Snacks		
		Coffee Whiteners		
		Condensed Milk	Flavoured Condensed Milk	
Ice Cream and Frozen Desserts	Frozen Desserts	Frozen Yoghurt		
	Ice Cream	Impulse Ice Cream	Single Portion Dairy Ice Cream	
			Single Portion Water Ice Cream	
		Take-Home Ice Cream	Take-Home Dairy Ice Cream	Bulk Dairy Ice Cream
				Ice Cream Desserts
				Multi-Pack Dairy Ice Cream

		Take-Home Water Ice Cream	*Bulk Water Ice Cream*
			Multi-Pack Water Ice Cream
Processed Fruit and Vegetables	Frozen Processed Fruit and Vegetables	*Frozen Processed Potatoes*	
Processed Meat and Seafood	Processed Meat	Shelf Stable Meat	*Shelf Stable Processed Red Meat*
			Shelf Stable Processed Poultry
	Processed Seafood	*Shelf Stable Seafood*	
	Meat Substitutes	*Chilled Meat substitutes*	
		Frozen Meat Substitutes	
		Shelf Stable Meat Substitutes	
Ready Meals	*Shelf Stable Ready Meals*		
	Chilled Lunch Kits		
	Chilled Pizza		
	Chilled Ready Meals		
	Dinner Mixes		
	Dried Ready Meals		
	Frozen Pizza		
	Frozen Ready Meals		
Rice, Pasta and Noodles	Noodles	Instant Noodles	*Instant Noodle Cups*
			Instant Noodles Pouches
Sauces, Dressings and Condiments	Cooking Ingredients	Bouillon	*Gravy Cubes and Powders*
			Liquid Stocks and Fonds
			Stock Cubes and Powders
		Dry Sauces	
		Monosodium Glutamate	
		Pasta Sauces	
		Cooking Sauces	

	Dips	
	Pickled Products	
	Table Sauces	*Barbecue Sauces*
		Fish Sauces
		Ketchup
		Mayonnaise
		Mustard
		Oyster Sauces
		Salad Dressings
		Soy Sauces
		Chilli Sauces
		Other Table Sauces
	Tomato Pastes and Purees	
	Other Sauces, Dressings and Condiments	
Savoury Snacks	Salty Snacks	*Potato Chips*
		Tortilla Chips
		Puffed Snacks
		Rice Snacks
		Vegetable, Pulse and Bread Chips
	Savoury Biscuits	
	Popcorn	
	Pretzels	
	Other Savoury Snacks	
Soup	*Shelf Stable Soup*	
	Chilled Soup	
	Dehydrated Soup	
	Frozen Soup	
	Instant Soup	

	Spreads	Chocolate Spreads		
		Jams and Preserves		
		Nut and Seed Based Spreads		
		Yeast-based Spreads		
	Sweet Biscuits, Snack Bars and Fruit Snacks	Fruit Snacks	Processed Fruit Snacks	
		Snack Bars	Cereal Bars	
			Energy Bars	
			Other Snack Bars	
		Sweet Biscuits	Chocolate Coated Biscuits	
			Cookies	
			Filled Biscuits	
			Plain Biscuits	
			Wafers	
SOFT DRINKS	Bottled Water	Flavoured Bottled Water		
	Carbonates	Cola Carbonates	Low Calorie Cola Carbonates	
			Regular Cola Carbonates	
		Non-Cola Carbonates	Lemonade/Lime	
			Mixers	Ginger Ale
				Seltzer
				Tonic Water/Other Bitters
			Orange Carbonates	
			Other Non-Cola Carbonates	
	Concentrates	Liquid Concentrates		
		Powder Concentrates		
	Juice	100% Juice	Reconstituted 100% Juice	
		Juice Drinks (Up to 24% Juice)		
		Nectars		
		Coconut and Other Plant Waters		

	RTD Coffee	
	RTD Tea	*Carbonated RTD Tea*
		Still RTD Tea
	Sport and Energy Drinks	*Energy Drinks*
		Sports Drinks
	Asian Specialty Drinks	

RTE ready-to-eat; RTD ready-to-drink

* Food sub groups at the most disaggregated level of detail available within Euromonitor (Food group Level 5 > Food group level 4 > Food group level 3 > Food group level 2 > Food group level 1) that were classified as ultra-processed, underlined and indicated in italic. All other food sub groups were classified as non-ultraprocessed and are not shown in this table.