# Comparison of consumed portion sizes and on-pack serving sizes of UK energy dense foods

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## Abstract

Studies indicate a ‘portion size effect’ association between increased portion size and energy intake, but direct links with obesity remain unproven. UK portion size guidance is outdated and evidence suggests that on-pack serving-sizes have increased in some energy-dense foods. Serving-sizes are compared with consumed portion sizes in popular energy, fat and sugar-dense foods, and patterns explored. Data was analysed for adults aged 19-64y (excluding under-reporters) from the UK National Diet & Nutrition Survey 2008-2014 (n=2377) for consumed portion sizes and a commercial product database of major UK retailers provided serving-sizes. Popular energy-dense food groups were split into 45 product-based subgroups. Means of consumed portion size and on-pack serving-size were calculated and compared and nutrition per 100 g and per serve was explored. Just 57% products had serving-size compared to 97% with pack-size information. Serving-size ranges were wide and varied across food groups. Consumed portion sizes were significantly higher than on-pack serving-size in all main food groups and most subgroups. The greatest difference between consumed portion size and on-pack serving-size was Crisps (44%), and within this, ‘popcorn’ (151%). In Chocolate and Crisps, food subgroups with the largest on-pack serving-sizes were also the most macronutrient dense. Serving-size was unavailable for many products. However, where available, consumed portion sizes were higher than on-pack serving-size in all main food groups and most subgroups. The results could inform updated portion size guidance of energy-dense foods. Further work is needed to clarify whether smaller serving and pack sizes lead to lower total consumption and energy/nutrient intake.

### Keywords

* Food portion size
* Serving size
* Energy dense foods
* Portion size guidance
* National diet surveys
* Nutritional epidemiology

### Abbreviations

* WHO – World Health Organisation
* NDNS (RP) – National Diet & Nutrition Survey (Rolling Programme)
* PHRD – Public Health Responsibility Deal
* CAPI – Computer Assisted Personal Interview
* DLW – Double Labelled Water
* EFSA – European Food Safety Authority
* NCD – Noncommunicable Diseases

## Introduction

Obesity is one of the biggest health problems facing the European population; it accounts for 2-8% of World Health Organisation (WHO) European health costs (WHO, 2017) and is estimated to cause 320,000 premature deaths annually in Western Europe alone (WHO, 2014a). NCDs and related conditions, including overweight and obesity, have significant and growing economic and social costs; therefore diet improvement via reduction in ‘energy dense, micronutrient poor foods’ high in energy, saturated fats, *trans* fats, sugar and salt, is needed across Europe to minimise this burden (WHO, 2014a).

In 87% (46) of WHO European countries over half of adults are overweight or obese (OWOB); in the UK this is over two thirds (67%) adult men and almost 60% (58%) women aged over 16y (Public Health England, 2017a). There is no established *causal* relationship between consumed portion size and obesity, only an association between increased consumed portion size and energy intakes and evidence that limiting consumed portion size contributes to reduced energy intake and therefore reduced weight gain (WHO, 2014b). Ledikwe et al. (2005) and Bhupathiraju & Hu (2016) associated increasing on-pack serving sizes, particularly of energy dense foods, with rising obesity levels via elevated energy intakes. Although both studies refer to America, Albar et al. (2014) found positive associations between BMI and consumed portion size of biscuits and cakes in UK adolescents aged 11-18y after excluding misreporters. Experimental literature also suggests that individuals consume more when exposed to larger portions (Hieke, Palascha, Jola, Wills, & Raats, 2016; Rolls, Roe, Kral, Meengs, & Wall, 2004; Wansink & Park, 2001). Assuming consumed portion size influences energy intake (WHO, 2014b), public access to appropriate portion size guidance, and on-pack serving-sizes that consistently reflect this, alongside decreased serving-sizes of discrete packaged foods may therefore be key to a healthy food and drink environment.

The positive association between on-pack serving-size and food intake is known as the ‘portion size effect’. In their meta-analysis Zlatevska et al. (2014) found, at least in the short-term, that although the association was not linear or uniform across all population groups, overall energy intake increased by 35% when the offered serving-size doubled. Bhupathiraju & Hu (2016) link the obesogenic environment, which includes availability of large serving-sizes of energy dense foods, with obesity and related diseases. Associations between consumed portion size of particular food groups and adiposity have been examined in previous UK National Diet and Nutrition Surveys (NDNS). Kelly et al. (2009) found few associations in the NDNS 2000-2001, but concluded that adult BMI and waist activity level was associated with the consumption of large portions of specific foods, particularly after adjustment for under-reporting.

Based on this evidence, reducing on-pack serving-sizes forms part of the UK’s ongoing calorie reduction drive. The Public Health Responsibility Deal (PHRD) calorie reduction pledge included on-pack serving-size reduction, including of single-serve items, in its suite of options (DH, 2011). Public Health England also highlight it as an objective of their recent calorie and sugar reduction plans, encouraging retailers to reduce the pack size of discrete, single-serve products in certain categories (Public Health England, 2018). However, UK Government guidance on consumed portion size has not been updated in over 20 years (Clift, 2013) and in Europe on-pack serving-sizes are set individually by manufacturers rather than standardised (Kirwan, et al., 2016). Evidence suggests that UK on-pack serving-sizes have increased in some energy dense food categories. Looking at a combination of consumed portion size and on-pack serving size information, Wrieden et al. (2008) found that although consumed portion sizes had not necessarily increased in all categories, fast food consumed portion sizes and availability of large confectionary serving-sizes had risen since government consumed portion size guidance was last issued in 1993 (Crawley, 1994). Studies have repeatedly found that although on-pack serving-sizes of some varieties of traditional biscuit and crisp packet items have changed little in 20 years, other biscuit and crisp varieties and other food types have increased (Church, 2008; Clift, 2013). For example, Clift (2013) found that ‘plain sweetmeal biscuits’ had increased by 17% and ‘American muffins’ by 81%. Even if on-pack serving-sizes or pack sizes of discrete single-serve products decrease, it is not clear what impact this would have on purchase and consumption. Consumers may buy more, thereby inadvertently increasing the total sales volume, or could consume multiples of the smaller portions, thus maintaining or potentially increasing energy and nutrient intake. A recent review (Bucher, Murawski, Duncanson, Labbe, & Van der Horst, 2018) found that the effects of on-pack serving size labelling on consumed portion size remained unclear, but that there was a clear need for consistent terminology, consumer education and further research.

To begin exploration of these issues, this paper will report the average manufacturer-set on-pack serving-size of frequently consumed energy, fat and sugar dense snack food types in the UK and then compare with consumed portion size derived from the UK NDNS. It will explore patterns and similarities to determine whether consumers of such foods have consumed portion size above the serving-size recommended on pack, and consider whether on-pack serving-sizes of certain food types should be amended, as they could have a potential impact on excess energy intake and consequently obesity.

## Methods

Almiron-Roig et al. (2018) define ‘portion’ as the amount a person eats on one occasion and ‘serving’ as the suggested amount to be eaten on one occasion. For clarity, we have adopted this definition and use consumed portion size as distinct from on-pack serving-size of purchased foods.

### Consumed Portion Size

The UK National Diet and Nutrition Survey (NDNS) Rolling Programme (RP) years 1-4 and 5-6 (2008-12 & 2012-14) (Bates, et al., 2016; Bates , et al., 2014) was obtained and analysed to derive consumed portion size of selected food groups in adults aged 19-64y (excluding under-reporters). Multi-stage random probability sampling from UK Postcode Address Files with postal sectors as the primary sampling units was used to select individuals aged 1.5-100y. The two datasets were appended and sample weightings were reassigned using Stata versions 14 & 15 (StataCorp, 2015, 2017). Existing weightings for the Y1-4 and Y5-6 datasets were rescaled to account for the different number of years and therefore respondents in each (see supplementary material 1). Food data was collected via a 4-day consecutive food diary. Participants were not expected to weigh food and drink consumed; consumed portion size was estimated using household measures (e.g. two digestive biscuits, 1 tbsp. chocolate spread), weights from food packaging labels e.g. 25g packet of crisps), or photographs. The food diary provided photographs of 15 frequently consumed foods as small, medium and large portion sizes, which participants could use to estimate portion sizes of similar foods consumed. Demographic and measured height and weight information was collected via a Computer Assisted Personal Interview (CAPI) (Bates, et al., 2016; Bates , et al., 2014).

The NDNS 2008-14 dataset was used to identify popular UK energy, fat and sugar-dense foods. The main NDNS food groups were listed by total number of eating occasions for adults aged 19-64y and the tertile with the lowest number of eating occasions were excluded. The average energy, fat and sugar density was then determined for each remaining food group and those with above average density in all three were selected for analysis – these were Biscuits; Buns, Cakes, Pastries & Fruit Pies (‘Cakes’) and Chocolate Confectionary (‘Chocolate’). Although the Crisps & Savoury Snacks (‘Crisps’) group did not have above average sugar density, it was also selected due to a high salt content, which is a WHO European nutrient of concern (WHO, 2014a).

Within the four selected main food groups homemade items were excluded in order to focus on commercially available products. This was done by searching for and excluding items with ‘homemade’ in the title on either the ‘SubFoodGroupDesc’ or ‘FoodName’ NDNS variable level. The remaining food items were then re-categorised by product type into newly created subgroups within each of the four selected main food groups based on their characteristics. Miscellaneous items were categorised as ‘other’; for example ‘other’ cakes consisted of Chinese cakes and pastries, rice flour cakes and plain pastry.

The mean consumed portion size and SD per eating occasion for adults aged 19-64y consuming each food subgroup were calculated and tabled. These means were weighted to make them nationally representative for that age group by correcting for unequal selection and non-response. The food subgroup consumed portion size per eating occasion was defined as the total weight of food consumed in each subgroup divided by the consumption frequency per person. Each consumer contributed a single mean portion weight to the population mean for each food subgroup to prevent risk of skewing by non-consumers or those who ate certain foods more frequently. Analyses were restricted to adults aged 19-64y to prevent distortion of results from children or the elderly, who may consume smaller portions. Under-reporters were excluded to improve the relevance of findings, as the NDNS does not exclude under-reporters in its results (Bates, et al., 2016; Bates , et al., 2014). Under-reporters (n=1285, 35%) and adults with missing BMI required to determine plausible/under-reporters (n=133, 4%) were excluded from the calculation of the mean consumed portion size. Under-reporter identification was based on energy intake of the whole diet rather than the specific food groups selected for review. Participant height and weight data were used to generate Basal Metabolic Rate (BMR) and BMR:energy intake ratio variables following the Oxford equations detailed in Henry (2005). A low cut-off was generated via the Goldberg method (Black, 2000) using a Physical Activity Level (PAL) of 1.55, as this is regarded as representative of a sedentary lifestyle in the UK and across Europe (Erlichman, Kerbey, & James, 2001; FAO, WHO, & UNU, 2001). Socio-demographic and dietary characteristics of those sampled from the NDNS were determined and tabled.

### On-Pack Serving-Size

A commercial UK database was obtained from 2013, containing product information taken from packaging labels from six major UK retailers (Asda, Co-op, Morrisons, Sainsbury’s, Tesco, Waitrose/Ocado) plus manufacturer data. The products were categorised into subgroups based on those created for the NDNS analysis of consumed portion size; these products were selected for analysis and the remainder excluded.

Pack-size and serving-size data as stated on the product packaging was then cleaned and harmonised so all values were displayed numerically in grams. Pack-size was defined as the weight declared on-pack for the entire pack contents; serving-size was defined as the weight provided on-pack as a suggested amount to consume per person in one eating occasion. Where serving-size was given as units of product e.g. ‘two biscuits’ or ‘half a bar’ the weight in grams was calculated, where possible, from the pack-size and product description. For example, a product with a serving-size of ‘two biscuits’, a pack-size of 150 g and a description of ’12 jam-filled biscuits’ would be given a serving-size of 25 g.

For each subgroup the number of products, number of products with pack-size and the number of products with serving-size information was totalled and the mean and SD of pack-size and serving-size in grams was calculated. The weighted mean consumed portion sizes (excluding under-reporters) were taken from the NDNS derived dataset and compared with the mean and confidence intervals of the on-pack serving-size in the commercial dataset. The difference between these values was tested for each food group using a one sample t-test. This, rather than an independent group t-test, was needed to compare the means due to the different observation types in each dataset; the consumer dataset unit observations were individual people, whereas those in the on-pack serving-size dataset were products. The percentage difference between these means was also reported. Statistical significance was set at p<0.01 due to the large number of statistical tests performed.

For each main and subgroup of foods studied here the mean nutrition per 100 g was determined for the macronutrients commonly available on back of pack (energy in kcal, energy in kJ, protein, CHO, total sugars, total fat, saturates, fibre, sodium/salt). This was calculated using back-of-pack nutrition information from the commercial database and finding the average value per nutrient from all products in each main and subgroup. The mean nutrition per 100 g and the mean serving-size was used to generate the average nutrition per serve for selected nutrients (energy in kcal, total sugars, total fat, saturates, salt) for each subgroup and the overall main food group. This process was repeated using the consumed portion size from the NDNS in place of the on-pack serving size to generate the commercial product mean nutrition per 100g and per serve based on consumed portion sizes. In this way the difference in nutritional content between the consumed portion size and the on-pack nutrition per serve was determined.

## Results

### Consumed Portion Size

Due to the number of food codes available in the NDNS, the NDNS-derived consumed dataset had 331 relevant foods across the selected four main food groups reported by the 2244 adults aged 19-64y (excluding under-reporters) analysed. Almost half of participants (49%) were female and the average age was 41y (table 1). The under-reporters excluded were significantly heavier, had a higher BMI and were less likely to have a degree; they also had significantly lower energy, fat and salt intakes and higher carbohydrate intakes.

The three food subgroups with the highest mean consumed portion size for all adults aged 19-64y in Cakes were ‘pastries’ (106 g [SD 42 g] 95%CI 92-121 g), ‘fruit pie’ (96 g [SD 35 g] 95%CI 87-105 g) and ‘éclairs’ (76 g [SD 36 g] 95%CI 63-90 g) compared to an overall mean for all Cakes of 71g (SD 16 g) (table 2). For Biscuits this was ‘cookies & flapjack’ (47 g [SD 25 g] 95%CI 40-53 g), ‘jaffa cakes’ (39 g [SD 25 g] 95%CI 31-46 g) and ‘filled, non-chocolate biscuit’ (34 g [SD 16 g] 95%CI 31-37 g) compared to an overall mean of 33 g (SD 7 g) for all Biscuits. For Chocolate this was ‘coated nuts/fruit’ (84 g [SD 59 g] 95%CI 59-108 g), ‘Mars-type bar’ (48 g [SD 13 g] 95%CI 46-50 g) and ‘chocolate with additions’ (45 g [SD 24 g] 95%CI 37-54 g) compared to an overall mean of 40 g (SD 15 g) and for Crisps this was ‘popcorn’ (86 g [SD 52 g] 95%CI 35-137 g), ‘nuts’ (77 g [SD 25 g] 95%CI 51-104 g) and ‘tortilla chips’ (46 g [SD 26 g] 95%CI 38-54 g) compared to an overall mean of 45 g (SD 24 g).

#### Table 1: General and dietary characteristics of all adults aged 19-64y in the UK NDNS (Y1-6) dietary survey

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UK NDNS** | **ALL unweighted (n=3662)** | **Plausible reporters (n=2244)** | **Under-reporters** **(n=1285)** | **p-value** |
| **Mean** | **95% CI** | **Mean** | **95% CI** | **Mean** | **95% CI** |
| **General characteristics (weighted)** |
| Age (y) | 41 | 41 | 42 | 41 | 40 | 42 | 41 | 40 | 42 | 0.4 |
| Female (%) | 50 | 48 | 52 | 49 | 46 | 51 | 52 | 49 | 56 | 0.1 |
| Height (cm) | 169 | 169 | 170 | 170 | 169 | 170 | 169 | 168 | 170 | 0.3 |
| Weight (kg) | 78 | 77 | 79 | 75 | 74 | 76 | 84 | 83 | 85 | <0.001 |
| BMI (kg/m²) | 27 | 27 | 27 | 26 | 26 | 26 | 29 | 29 | 30 | <0.001 |
| Ethnicity (% white) | 88 | 86 | 89 | 89 | 87 | 91 | 86 | 83 | 88 | 0.06 |
| Education (% with degree) | 28 | 26 | 30 | 31 | 29 | 34 | 22 | 19 | 25 | <0.001 |
| Under-reporters (% of all adults 19-64y) | 35 | 33 | 37 | N/A |
| **Dietary characteristics (weighted)** |
| Total energy (kcal) | 1857 | 1831 | 1882 | 2127 | 2099 | 2156 | 1364 | 1338 | 1390 | <0.001 |
| Fat (%E) | 33 | 33 | 33 | 34 | 33 | 34 | 31 | 31 | 32 | <0.001 |
| Protein (%E) | 16 | 16 | 17 | 16 | 16 | 16 | 18 | 18 | 18 | <0.001 |
| Carbohydrates (%E) | 46 | 46 | 46 | 45 | 45 | 46 | 48 | 47 | 48 | <0.001 |
| Sugars (%E) | 19 | 19 | 20 | 20 | 19 | 20 | 19 | 19 | 20 | 0.1 |
| Salt (g) | 5.6 | 5.5 | 5.7 | 6.3 | 6.2 | 6.4 | 4.3 | 4.2 | 4.4 | <0.001 |
| Under-reporter energy intake (kcal) | 1364 | 1338 | 1390 | N/A |

### On-Pack Serving-Size

In the commercial on-pack dataset there were 13,313 relevant products; 97% of products in the four selected main food groups had available pack-size information, but only 57% had on-pack serving-size information. Of the four selected main food groups, Crisps had the most products with serving-size information, at 79% (n=2234), and Cakes had over three quarters (n=2061) products with this information (table 2). However, only half (n=1731) of Biscuit products and 35% (n=1539) Chocolate products had serving-size information. The serving-size range was wide and varied across food groups. In Biscuits the SD in all subgroups except ‘cereal bars’ was over half the mean, compared to Crisps, where only the ‘popcorn’ subgroup SD was over half the mean. The subgroup composition influenced the mean on-pack serving-size; for example ‘muffins and cupcakes’ had a mean serving-size of 61g, but excluding cupcakes in a sensitivity analysis increased this to 74 g. Consumed portion size was higher than on-pack serving-size in all four main food groups and the majority of subgroups (figures 1-4).

#### Figure 1: Mean adult consumed portion sizes and on-pack serving sizes - Cakes

#### Figure 2: Mean adult consumed portion sizes and on-pack serving sizes - Biscuits

#### Figure 3: Mean adult consumed portion sizes and on-pack serving sizes - Chocolate

#### Figure 4: Mean adult consumed portion sizes and on-pack serving sizes - Crisps

#### Table 2: Mean UK pack-size and on-pack serving size of selected product categories compared to mean adult (aged 19-64y) consumed portion size

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Food group** | **No. products** | **No. products pack-size info** | **No. products serving-size** | **Mean pack-size (g)** | **Pack-size SD (g)** | **Mean serving-size** **(g)** | **Serving-size** **SD (g)** | **n \*****(2377)** | **Mean adult consumed portion size (g)** | **Adult consumed portion size SD (g)** |
| **Cakes** | **Commercial database – on-pack information** | **NDNS – consumed portion size** |
| **TOTAL** | **2669** | **2423** | **2061** | **330** | **421** | **61** | **31** | **2282** | **71** | **16** |
| Pastries | 153 | 146 | 127 | 427 | 1001 | 69 | 32 | 117 | 106 | 42 |
| Fruit Pie (inc mince) | 223 | 211 | 176 | 364 | 255 | 95 | 37 | 186 | 96 | 35 |
| Doughnut | 57 | 56 | 50 | 113 | 116 | 57 | 26 | 151 | 76 | 22 |
| Eclairs | 25 | 25 | 24 | 113 | 71 | 47 | 36 | 62 | 76 | 36 |
| Chocolate Cake & Gateau | 279 | 238 | 209 | 479 | 549 | 62 | 28 | 161 | 75 | 33 |
| Croissant | 81 | 81 | 72 | 457 | 1250 | 50 | 20 | 177 | 74 | 30 |
| Tart | 300 | 289 | 216 | 356 | 489 | 73 | 38 | 112 | 71 | 35 |
| Scones, Pancakes & Sweet Dough | 268 | 265 | 190 | 386 | 514 | 54 | 27 | 263 | 70 | 35 |
| Muffins & Cupcakes | 252 | 248 | 218 | 239 | 497 | 61 | 36 | 194 | 70 | 22 |
| Fruit cake & Malt Loaf | 168 | 139 | 95 | 615 | 425 | 55 | 21 | 95 | 69 | 27 |
| Teacakes | 48 | 46 | 40 | 304 | 171 | 57 | 21 | 197 | 64 | 24 |
| Swiss Roll | 15 | 11 | 13 | 346 | 109 | 93 | 56 | 110 | 59 | 36 |
| Other buns, cakes, pastries & fruit pie | 12 | 12 | 9 | 111 | 98 | 52 | 29 | 78 | 57 | 31 |
| Cake & Gateau Non-Chocolate | 468 | 348 | 338 | 427 | 423 | 60 | 39 | 241 | 50 | 21 |
| Bars & Slices | 320 | 308 | 284 | 207 | 353 | 36 | 18 | 138 | 45 | 18 |
| **Biscuits** | **Commercial database – on-pack information** | **NDNS – consumed portion size** |
| **TOTAL** | **3431** | **3353** | **1731** | **184** | **189** | **24** | **17** | **3786** | **33** | **7** |
| Cookies & flapjack | 436 | 423 | 212 | 192 | 157 | 40 | 25 | 312 | 47 | 25 |
| Jaffa cakes | 29 | 25 | 20 | 151 | 102 | 16 | 12 | 139 | 39 | 25 |
| Filled non-chocolate | 178 | 172 | 87 | 224 | 273 | 22 | 15 | 425 | 34 | 16 |
| Unfilled coated and/or inclusions | 824 | 810 | 410 | 191 | 158 | 28 | 18 | 678 | 33 | 15 |
| Filled chocolate | 306 | 294 | 193 | 157 | 174 | 24 | 14 | 139 | 33 | 10 |
| Cereal bar | 120 | 117 | 116 | 128 | 71 | 28 | 12 | 316 | 33 | 9 |
| Unfilled uncoated | 403 | 397 | 188 | 217 | 162 | 19 | 16 | 685 | 29 | 20 |
| Savoury biscuits plain | 381 | 377 | 155 | 197 | 514 | 17 | 14 | 657 | 29 | 15 |
| Short biscuits | 295 | 286 | 115 | 233 | 152 | 24 | 24 | 301 | 26 | 15 |
| Savoury biscuits flavoured | 459 | 452 | 235 | 149 | 122 | 23 | 15 | 134 | 23 | 9 |
| **Chocolate** | **Commercial database – on-pack information** | **NDNS – consumed portion size** |
| **TOTAL** | **4383** | **4359** | **1539** | **179** | **262** | **32** | **16** | **2399** | **40** | **15** |
| Coated nuts/fruit | 188 | 187 | 60 | 213 | 395 | 42 | 20 | 121 | 84 | 59 |
| Mars type bar | 176 | 176 | 134 | 175 | 133 | 37 | 12 | 590 | 48 | 13 |
| Chocolate with additions | 240 | 239 | 108 | 146 | 104 | 27 | 14 | 47 | 45 | 24 |
| Sugar coated | 178 | 178 | 77 | 187 | 363 | 34 | 17 | 197 | 39 | 20 |
| Crème filled | 172 | 171 | 58 | 184 | 206 | 30 | 12 | 133 | 38 | 26 |
| Milk chocolate | 1593 | 1585 | 553 | 169 | 328 | 32 | 26 | 50 | 35 | 25 |
| Honeycomb/crunch | 220 | 216 | 116 | 192 | 299 | 31 | 13 | 127 | 35 | 13 |
| Caramel | 159 | 158 | 88 | 162 | 183 | 32 | 15 | 306 | 34 | 19 |
| Dark chocolate | 244 | 240 | 83 | 220 | 697 | 30 | 13 | 71 | 32 | 31 |
| White chocolate | 185 | 184 | 82 | 123 | 104 | 33 | 22 | 93 | 31 | 18 |
| Wafer bar | 85 | 85 | 72 | 156 | 155 | 31 | 12 | 502 | 31 | 11 |
| Truffles | 943 | 940 | 108 | 217 | 180 | 24 | 16 | 162 | 26 | 19 |
| **Crisps** | **Commercial database – on-pack information** | **NDNS – consumed portion size** |
| **TOTAL** | **2830** | **2773** | **2234** | **155** | **134** | **31** | **11** | **2170** | **45** | **24** |
| Popcorn | 217 | 202 | 173 | 153 | 143 | 34 | 22 | 25 | 86 | 52 |
| Nuts | 872 | 846 | 558 | 233 | 263 | 38 | 15 | 9 | 77 | 25 |
| Tortilla chips | 107 | 105 | 82 | 191 | 71 | 34 | 10 | 146 | 46 | 26 |
| Potato crisps crinkle | 186 | 186 | 175 | 126 | 77 | 30 | 8 | 145 | 39 | 10 |
| Potato and veg crisps std | 833 | 828 | 705 | 148 | 138 | 29 | 10 | 1260 | 31 | 13 |
| High fat bar snacks | 65 | 63 | 47 | 133 | 115 | 31 | 10 | 64 | 27 | 15 |
| Potato snack shapes & puffed | 381 | 374 | 346 | 141 | 184 | 24 | 8 | 306 | 26 | 8 |
| Corn and maize snacks | 169 | 169 | 148 | 115 | 79 | 26 | 7 | 215 | 25 | 10 |

\* Unweighted number of individuals consuming each food subgroup. There were 2377 individuals included in the analysis.

NB – the consumed portion sizes derived from the NDNS (2008-2014) were weighted to make them nationally representative of plausible reporters; there was no weighting factor applied to the on-pack serving-sizes.

In the Chocolate and Crisps groups the food subgroups with the highest macronutrients and salt per 100 g also had the highest per serve, though the subgroups in question varied depending on the nutrient (table 3). For example in Chocolate ‘sugar-coated chocolate’ had the highest sugar per 100 g and per serve (62 g, 21 g respectively); ‘dark chocolate’ had the highest fat and saturated fat content (38 g, 11 g and 23 g, 7 g respectively) and ‘Mars-type bars’ had the highest salt content (0.58 g, 0.21 g). In Crisps ‘popcorn’ had the highest sugar content (21 g, 7 g); ‘nuts’ had the highest fat and saturated fat content (49 g, 19 g and 8 g, 3 g respectively) and ‘high fat bar snacks’ had the highest salt content (2.18 g, 0.67 g). In Cakes this pattern was true in all nutrients except fat. In Biscuits, different subgroups had the highest levels per 100 g compared to those with the highest levels per serve in all nutrients except salt (table 3).

In all four main food groups the mean overall consumed portion size was statistically significantly larger than the mean overall on-pack serving-size (table 4). The consumed portion size was also larger than the on-pack serving-size in the majority of subgroups; only two subgroups had a statistically significant lower consumed portion size than on-pack serving-size: ‘cake & gateau non-chocolate’ and ‘high fat bar snacks’.

Differences over 10% existed between consumed portion size and on-pack serving-size in most subgroups, with the majority of consumed portion sizes being higher than on-pack serving-size (Table 4). Only ‘wafer bar’ had the same consumed portion size and on-pack serving-size (31 g). The greatest difference between consumed portion size and on-pack serving-size was in Crisps (44%) and within this ‘popcorn’ (151%). For Crisps overall this equates to consumption of an extra 69kcal, 0.9 g sugar, 3.8 g fat, 0.6 g sat fat and 0.2 g salt per serve and for ‘popcorn’ 240kcal, 11 g sugar, 10.2 g fat, 2.5 g saturated fat and 0.48 g more salt than if consumers adhered to the recommended on-pack serving-size (table 4). Other subgroups with a consumed portion size over 50% greater than the on-pack serving-size were ‘éclair’ (60%) equating to a 109 kcal difference per serve; ‘pastries’ (53% 134 kcal) ‘unfilled uncoated biscuits’ (51% 47 kcal), ‘filled non-chocolate biscuits’ (53%, 55 kcal); ‘savoury biscuits plain’ (69%, 50 kcal); ‘jaffa cakes’ (149%, 87 kcal); ‘chocolate with additions’ (66%, 97 kcal); ‘coated nuts & fruit’ (101%, 205 kcal) and ‘nuts’ (105%, 238 kcal).

#### Table 3: Mean nutrition per 100g and per serve of selected product categories based on mean UK (2013) commercial on-pack food-label serving size and nutrition information

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Food subgroup** | **Energy (kcal)** | **Total Sugar (g)** | **Total Fat (g)** | **Saturates (g)** | **Salt (g)** | **On-pack serving-size** **(g)** | **Energy (kcal)** | **Total Sugar (g)** | **Total Fat (g)** | **Saturates (g)** | **Salt (g)** |
| **Cakes** | **Commercial database - nutrition per 100g** | **Commercial database - nutrition per serve** |
| **TOTAL** | **377** | **27** | **17** | **8** | **0.48** | **61** | **231** | **17** | **10** | **5** | **0.29** |
| Teacakes | 290 | 20 | 5 | 2 | 0.63 | 57 | 165 | 11 | 3 | 1 | 0.36 |
| Cake & Gateau Non-Chocolate | 375 | 36 | 15 | 6 | 0.30 | 60 | 225 | 21 | 9 | 3 | 0.18 |
| Swiss Roll | 367 | 27 | 13 | 7 | 0.45 | 93 | 341 | 25 | 12 | 7 | 0.42 |
| Doughnut | 364 | 19 | 19 | 9 | 0.58 | 57 | 207 | 11 | 11 | 5 | 0.33 |
| Croissant | 415 | 10 | 23 | 13 | 0.95 | 50 | 208 | 5 | 11 | 7 | 0.48 |
| Muffins & Cupcakes | 411 | 33 | 20 | 5 | 0.48 | 61 | 251 | 20 | 12 | 3 | 0.29 |
| Chocolate Cake & Gateau | 398 | 33 | 19 | 8 | 0.38 | 62 | 247 | 20 | 12 | 5 | 0.23 |
| Bars & Slices | 437 | 40 | 19 | 9 | 0.43 | 36 | 157 | 14 | 7 | 3 | 0.15 |
| Fruit Pie (inc mince) | 301 | 22 | 12 | 5 | 0.23 | 95 | 286 | 21 | 11 | 5 | 0.21 |
| Eclairs | 377 | 18 | 27 | 16 | 0.30 | 47 | 177 | 8 | 13 | 8 | 0.14 |
| Tart | 373 | 26 | 18 | 9 | 0.33 | 73 | 272 | 19 | 13 | 7 | 0.24 |
| Scones, Pancakes & Sweet Dough | 333 | 22 | 11 | 5 | 0.90 | 54 | 180 | 12 | 6 | 3 | 0.49 |
| Pastries | 362 | 19 | 19 | 10 | 0.50 | 69 | 250 | 13 | 13 | 7 | 0.35 |
| Fruit cake & Malt Loaf | 349 | 41 | 9 | 3 | 0.25 | 55 | 192 | 23 | 5 | 2 | 0.14 |
| Other buns, cakes, pastries & fruit pie | 501 | 47 | 22 | 16 | 0.48 | 52 | 261 | 25 | 12 | 8 | 0.25 |
| **Biscuits** | **Commercial database - nutrition per 100g** | **On-pack serving-size** **(g)** | **Commercial database - nutrition per serve** |
| **TOTAL** | **456** | **28** | **18** | **9** | **0.78** | **24** | **110** | **7** | **4** | **2** | **0.19** |
| Unfilled coated and/or inclusions | 488 | 34 | 21 | 11 | 1.28 | 28 | 137 | 9 | 6 | 3 | 0.36 |
| Unfilled uncoated | 469 | 27 | 18 | 8 | 0.78 | 19 | 89 | 5 | 3 | 2 | 0.15 |
| Filled non-chocolate | 458 | 32 | 19 | 10 | 0.48 | 22 | 101 | 7 | 4 | 2 | 0.10 |
| Cereal bar | 406 | 35 | 12 | 5 | 0.45 | 28 | 114 | 10 | 3 | 1 | 0.13 |
| Cookies & flapjack | 476 | 31 | 22 | 11 | 0.63 | 40 | 190 | 12 | 9 | 4 | 0.25 |
| Short biscuits | 492 | 23 | 25 | 13 | 0.58 | 24 | 118 | 6 | 6 | 3 | 0.14 |
| Savoury biscuits plain | 415 | 4 | 12 | 4 | 1.33 | 17 | 71 | 1 | 2 | 1 | 0.23 |
| Savoury biscuits flavoured | 458 | 5 | 19 | 7 | 1.73 | 23 | 105 | 1 | 4 | 2 | 0.40 |
| Jaffa cakes | 378 | 53 | 9 | 5 | 0.15 | 16 | 60 | 8 | 1 | 1 | 0.02 |
| Filled chocolate | 523 | 38 | 25 | 14 | 0.40 | 24 | 126 | 9 | 6 | 3 | 0.10 |
| **Chocolate** | **Commercial database - nutrition per 100g** | **On-pack serving-size** **(g)** | **Commercial database - nutrition per serve** |
| **TOTAL** | **519** | **50** | **28** | **16** | **0.27** | **32** | **166** | **16** | **9** | **5** | **0.09** |
| Milk chocolate | 535 | 54 | 31 | 19 | 0.23 | 32 | 171 | 17 | 10 | 6 | 0.07 |
| Mars type bar | 478 | 51 | 23 | 12 | 0.58 | 37 | 177 | 19 | 8 | 4 | 0.21 |
| Wafer bar | 540 | 50 | 26 | 15 | 0.20 | 31 | 167 | 15 | 8 | 5 | 0.06 |
| Caramel | 482 | 53 | 24 | 14 | 0.40 | 32 | 154 | 17 | 8 | 4 | 0.13 |
| Sugar coated | 498 | 62 | 23 | 14 | 0.15 | 34 | 169 | 21 | 8 | 5 | 0.05 |
| Dark chocolate | 550 | 36 | 38 | 23 | 0.18 | 30 | 165 | 11 | 11 | 7 | 0.05 |
| Honeycomb/crunch | 516 | 52 | 28 | 16 | 0.35 | 31 | 160 | 16 | 9 | 5 | 0.11 |
| Crème filled | 499 | 54 | 26 | 15 | 0.25 | 30 | 150 | 16 | 8 | 4 | 0.08 |
| Truffles | 557 | 47 | 34 | 20 | 0.20 | 24 | 134 | 11 | 8 | 5 | 0.05 |
| White chocolate | 548 | 56 | 32 | 20 | 0.25 | 33 | 181 | 19 | 11 | 7 | 0.08 |
| Chocolate with additions | 537 | 46 | 33 | 18 | 0.18 | 27 | 145 | 13 | 9 | 5 | 0.05 |
| Coated nuts/fruit | 489 | 45 | 26 | 12 | 0.30 | 42 | 205 | 19 | 11 | 5 | 0.13 |
| **Crisps** | **Commercial database - nutrition per 100g** | **On-pack serving-size** **(g)** | **Commercial database - nutrition per serve** |
| **TOTAL** | **499** | **6** | **27** | **5** | **1.44** | **31** | **153** | **2** | **8** | **1** | **0.44** |
| Potato and veg crisps std | 485 | 4 | 27 | 3 | 1.40 | 29 | 141 | 1 | 8 | 1 | 0.41 |
| Corn and maize snacks | 481 | 4 | 22 | 5 | 1.73 | 26 | 125 | 1 | 6 | 1 | 0.45 |
| Potato snack shapes & puffed | 491 | 4 | 25 | 4 | 2.05 | 24 | 118 | 1 | 6 | 1 | 0.49 |
| Tortilla chips | 489 | 3 | 24 | 3 | 1.20 | 34 | 166 | 1 | 8 | 1 | 0.41 |
| Potato crisps crinkle | 502 | 3 | 28 | 3 | 1.55 | 30 | 151 | 1 | 9 | 1 | 0.47 |
| Popcorn | 461 | 21 | 20 | 5 | 0.93 | 34 | 157 | 7 | 7 | 2 | 0.31 |
| High fat bar snacks | 473 | 4 | 24 | 7 | 2.18 | 31 | 147 | 1 | 7 | 2 | 0.67 |
| Nuts | 610 | 8 | 49 | 8 | 0.48 | 38 | 232 | 3 | 19 | 3 | 0.18 |

#### Table 4: Difference in consumed portion size and on-pack serving size and estimated nutritional difference

|  |  |  |
| --- | --- | --- |
| **Food subgroup** | **Mean consumed portion size and on-pack serving-size (g)** | **Nutritional difference between consumed portion size and on-pack serving-size\*\*** |
| **Consumed portion size** | **On-pack serving-size** | **95% CI** | **% Difference** | **p-value** | **Energy (kcal)** | **Total sugar (g)** | **Total fat (g)** | **Saturated fat (g)** | **Salt (g)** |
| **Cakes** |
| **TOTAL** | **71** | **61** | **59** | **62** | **16%** | **<0.001** | **34** | **2.5** | **1.5** | **0.8** | **0.04** |
| Eclairs | 76 | 47 | 32 | 62 | 60% | <0.001 | 109 | 5.2 | 7.9 | 4.6 | 0.09 |
| Pastries | 106 | 69 | 64 | 75 | 53% | <0.001 | 134 | 6.9 | 7.2 | 3.7 | 0.19 |
| Croissant | 74 | 50 | 46 | 55 | 47% | <0.001 | 100 | 2.4 | 5.4 | 3.1 | 0.23 |
| Doughnut | 76 | 57 | 50 | 65 | 33% | <0.001 | 69 | 3.6 | 3.6 | 1.7 | 0.11 |
| Scones, Pancakes & Sweet Dough | 70 | 54 | 50 | 58 | 30% | <0.001 | 53 | 3.5 | 1.8 | 0.8 | 0.14 |
| Fruit cake & Malt Loaf | 69 | 55 | 50 | 59 | 26% | <0.001 | 49 | 5.8 | 1.2 | 0.5 | 0.04 |
| Bars & Slices | 45 | 36 | 34 | 38 | 26% | <0.001 | 39 | 3.6 | 1.7 | 0.8 | 0.04 |
| Chocolate Cake & Gateau | 75 | 62 | 58 | 66 | 21% | <0.001 | 52 | 4.3 | 2.5 | 1.1 | 0.05 |
| Muffins & Cupcakes | 70 | 61 | 56 | 66 | 15% | <0.001 | 37 | 3.0 | 1.8 | 0.4 | 0.04 |
| Teacakes | 64 | 57 | 50 | 63 | 12% | 0.03 | 20 | 1.4 | 0.3 | 0.1 | 0.04 |
| Other buns, cakes, pastries & fruit pie | 57 | 52 | 30 | 74 | 10% | 0.6 | 25 | 2.4 | 1.1 | 0.8 | 0.02 |
| Tart | 71 | 73 | 68 | 78 | -3% | 0.4 | -7 | -0.5 | -0.4 | -0.2 | -0.01 |
| Fruit Pie (inc. mince) | 96 | 95 | 90 | 101 | 1% | 0.8 | 3 | 0.2 | 0.1 | 0.1 | 0.00 |
| Cake & Gateau Non-Chocolate | 50 | 60 | 55 | 64 | -16% | <0.001 | -38 | -3.6 | -1.5 | -0.6 | -0.03 |
| Swiss Roll | 59 | 93 | 60 | 127 | -37% | 0.05 | -125 | -9.1 | -4.5 | -2.4 | -0.15 |
| **Biscuits** |
| **TOTAL** | **33** | **24** | **19** | **29** | **27%** | **0.003** | **39** | **2.4** | **1.5** | **0.7** | **0.07** |
| Jaffa cakes | 39 | 16 | 10 | 21 | 149% | <0.001 | 87 | 12.1 | 2.0 | 1.1 | 0.03 |
| Savoury biscuits plain | 29 | 17 | 15 | 19 | 69% | <0.001 | 50 | 0.5 | 1.4 | 0.5 | 0.16 |
| Filled non-chocolate | 34 | 22 | 19 | 25 | 53% | <0.001 | 55 | 3.9 | 2.2 | 1.2 | 0.06 |
| Unfilled uncoated | 29 | 19 | 17 | 22 | 51% | <0.001 | 47 | 2.7 | 1.8 | 0.8 | 0.08 |
| Filled chocolate | 33 | 24 | 22 | 26 | 36% | <0.001 | 47 | 3.4 | 2.2 | 1.3 | 0.04 |
| Unfilled coated and/or inclusions | 33 | 28 | 26 | 30 | 18% | <0.001 | 24 | 1.7 | 1.1 | 0.6 | 0.06 |
| Cereal bar | 33 | 28 | 26 | 31 | 16% | <0.001 | 20 | 1.7 | 0.6 | 0.2 | 0.02 |
| Cookies & flapjack | 47 | 40 | 37 | 44 | 16% | <0.001 | 33 | 2.1 | 1.6 | 0.8 | 0.04 |
| Short biscuits | 26 | 24 | 20 | 28 | 9% | 0.4 | 10 | 0.5 | 0.5 | 0.3 | 0.01 |
| Savoury biscuits flavoured | 23 | 23 | 21 | 24 | 0% | 0.6 | 0 | 0.0 | 0.0 | 0.0 | 0.00 |
| **Chocolate** |
| **TOTAL** | **40** | **32** | **31** | **33** | **26%** | **<0.001** | **41** | **4.0** | **2.3** | **1.3** | **0.02** |
| Coated nuts/fruit | 84 | 42 | 36 | 47 | 101% | <0.001 | 205 | 19.0 | 10.8 | 4.9 | 0.13 |
| Chocolate with additions | 45 | 27 | 25 | 30 | 66% | <0.001 | 97 | 8.3 | 5.9 | 3.2 | 0.03 |
| Mars type bar | 48 | 37 | 35 | 39 | 28% | <0.001 | 53 | 5.6 | 2.5 | 1.3 | 0.06 |
| Honeycomb/crunch | 35 | 31 | 28 | 33 | 15% | <0.001 | 21 | 2.1 | 1.1 | 0.7 | 0.01 |
| Crème filled | 38 | 30 | 27 | 34 | 26% | <0.001 | 40 | 4.3 | 2.1 | 1.2 | 0.02 |
| Milk chocolate | 35 | 32 | 30 | 34 | 10% | 0.008 | 16 | 1.6 | 0.9 | 0.6 | 0.01 |
| Caramel | 34 | 32 | 29 | 35 | 6% | 0.3 | 10 | 1.1 | 0.5 | 0.3 | 0.01 |
| Truffles | 26 | 24 | 21 | 27 | 9% | 0.2 | 11 | 0.9 | 0.7 | 0.4 | 0.00 |
| Sugar coated | 39 | 34 | 30 | 38 | 15% | 0.01 | 25 | 3.1 | 1.2 | 0.7 | 0.01 |
| Wafer bar | 31 | 31 | 28 | 33 | 0% | 0.7 | 0 | 0.0 | 0.0 | 0.0 | 0.00 |
| Dark chocolate | 32 | 30 | 27 | 33 | 6% | 0.2 | 11 | 0.7 | 0.8 | 0.5 | 0.00 |
| White chocolate | 31 | 33 | 29 | 38 | -7% | 0.3 | -11 | -1.1 | -0.6 | -0.4 | -0.01 |
| **Crisps** |
| **TOTAL** | **45** | **31** | **30** | **32** | **44%** | **<0.001** | **69** | **0.9** | **3.8** | **0.6** | **0.20** |
| Popcorn | 86 | 34 | 31 | 38 | 151% | <0.001 | 240 | 11.0 | 10.2 | 2.5 | 0.48 |
| Nuts | 77 | 38 | 36 | 39 | 105% | <0.001 | 238 | 3.0 | 19.1 | 3.0 | 0.19 |
| Potato crisps crinkle | 39 | 30 | 29 | 32 | 28% | <0.001 | 45 | 0.2 | 2.6 | 0.3 | 0.14 |
| Tortilla chips | 46 | 34 | 31 | 36 | 37% | <0.001 | 59 | 0.3 | 2.9 | 0.3 | 0.14 |
| Potato snack shapes & puffed | 26 | 24 | 23 | 25 | 8% | <0.001 | 10 | 0.1 | 0.5 | 0.1 | 0.04 |
| Potato and veg crisps std | 31 | 29 | 28 | 30 | 6% | <0.001 | 10 | 0.1 | 0.5 | 0.1 | 0.03 |
| High fat bar snacks | 27 | 31 | 28 | 34 | -12% | 0.01 | -19 | -0.1 | -0.9 | -0.3 | -0.09 |
| Corn and maize snacks | 25 | 26 | 24 | 27 | -2% | 0.3 | -5 | 0.0 | -0.2 | -0.1 | -0.02 |

\* Consumed portion size data was derived from the NDNS 2008-2014 dataset and the on-pack serving size from the commercial UK database (2013) as described in the methods section.

\*\* This was calculated using back-of-pack per 100g nutrition information from the commercial database and finding the average per serve value from all products for each nutrient, using first the on-pack serving size and then the consumed portion size from the NDNS. The difference in the nutritional content between the consumed and the on-pack nutrition per serve was calculated by subtracting one from the other.

## Discussion

In all four energy-dense main food groups over 90% of products had pack-size information, but in the Chocolate group only 35% products had available on-pack serving-size, rising to 79% for the Crisps category. This illustrates that lack of on-pack serving-size guidance is a widespread issue, particularly in some energy-dense snack foods. Unlike the requirement to state pack-size, providing serving-size information is not currently legally required in the UK (Food Standards Agency, 2014) and without an on-pack serving-size consumers may substitute pack-size as a unit of consumption, resulting in over-consumption and excess energy intake. Additionally, this ‘unit bias’ could result in individuals underestimating their consumed portion size, where they recognise that the whole unit is larger than an appropriate portion, but still eat the whole unit (Almiron-Roig, et al., 2018). This is particularly relevant in snack foods, which are the focus of this analysis. Similarly, the nutrition information per serve as displayed on the front-of-pack labelling scheme currently recommended in the UK (Department of Health & Food Standards Agency, 2016) would be based on a lower quantity than consumers are eating, leading to a misleading perception of macronutrient intakes.

Evidence suggests that increasing on-pack single-serves of commercially available foods may normalise larger on-pack serving-sizes, leading to overconsumption and larger consumed portion sizes in home-prepared meals (WHO, 2014b). Consumed portion size was higher than on-pack serving-size in all four main food groups and the majority of subgroups (figure 1). This discrepancy could partly be explained by differences in the products included in the commercial database used to derive on-pack serving-sizes and those included as consumed in the NDNS survey. Yet consumers of these foods could be eating more than the on-pack serving-size, and perhaps consuming multiple single-serve packs in one eating occasion, demonstrating the need for policies and interventions aimed at setting product pack and serving-sizes that help individuals consume smaller portions. In the case of foods in discrete packs, such as single-serve chocolate bars, size reduction may be more effective than requiring consumers to judge appropriate consumed portion sizes. One means of achieving this could be government recommendations for standardised rather than industry-led pack sizes and on-pack serving-sizes, though this is not yet evident in recent discussions on sugar and calorie reduction (Public Health England, 2017b, 2018).

However, further consideration is needed on how consumers understand on-pack serving-size messaging and the interplay between this and front-of-pack labelling and overall pack size. In America, Zhang, Kantor & Juan (2016) found that the different terminologies used in relation to on-pack serving sizes set by manufacturers and both government recommended and typical consumed portion sizes confused consumers. Similarly, Dallas, Liu & Ubel (2015) found that the majority of their American study population incorrectly believed that on-pack serving size information referred to amount that should be consumed for a healthy diet, rather than the amount typically consumed by the average consumer. In addition, consumers exposed to labels with larger on-pack serving sizes ate more than those given the same product with smaller on-pack serving sizes. If on-pack serving sizes were increased to better reflect consumed portion sizes, individuals may increase consumption further, believing this to be in line with official dietary guidance. However, increased on-pack serving sizes that better reflect typical consumed portion sizes may enable consumers to more accurately estimate their energy intake. A recent review (Moore, Donnelly, Jones, & Cade, 2018) found that consumer education to improve label understanding could potentially increase the effect of such information on dietary health.There is a fine balance to be struck in creating realistic, consistent serving-size guidance without encouraging consumers to eat larger portions or multiple units, particularly as consumers may not be using on-pack serving-sizes to guide their intake. Another recent review (Bucher, et al., 2018) concluded that there was insufficient evidence to determine the effect of on-pack serving size labels on consumed portion size. Further work is needed to consider sales volume in addition to eating occasion and intake, in order to fully understand whether smaller pack and serving-sizes lead to lower total consumption and energy/nutrient intake.

The greatest difference between consumed portion size and on-pack serving-size was in Crisps and within this ‘popcorn’, where consumed portion size was respectively 44% and 151% larger than on-pack serving-size. Both the consumed portion size and on-pack serving-size for popcorn are greater than the 25g 1993 government standard portion size. Consumers may have less ability to estimate appropriate consumed portion sizes in these foods, which are often sold in larger packs with no visual or practical serving-size indicator beyond a printed number on the pack. The potential for overconsumption is therefore high – the difference between the on-pack serving-size and consumed portion size for ‘popcorn’ equates to an extra 12% of an adult’s daily recommended energy intake (DoH, 1991; FAO & WHO, 2003) per eating occasion.

Within each food group there was a wide on-pack serving-size range, particularly in Biscuits. This fits with the literature; Lewis et al. (2012) found that UK serving-sizes were highly variable, which could cause consumer confusion. This degree of variability could be caused by the myriad definitions and measurement methods of portion size used in industry, non-Governmental organisations (NGOs) and health bodies (Almiron-Roig, et al., 2018). Industry-based serving-sizes were larger than those set by NGOs and healthcare professionals for biscuits, crisps and chocolate (Lewis, et al., 2012). Considering consumed portion size was generally higher than on-pack serving-size in these analyses, consumers may be over-eating to an even greater degree than initially thought. Updated guidelines are required, but should be realistic and formulated with sensitivity in order to avoid encouraging consumers to further increase consumed portion size.

Official UK portion size advice has not changed since 1993, and in the following 20 years, single-serve pack sizes for many types of cakes, biscuits, chocolate and crisps increased (Clift, 2013; Crawley, 1994). For example, an average American-style muffin was 85 g in the 1993 guidance and 72-130 g in 2013 (Clift, 2013). Our analyses grouped muffins and cupcakes, but when looking solely at muffins in a sensitivity analysis our findings were similar, at a 74 g average serving-size and 12-150 g range, suggesting that the upper serving-size limit has increased.

On-pack serving-size change has occurred at different rates and varies between manufacturers, leaving a lack of understanding of appropriate serving-size and consistent elevation of consumed portion size (Clift, 2013). However, the trend is not linear; recently there has been increasing spotlight on shrinking pack-size, particularly in chocolate confectionary (Office for National Statistics, 2017). This could be a function of the PHRD calorie reduction pledge (DH, 2011), or recent sugar reduction and wider industry reformulation discussions between industry and government, which have included on-pack serving-size reduction as a means of calorie reduction and ‘calorie capping’ (Clift, 2013; Public Health England, 2017b). This may have resulted in pack and serving-size reductions since the data used in these analyses was collected. However, this does not necessarily equate to reduced intakes; smaller units are often sold as multipacks and larger ‘sharer packs’ of some crisp products have become more common (Church, 2008). Both could result in over-consumption; one industry report found that 40% of those aged <25y eat a whole 150 g ‘sharing bag’ of crisps (Brown, 2015); this 150 g pack size is 50% larger than the 1993 guidance (Clift, 2013; Crawley, 1994) and matches the mean pack-size in the present analyses. Additionally, people may consume multiple units from a multipack if a single unit is perceived to be too small.

In their study of six European countries, Hieke et al. (2016) found evidence of a ‘pack-size effect’ where larger packs resulted in larger consumed portion size estimates. Although effect sizes were small, over time this could result in substantial increases in energy intakes, particularly given the extensive gaps in on-pack serving-size information for some food groups in these analyses.

Herman et al. (2016) report that evidence to link excess energy intake to the obesity epidemic via elevated portion size is lacking, stating that other factors like eating frequency may be more significant. They claim most small experimental studies show that large consumed portion sizes increase energy intake by testing this in only one meal; larger studies of average intakes are also cross-sectional, which is insufficient to position portion size as a causal factor for obesity. However, Kelly et al.’s (2009) small experimental study provides evidence for associations over a 4-day period, where adult food consumption and energy intake was significantly higher (14%), with little evidence of compensation, when consuming a larger portion of pre-packed foods. Rolls et al. (2004) also found that energy intake increased, with no compensation, when larger portions of pre-meal snacks were consumed. This suggests that large on-pack serving-sizes in commercially available, particularly snack, foods potentially act as an environmental influence leading to increased energy intake and therefore weight gain.

### Strengths and Limitations

This is an innovative analysis that links consumed portion size and on-pack serving-size. It uses detailed consumed portion sizes of energy dense foods for UK adults aged 19-64y and an extensive set of commercially available on-pack serving-sizes from six major UK food retailers, which are sufficiently representative to justify the conclusions made. We did not have access to data from small convenience stores or snack bars, so cannot guarantee that our analyses are representative of this sector. However, the commercial database used included manufacturer data for products that could potentially be stocked in outlets not included in the analysis. The categorisation of foods by product type for the consumed portion size and the on-pack serving-size of similar products as purchased is aligned as far as possible. It provides a more meaningful assessment of consumed portion size patterns than previous studies, which tend to use broader food groups, where the diversity of foods in each group is higher and therefore comparability is lower (Kirwan, et al., 2016; O'Brien, et al., 2015; Wrieden, et al., 2008), or compare incompatible food groups from previous survey iterations, where the foods within these groups do not correspond across surveys (Kelly, Rennie, et al., 2009).

According to WHO, regulatory policy is needed to reduce commercial serving-sizes in the food environment (WHO, 2014b). Based on a systematic review (Hollands, et al., 2015) that included assessing interventions on on-pack serving-size and pack size, Marteau et al. (2015) argue that policy does not adequately reflect the importance of consumed portion size in obesity and that effective interventions could reduce demand and supply of large pack and serving-sizes, potentially reducing energy intake in UK adults by 12-16% (Marteau, et al., 2015). Similar information from other European countries could be used to help build policy and updated portion size guidance in the UK and across Europe (WHO, 2014b). However, this depends on comprehensive, accessible databases and retailer websites in other European countries. The data used is also cross-sectional, providing a snapshot in time, whereas commercially available products change regularly, leaving on-pack serving-size data outdated.

Another limitation is that this study covers a limited range of energy-dense foods; future work should consider other energy-dense food and drinks such as fast food, breakfast cereals, ice cream, sugar-sweetened beverages or alcohol. In addition, the consumed analyses were restricted to adults aged 19-64y to prevent distortion of results from children or the elderly, who may consume smaller portions. However, this was not possible for the on-pack analyses, where the majority of serving-sizes target all consumers.

Under-reporting presents a limitation in using NDS to assess consumed portion size. Doubly-labelled water (DLW) feasibility studies suggest energy intake in the NDNS 2008-2012 was under-reported by over 30% (Harper & Hallswoth, 2016; Lennox, et al., 2014). Evidence also suggests that under-reporting is higher for energy-dense foods (Piernas & Popkin, 2011; Rasmussen, Matthiessen, Biltoft-Jensen, & Tetens, 2007; Vanrullen, Volatier, Bertaut, Dufour, & Dallongeville, 2014), so the impact on these analyses may be greater than if other food groups had been selected. Therefore, updated guidance may be more robust if based on plausible reporters only, as used in these analyses. Additionally, as food photographs were provided to aid consumed portion size estimation in the NDNS, the risk of large portions being underestimated is reduced. This minimises the likelihood of the exclusion of under-reporters resulting in bias if they tended to consume and underestimate larger portions. There is also evidence that snack foods are associated with lower levels of under-reporting, and that under-reporters of energy intake are more likely omit reporting a food than report a smaller consumed portion size (Vanrullen, et al., 2014).

The accuracy with which under-reporters could be identified was limited by the use of a 1.55 PAL across all individuals in these analyses rather than being estimated per individual, as data was not available to do this. However, 1.55 is an accepted value for a sedentary lifestyle in the populations used (Erlichman, et al., 2001; FAO, et al., 2001; Vanrullen, et al., 2014) and makes analysis of a large number of individuals more feasible. In addition, Rennie et al. (2007) found no significant difference in under-reporter identification when using individual PAL compared to a set cut-off. Yet the European Food Safety Authority (EFSA) continue to recommend including under-reporters to minimise selection bias (EFSA, 2009), so there is likely to be continued discrepancies on the treatment of under-reporters.

## Conclusion

This paper compares commercially available on-pack serving-sizes in commonly consumed energy, fat and sugar-dense snack foods with corresponding consumed portion sizes, by characteristic-based product categories. It explores patterns, highlights areas of difference and discusses the need to update on-pack serving-size or alter pack-size. Most products had pack-size information, but far fewer had on-pack serving-size, particularly Chocolate products. Consumed portion sizes were higher than on-pack serving-size in all four main food groups and the majority of subgroups. The greatest difference between consumed portion size and on-pack serving-size was in Crisps, and within this, ‘popcorn’. Future work could model scenarios based on the relationship between consumed portion size and on-pack serving-size, both nationally and in other European countries, and also in non-discrete foods.

### Author Contributions

All authors have contributed to the concept and design of the research and to the writing and/or revision of the manuscript, and have approved the manuscript for submission.

### Declaration of Interest

The authors declare no conflict of interest. The co-authors Joao Breda and Jo Jewell are staff members of the World Health Organization Regional Office for Europe; however, the authors are responsible for the views expressed in this publication and they do not necessarily represent the decisions or stated policy of WHO.

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