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Is there an association between food portion size and BMI among British adolescents?

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Abbreviations: Food portion size (FPS); Energy intake (EI); Body mass index (BMI); National Diet and Nutrition Survey (NDNS), Basal metabolic rate (BMR)

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Abstract

The prevalence of obesity has increased simultaneously with the increase in the consumption of large food portion sizes (FPS). Studies investigating this association among adolescents are limited; fewer have addressed energy-dense foods as a potential risk factor. In the present study, the association between the portion size of the most energy-dense foods and BMI was investigated. A representative sample of 636 British adolescents (11–18 years) was used from the 2008–2011 UK National Diet and Nutrition Survey. FPS were estimated for the most energy-dense foods (those containing above 10·5 kJ/g (2·5 kcal/g)). Regression models with BMI as the outcome variable were adjusted for age, sex and misreporting energy intake (EI). A positive association was observed between total EI and BMI. For each 418 kJ (100 kcal) increase in EI, BMI increased by 0·19 kg/m2 (95% CI 0·10, 0·28; P,0·001) for the whole sample. This association remained significant after stratifying the sample by misreporting. The portion sizes of a limited number of high-energy-dense foods (high-fibre breakfast cereals, cream and high-energy soft drinks (carbonated)) were found to be positively associated with a higher BMI among all adolescents after adjusting for misreporting. When eliminating the effect of under-reporting, larger portion sizes of a number of high-energy-dense foods (biscuits, cheese, cream and cakes) were found to be positively associated with BMI among normal reporters. The portion sizes of only high-fibre breakfast cereals and high-energy soft drinks (carbonated) were found to be positively associated with BMI among under-reporters. These findings emphasise the importance of considering under-reporting when analysing adolescents' dietary intake data. Also, there is a need to address adolescents' awareness of portion sizes of energy-dense foods to improve their food choice and future health outcomes.

Introduction

The prevalence of obesity has increased all over the world, particularly in England, where it has more than doubled in the last 25 years. In 2011, three in ten boys and girls were classified as overweight or obese (31% and 28% respectively) [(1)]. Obesity is considered to have adverse implications for health, with higher risk of morbidity and mortality as obese adolescents become obese adults [(2)]. Although weight gain is commonly understood to be a result of the balance between what people eat and how much they exercise [(3)], growing research points to food intake as the primary cause of the obesity epidemic [(4)]. As such, there is an urgent need to identify important nutrition-related risk factors for obesity [(5)].

Many dietary factors can directly or indirectly influence the balance of energy intake (EI) and thus affect weight gain[(3)]. However, evidence of specific dietary factors that promote excessive weight in children and adolescents is more limited than for adults [(6)]. Total grams of food, sweetened beverages, sweet, low-nutritional foods, and portion size during dinner, are the main determinants of obesity in American young people according to one study [(7)]. The last decade witnessed marked increases in the portion size of many foods. According to data from the US Nationwide Food Consumption Survey, between 1977 and 1998, the energy content of salty snacks increased by 389kJ (93kcal); soft-drinks increased by 205kJ (49kcal); hamburgers by 406 kJ (97kcal); and French fries by 285 kJ (68kcal) per portion[(8)]. A similar trend in food portion sizes (FPS) consumption has also been observed in the Netherlands [(9)] and the UK[(10, 11)], but there is less direct evidence from these countries.

As the trend of consuming larger food portions has occurred at the same time as the increase in the prevalence of obesity, investigation of FPS as a potential health risk factor leading to obesity is required[(12)]. It is often assumed that obese adolescents eat more fast food and energy-dense foods than adolescents of normal weight. However, there is little evidence to support this belief [(13, 14)].

The energy density of food is defined as the number of kJ in a given weight of food (kJ/g) (15). The World Cancer Research Fund UK (16) has classified foods that contain more than 941–1151 kJ/100 g (225–275 kcal/100 g) as high-energy-dense foods, normally due to high fat and/or sugar content and low fibre and water content. Foods that contain 418–941 kJ/100 g (100–225 kcal/100 g) are defined as medium-energy-dense foods and foods that contain 251–628 kJ/100 g (60–150 kcal/100 g) are defined as low-energy-dense foods. Larger portion sizes of energy-dense foods are more likely to increase EI beyond requirements [17, 18]. Furthermore, the high palatability of energy-dense foods may lead to greater consumption of these foods [14].

Several experimental studies have provided evidence of a relationship between FPS and EI [17, 18, 19], however epidemiological studies on the relationship between FPS and weight gain are limited [12, 20], particularly among adolescents [5]. Some studies considered only snack foods [21], fast foods, or sugar-sweetened beverages [22, 23], while some have investigated the general trends of FPS over time[10, 24]. Epidemiological studies that address the association between high energy-dense foods and weight gain need to be examined [20]. Although cross-sectional studies by their nature cannot prove causality, using nationally representative data with adjustment for potential confounders can provide useful information on the relationships between diet and health where longitudinal and trial data are unavailable [12, 13, 14, 23]. Therefore, the present study is the first to assess the relationship between portion sizes of energy-dense foods and BMI among British adolescents aged 11–18 years using data from the newly updated National Diet and Nutrition Survey (NDNS) for 3 years combined (from 2008 to 2011).

Methodology

National Diet and Nutrition Survey data

NDNS data were obtained from the UK Data Archive, University of Essex [25]. The NDNS data on adolescents aged 11-18 years are part of a rolling programme of government-commissioned surveys of different age groups of the free living British population. This cross-sectional survey has an advanced sample design intended to obtain a nationally representative sample of British adolescents. The survey design and sampling frame work have been described in greater detail in published reports [26]. A total of 666 adolescents participated in the NDNS from 2008 to 2011, (218, 222 and 196 in each year respectively). Of these participants, twenty (3%) were excluded, as their weight or height was not reported and ten (2%) were excluded due to reporting being on a weight-loss diet during the study, and thus potentially avoiding the intake of high-energy foods. The final sample included 636 respondents.

Dietary methods

A 4d estimated food diary was used in the 2008-2011 NDNS. Adolescents aged ≥12 years were encouraged to complete the diary by themselves. Participants were asked to keep a record of everything eaten or drunk over four consecutive days at home and away from home using household measurements (pictures of actual size spoons and glasses were provided to aid accurate recording). Also, to enhance the accuracy of the estimation of FPS, a young person's photo food atlas [27, 28] was used in the group that reported its dietary intake in 2010-2011. Trained interviewers demonstrated procedures and visited each participant three times to review the diary, deal with problems, and edit possible omissions and missing detail. In the 2008–2011 NDNS, food items were categorised into one of the ten food types, fifty food groups and 140 subfood groups; details regarding the components of each category have been published in previous reports [29]. The top twenty high-energy-dense subfood groups (from here on referred to as food groups) were used to calculate FPS, and these are defined in online supplementary table Appendix 1. Food and nutrient intakes were calculated based on McCance and Widdowson's Composition of Food series (6th edition)[30] and manufacturers' data where applicable[26].

Food portion size

In the present study, the method used by Wrieden et al[31] was followed to calculate FPS. For each participant, the mean portion size of each food group was calculated by dividing the total weight of the food consumed by the frequency of consumption. So each subject contributed a single portion weight to avoid the possibility of participants who eat a certain food more frequently than others skewing the data [31]. For example, if participants consumed white bread two times in the 1st day and three times in 2nd day, then the total grams of white bread consumed over the 2d would be divided by 5.

Energy-dense food

To determine the energy-density of food groups, the total energy of each food group portion was divided by total grams of food consumed [15, 32]. Food groups that contained above 10·5 kJ/g (at least 2·5 kcal/g) were used in the present study as a cut-off point based on World Cancer Research Fund classification and beverages that contained .1·7 kJ/ml (at least 0·4 kcal/ml) were the focus of the analysis.

Although beverages contain less energy per ml (it is known that water has the greatest impact on the energy density of foods, adding substantial weight without adding energy [18]), they too were tested, due to their contribution to adolescents' total EI being high, at 9% according to the 2008–2011 NDNS(SA Albar, NA Alwan, CEL Evans and JE Cade, unpublished results). All types of fats (polyunsaturated oils, cooking fats and oils (not PUFA), butter, reduced-fat spreads (not PUFA) and low-fat spreads (polyunsaturated)) were combined together in one food group as the number of adolescents consuming individual items from this food group was small.

Anthropometric measurements

The height and weight of the participants were measured to the nearest 0.1 cm and kg by trained interviewers. BMI was calculated using Quetelet's formula (weight (kg)/ height (m^2)). BMI was classified on the basis of the growth values of UK children (UK 1990 reference values). Adolescents were classified as obese if their BMI was >95th centile and overweight if their BMI was >85th and ≤95th centile according to sex and age [(33)].

Misreporting

To reduce the impact of misreporting EI on the association between FPS and BMI, misreporting was calculated. It was based on the principle that an individual of a given sex, age and body weight has a minimum EI and that an intake below this EI has adverse effects on habitual intake and long term survival. The body weight of adolescents was used to determine their BMR using the standard equations of Schofield[(34)] for each sex. Cut-off points based on multiples of BMR with minimum (1.39 & 1.30) and maximum (2.24 & 2.10) cut-off points (MJ/d) for males and females respectively, were used to identify probable under-reporters. These cut-offs were proposed by Torun et al. [(35)] for use among adolescents. This was considered to be the most practical and suitable approach due to there being no data available regarding the physical activity of adolescents.

Statistical analysis

Analyses were carried out using Stata statistical software release 12 (Stata Corporation), with a P value < 0.05 representing statistical significance for all tests. Descriptive statistics were used to describe general characteristics, EI and macronutrients, and FPS for all adolescents and the whole sample stratified by weight status.

The associations between BMI as a continuous variable and total EI and macronutrients intake was investigated, adjusting for important confounders (age, sex and misreporting EI) using multivariable regression (model 1).

Multivariable regression analysis was carried out using FPS for each energy-dense food group to investigate the association between BMI as the dependent variable and FPS as the independent variable, adjusting for age, sex, and misreporting (model 2). A stratified analysis was also carried out, splitting the sample into two groups, normal reporters and under-reporters (model 3), to determine any potential effect of under-reporting on the associations under investigation.

Results

Sample characteristics

A total of 636 adolescents aged 11-18 years old were included in the study. The majority (88%) were of White European origin. The average age of the participants was 15 years, and 52% were males. Among those included, 2% were vegetarian (Table 1). An association between BMI, age, and sex was observed. When age increased by 1 year, BMI increased by 0.45 kg/m^2 (95% CI: 0.31 to 0.59; P<0.001). Females had higher BMI by 0.89 kg/m^2 than males (95% CI: 0.21 to 1.56; P <0.01). The percentage of misreporting was high at 73%,

Association between BMI and energy intake

The total mean EI of UK adolescents aged 11–18 years was 7527 kJ/d; 95% CI 7364, 7686 kJ (1799 kcal/d; 95% CI 1760, 1837 kcal). A significant association was observed between total EI (kJ) and BMI after adjusting for age, sex and misreporting EI. For each additional 418 kJ (100 kcal) in the adolescent diet, BMI increased by 0·19 kg/m2 (95% CI 0·10, 0·28; P,0·001). After stratifying the sample by normal reporters and under-reporters, a significant association was observed between EI and BMI in both groups, but the association was stronger among normal reporters (Table 2).

There was a significant positive association between BMI and intake of protein, fat, carbohydrates and total sugars among all adolescents and normal reporters. The association was stronger among normal reporters than in the whole sample. However, the association was only significant for total EI among under-reporters.

Association between BMI and portion size of the most energy-dense foods

In the NDNS, twenty food groups were defined as energy dense, with a minimum density of 10·5 kJ/g (2·5 kcal/g). Half of these foods (ten food items) were considered as foods that are commonly consumed by adolescents (Fig. 1). At least 20% of the sample consumed these foods. The mean and 95% CI of each FPS are summarised in Table 3 for all adolescents, normal-weight adolescents and overweight/obese adolescents. The average portion size of some energy-dense foods such as chocolate confectionery, ‘buns cakes and pastries’ (from here on referred to as cakes) and cheese was found to be higher among normal-weight adolescents than among overweight/obese adolescents.

A positive association was observed between portion size and BMI for a number of energy-dense foods (Table 4). For the whole sample, the portion sizes of only two food groups, cream and high-fibre breakfast cereals, were positively associated with a higher BMI after adjusting for age, sex and misreporting. The number of food groups significantly associated with BMI was higher among normal reporters, with a significant positive association being observed for four of the top twenty energy-dense food groups. The portion sizes of biscuits, cheese, cakes and cream were significantly associated with BMI. For example, for each 10 g of biscuits, cheese or cakes consumed, BMI increased by 0·28, 0·26 and 0·19 kg/m2, respectively. Among under-reporters, the association was significant for the portion size of only high-fibre breakfast cereals. A statistically significant association was observed between portion size and BMI for a limited number of high-energy-dense food types.

Association between BMI and portion size of beverages

The portion size of high-energy soft drinks (carbonated) was positively associated with BMI. This was significant among all adolescents after adjusting for age, sex, and misreporting, as well as among under-reporters; however, there was no association between beverage portion size and BMI among normal reporters (Table 5). The portion size of the food group ‘Other milk’ (which includes flavoured milk and hot chocolate) was negatively associated with the BMI of adolescents.

Discussion

The findings of the present study indicate a positive association between BMI and total EI and macronutrient intake. After stratifying the sample by misreporting, a stronger association was observed in normal reporters than in under-reporters. Similar findings were recorded when the association between weight and EI was tested (data not shown), as some may argue that individuals with a larger body size require a higher EI. However, BMI is a better measure of adiposity for all childhood age groups, and the advantage of using BMI raw values is that arbitrary cut points are not required to define obesity [(36)]. Furthermore, exclusion of misreporters provides the most appropriate model to examine cross-sectional associations between EI and BMI [(37)]. Cross-sectional surveys of adolescents have reported contradictory results on the association between EI and BMI; for example, in the large National Health and Nutrition Examination Survey study, overweight and obese adolescents reported consuming lesser energy than their normal-weight peers[(38)]. Similar to these findings, an Australian study of 2460 boys and girls aged 5-17 years has reported that BMI z-score is weakly but significantly associated with total EI among all age groups when misreporting is taken into account [(39)].

Among the few longitudinal studies carried out in adolescents [(14)], a study comprising 6149 girls and 4620 boys aged 9–14 years from across the USA has found that EI during 1 year is positively associated with an increase in BMI (kg/m^2) when taking growth and development into account [(36)].

The average EI reported in the NDNS series is consistently less the level indicated by the estimated average requirements [(40)]. In reality, average EI in the UK adolescents is more likely to exceed energy needs, as the evidence shows that the number of adolescents who are classified as overweight and obese is increasing. Thus, under-reporting of food intake may explain this paradox[(40)]. All current methods of dietary intake assessment are prone to error although research is ongoing to find more valid methods for this age group.

Some studies that have investigated the relationship between BMI and diet composition suggest that the macronutrient (protein, carbohydrates and fat) may play an important role in the development of obesity in young people[(41, 42)]. However, conflicting results have been reported[(14)]. One study has demonstrated that obese adolescents consume more energy from fat and protein, and less from carbohydrates, when compared with normal-weight adolescents[(13)]. In the percent study, total intakes from fat, carbohydrates, protein, and sugar (in g), was found to be positively associated with BMI in the whole sample and normal-reporters only. There was no association between the percentage of EI from each macronutrient and BMI in either of these groups. Neither of these associations was observed in under-reporters. This is in agreement with the findings of a study carried out by Elliott et al.[39], in which no evidence for an association between BMI and percentage of EI from fat, carbohydrates and protein was found, although participants with a higher BMI consumed significantly more energy than lean counterparts.

The present results indicated that the lack of an association between the percentage of EI from macronutrients and BMI was not a direct result of misreporting, and it is more likely that EI influences the development of obesity rather than the source of energy. Similarly, one longitudinal study has also found no significant relationship between the percentage EI from any macronutrient and weight gain[43]. In Germany, different dietary patterns during childhood and adolescence could not explain the development of obesity in a long term evaluation [44, 45].

The portion sizes of only a limited number of food groups among the twenty most energy-dense food groups were positively associated with BMI in the whole sample, and there were differences between normal reporters and under-reporters. The portion sizes of biscuits, cakes and cheese were significantly positively associated with BMI in normal reporters but not in under-reporters. The portion sizes of cream and high-fibre breakfast cereals were positively associated with BMI among all adolescents, and a significant association was observed in under-reporters for the latter food group. The portion size of carbonated soft drinks (not low energy) was positively associated with BMI among all adolescents and under-reporters but not among normal reporters.

Similarly, a cross-sectional study of young French children showed that overweight in children was positively correlated with the portion size of biscuits and sweetened pastries[12]. Additionally, positive trends were observed for croissant-like pastries and other sweetened pastries, although they were not significant[12]. According to Church [10] there have been minimal changes in the weight of traditional biscuits and cakes in the UK since the 1990s. However, luxury cookies and those from retail food service outlets are larger than traditional ones (traditional cookies have a weight of 10g to 12g, while a luxury cookie, e.g. that of Starbucks, weighs about 110g) and they are likely to be more energy dense than traditional ones[10]. Also, there is some evidence of an increase in the range of confectionary items available in king and giant size in the UK[24]. In fact, when provided in large portion sizes, this food choice could significantly contribute to weight gain[46].

Moreover, the portion sizes of other foods such as savoury snacks and confectionery were found to be not associated with BMI, which may be because these foods are sold in small or standard portion sizes, so all adolescents consumed similar portion sizes of these foods. Other researchers have found no statistically significant difference in the number of savoury snack servings/d between obese and normal-weight children [8 – 10, 47]. In one study, EI from candy, packed goods and ice cream has been found to be significantly greater in normal-weight adolescents than in obese although under reporting cannot be ruled out [13].

Although consumption of ready-to-eat cereals has been reported to be associated with a lower BMI in children aged 4-12 years [48] and adults 35-64 years [49], in the present study, we found that the portion size of high-fibre breakfast cereal was positively associated with BMI among all adolescents and under-reporters and not significantly associated among normal reporters. This may be because of the incorporation of nuts, honey, sugar and fruit in the high-fibre breakfast cereals, which made them more energy dense. This was also perhaps due to under-reporters being more likely to be overweight or obese than normal reporters; this has also been found in other studies[50]. Obese under-reporters may be more likely to be following or at least report eating a healthy diet at the time data were collected. A previous study [21] has found no differences in reported breakfast cereal and savoury snack intake between normal-weight and overweight participants using NDNS-1997 and Northern Ireland-2005 data. However, this may be because the authors did not consider confounders in their analysis.

With regards to beverages, the scientific literature on the effects of carbonated soft drink (not low energy) consumption in relation to obesity is varied. Several reviews have provided evidence regarding the hypothesis that increased energy from sweetened beverages leads to increased weight. However, results of trials to reduce sugar sweetened beverage intake and effect on risk of obesity are inconsistent in children, perhaps due to a failure to control for confounders and methodological limitations[51-54]. Similar to the findings of the present study, other cross-sectional studies have reported significant positive associations between soft drink and BMI [55-58] but the strength of the association is generally attenuated compared to results from longitudinal studies [59- 61].

In the USA, sweetened drinks (soda, energy drinks and sports drinks) are the top energy source in the adolescent diet (946 kJ (226 kcal)/d)[62]. In the UK, the contribution of non-alcoholic beverages to EI increased from 7% in 1997 to 9% in 2008-2011, of which soft drinks (not low energy) were the largest contributors (SA Albar, NA Alwan, CEL Evans and JE Cade, unpublished results). In a prospective, observational analysis, it has been found that with each additional 12oz soda that children consumed a day, the odds of becoming obese over 1.5 years increased by 60% after follow-up[59]. According to Glickman et al.[62] the rising consumption of sweetened drinks has been a major contributor in the obesity epidemic. The intake of liquid carbohydrates, or "liquid candy", causes less satiety compared with that of solid carbohydrates, which leads to an increase in total long-term EI as energy from liquids may not be compensated by subsequent meals [63, 64].

Milk is promoted as a healthy beverage. However, some researchers believe that protein in dairy products may cause weight gain[65]. Others state that dairy Ca promotes weight loss[66]. The results in the present study indicated that the portion sizes of other milk products (e.g. soya milk, goats, sheeps, condensed, dried milk) were inversely associated with BMI among all adolescents and under-reporters, but we did not see the same trend with plain whole milk or semi-skimmed milk. A French cross-sectional study found that the portion size of liquid dairy products (milk, milk-shakes and yogurt drinks) are negatively associated with overweight children (aged 7-11 years)[12]. Conversely, the portion size of cheese was found to be positively associated with BMI among normal reporter adolescents in the present study. A longitudinal US study among 12829 adolescents aged 11-14 years concluded that drinking large amounts of milk, skimmed milk and dairy Ca may provide excess energy resulting in an increase in body weight[65]. Further research is needed to investigate and explain the role of dairy intake in obesity risk.

Although in the present study self-reported dieters were excluded and adjustment for misreporting was undertaken in the whole sample, the portion size of a limited number of food groups were found to be associated with BMI. This may be due to several factors. Obese adolescents and even adolescents of normal weight tend to underestimate their dietary intake, either consciously or unconsciously [67, 68]; and they are frequently on a special diet to control their body weight [14]. Additionally, the study sample may still include adolescents who might have limited their food intake during the study without declaring it. Research suggests that people report or under-report the intake of food that is perceived to be unhealthy or associated with obesity[70]. From Table 3, it can be observed that the average portion sizes of some energy-dense foods consumed by normal-weight adolescents were larger than those consumed by overweight/obese adolescents. Furthermore, the findings of the present study did not indicate an association between the percentage of EI from macronutrients and BMI, which may explain why fewer associations were observed between the portion sizes of high-energy-dense foods and BMI in the whole sample.

The present study has notable limitations. First, the crosssectional nature of the study prevented the determination of the direction of association. A high percentage of under-reporters were observed, and this had been previously reported in the 1997 NDNS [70]. among adolescents, where a weighed record was used. Estimated FPS have been used in the recent NDNS (2008-2011) to minimise respondent burden; however, that may have reduced the accuracy of the portion sizes reported. Measuring young people's dietary intake is challenging and less likely to give accurate FPS[50]. Adolescents are less interested, less motivated and less cooperative compared with other age groups [50, 71]. However, it has been found that adolescents preferred dietary intake assessment methods that use new technology over the pen-and-paper method[72]. Tailoring dietary intake assessment methods to the specific needs of the population under investigation will greatly improve the accuracy of dietary records[28]. Thus, further work is required to develop and test dietary assessment methods that use new technology to obtain better quality and more accurate dietary records from adolescents.

An additional limitation is the lack of consensus in the definition of high-energy-dense foods and beverages. The British Nutrition Foundation has classified foods that contain 0–2·5 kJ/g (0–0·6 kcal/g) as very-low-energy-dense foods; 2·55–6·3 kJ/g (0·61–1·5 kcal/g) as low; 6·7–17 kJ/g (1·6–4 kcal/g) as medium; and 17·1–38 kJ/g (4·1–9 kcal/g) as high[73]. However, the medium and high classifications are wider than the World Cancer Research Fund classification, which considers foods that contain more than 9·41–11·50 kJ/g (2·25–2·75 kcal/g) as high-energy-dense foods. Therefore, there is a need for more research to identify clear cut-off points of both energy-dense foods and beverages, due to the contribution of beverages to adolescents' EI.

Nevertheless, in the present study, new nationally representative data of British adolescents (NDNS 2008–2011) were used. To our knowledge, the present study is the first to examine the epidemiological relationship between the portion size of energy-dense foods and BMI among British adolescents. Other potential confounders such as age, sex and misreporting EI were taken into account and all adolescents who were dieting to lose weight were excluded to reduce the risk of bias. Also, data were stratified by misreporting to explore any potential effects of under-reporting. Therefore, the present study provides a useful insight into the association between the portion size of energy-dense foods and obesity and emphasises the importance of considering misreporting when assessing possible associations between dietary intake and variables of interest. Prospective studies with physical activity data are needed to confirm our findings.

Conclusion

In the present study carried out using a nationally representative sample of British adolescents, EI was found to more likely influence the development of obesity than the source of energy. This was significant after adjusting for misreporting and also after stratifying the sample into normal reporters and under-reporters. The portion sizes of a limited number of high-energy-dense foods (high-fibre breakfast cereals, cream and carbonated high-energy soft drinks) were found to be associated with a higher BMI among all adolescents. However, when eliminating the effect of under-reporting, larger portion sizes of a number of high-energy-dense foods, including biscuits, cheese, cream and cakes, were found to be associated with a higher BMI. The portion sizes of only high-fibre breakfast cereals and carbonated high-energy soft drinks were found to be associated with BMI among under-reporters. These findings emphasise the importance of considering under-reporting when analysing adolescents' dietary intake data as it is prone to reporting error. Further improvements in dietary intake assessment methods among adolescents are required. Moreover, multiple approaches directed at adolescents to enhance their food choices and portion sizes of high-energy-dense food are necessary to prevent and control obesity among all adolescents.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S0007114514001548

Acknowledgments

S. A. A. designed the study, analysed and interpreted the data and wrote the manuscript. J. E. C., N.A.A. and C.E.L.E. assisted in designing the study and interpreting the data. All authors have reviewed and approved the final manuscript. The authors declare that there is no conflict of interest. Funding: S.A.A. is in receipt of a scholarship from King Abdul-Aziz University, Jeddah, Saudi Arabia.

Tables

Table 1: General characteristics and dietary intake for all adolescents (11-18 years) who participated in the National Diet and Nutrition Survey (Mean values and 95% confidence intervals)

	All adolescents (n 636)		Normal weight adolescents (n 418)		Overweight and obese adolescents (n 218)	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
General characteristics						
Age (years)*	14.6	14.4, 14.8	14.8	14.6, 15	14.2	13.9, 14.5
Height (m)	164.2	163.3, 165	164.4	163.4, 165.5	163.6	162.2, 165
Weight (kg)	59.3	58.1, 60.5	53.5	52.5, 54.6	70.5	68.3, 72.6
BMI(kg/m2)	21.8	21.5, 22.1	19.6	19.4, 19.8	26.1	25.5, 26.6
Waist circumference	57.1	54.4, 59.7	53.1	49.9, 56.2	64.8	59.7, 69.9
Female † (%)	48.4	45.0, 52.3	47.6	42.8, 52.4	50.0	43.3, 56.6
Ethnicity						
White (%)	88.2	85.6, 90.7	87.1	83.8, 90.3	90.4	86.4, 94.3
Vegetarian (%)	2.0	0.9, 3.1	2.2	0.7, 3.5	1.8	0.03, 0.04
Under-reporter EI *(%)	73.1	69.7,76.5	66.3	61.7, 70.8	86.2	81.6, 90.8
Dietary characteristics						
Total energy						
kcal	1798	1759, 1837	2251	2183, 2319	1633	1596, 1669
kJ	7573	7411, 7736	7654	7458, 7849	7419	7127, 7712
Protein (g)	66	64.6, 67.7	66.6	65, 68.5	65	63, 68
% Energy from Protein	15	15, 15	15	14.5, 15	15	14.7, 15.5
Fat (g)	68	66, 70	68.9	67, 71	66	63, 69
% Energy from Fat	34	34, 34	34	34, 35	34	33, 34
Carbohydrate (g)	241	235, 246	243	237, 250	236	227, 245
% Energy from carbohydrate	50	50, 51	50	50, 51	50.5	50, 51
Total sugars (g)	105	101, 108	107	102, 111	101	95, 107
% Energy from total sugar	22	21, 22	22	22, 23	21	21, 22

EI, energy intake.
*Significant differences between normal-weight and overweight adolescents ($P < 0·01$).

†Significant differences between normal-weight and overweight ($P < 0·001$).

Table 2: Associations between BMI and total energy intake and intake of macronutrients*

Energy and macronutrients /d	All adolescents † (n 636)			Normal reporters ‡ (n 171)			Under reporter‡ (n 465)		
	Change in BMI§	95% CI	P	Change in BMI	95% CI	P	Change in BMI	95% CI	P
Total energy									
kcal	0.189	0.100, 0.278	0.001	0.353	0.233, 0.474	0.001	0.126	0.011, 0.241	0.032
kJ	0·791	0·418, 1·163	0·004	1·477	0·975, 1·983	0·004	0·527	0·046, 1·008	0·134
Protein (g)	0.029	0.010, 0.048	0.003	0.042	0.015, 0.070	0.003	0.023	-0.001, 0.0475	0.058
% Energy from Protein/d	0.003	-0.110, 0.116	0.955	-0.111	-0.282, 0.085	0.212	0.038	-0.108,0.166	0.584
Fat (g)	0.035	0.016, 0 052	0.001	0.059	0.037, 0.082	0.001	0.020	-0.002, 0.046	0.070
% Energy from Fat/d	0.026	-0.038, 0.090	0.416	0.068	-0.029, 0.164	0.168	0.015	-0.065,0.094	0.717
Carbohydrate (g)	0.009	0.003, 0.015	0.002	0.015	0.008, 0.022	0.001	0.006	-0.002, 0.014	0.123
% Energy from carbohydrate	-0.033	-0.090, 0.024	0.263	-0.018	-0.099, 0.063	0.661	-0.035	-0.107, 0.037	0.346
Total sugars(g)	0.009	0.000, 0.0168	0.043	0.016	0.007, 0.025	0.001	0.003	-0.009, 0.0143	0.647
% Energy from Total sugar	-0.029	-0.077, 0.019	0.246	0.039	-0.029, 0.109	0.258	-0.051	-0.111, 0.009	0.101

*From food source only
† Age-, sex- and misreporting-adjusted regression (model 1).
‡ Age- and sex-adjusted regression (model 3).
§ Changes in BMI (kg/m2) per each 418 kJ or 1 g of macronutrients.

Fig. 1. The twenty most energy-dense food groups, in order of increasing energy density, consumed by British adolescents and their contribution to the average energy intake (EI) of a consumer only. ☐, Percentage of food groups contributing to EI; ■, energy density of food (kcal/g; 1 kcal = 4·2 kJ).* Most commonly consumed foods by adolescents.

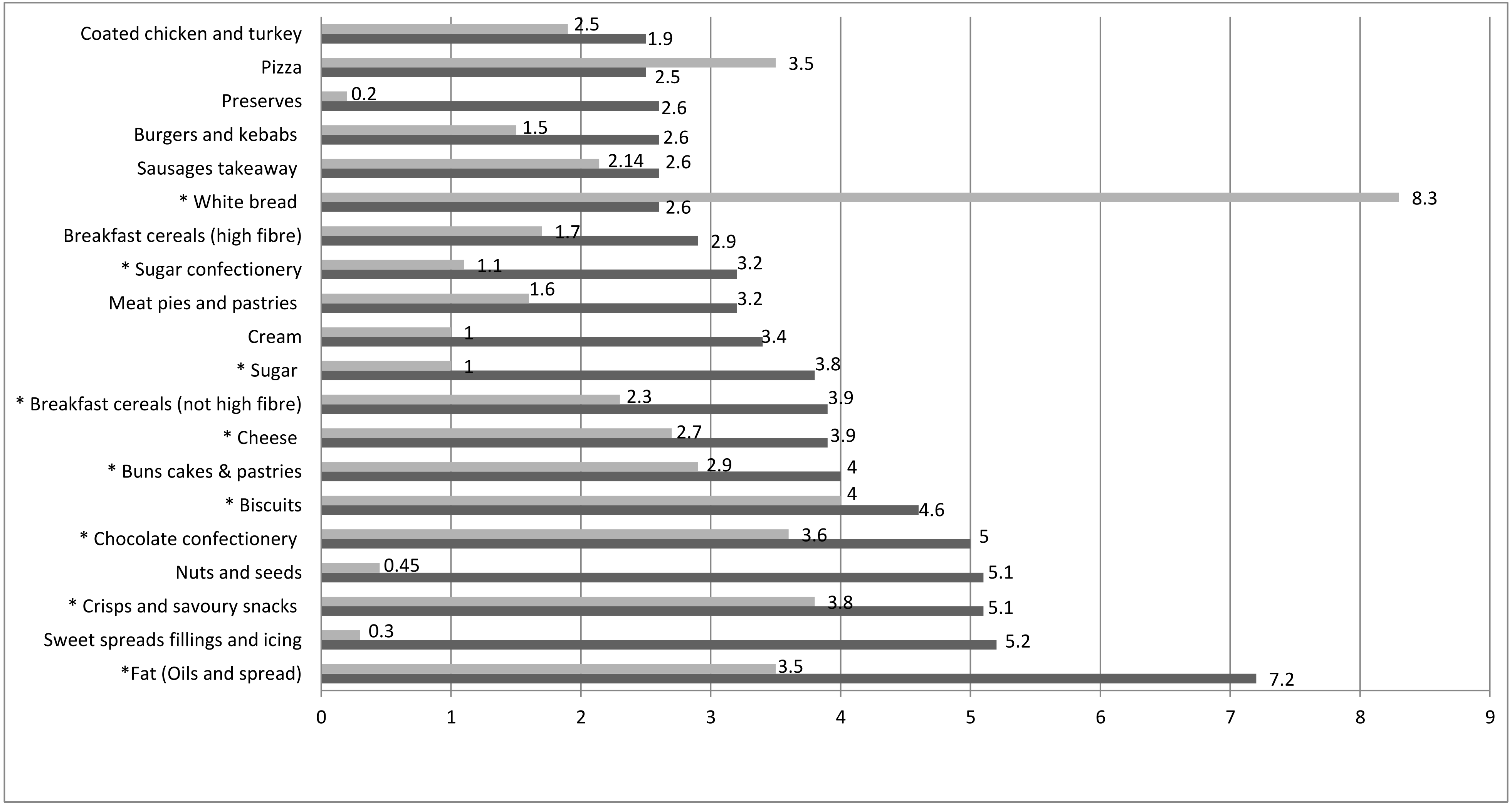

Table 3. Food portion size (g) and beverage portion size (ml) for all adolescents (11–18 years) who participated in the National Diet and Nutrition Survey*
(Number of adolescents who consumed this food, mean values and 95% confidence intervals)

Food groups (g)†	All adolescents			Normal-weight adolescents			Overweight adolescents		
	n	Mean	95% CI	n	Mean	95% CI	n	Mean	95% CI
Fat (oils and spreads)	636	10.7	10.3, 11.2	418	10.9	10.3, 11.5	218	10.3	9.6, 11.1
Sweet spreads fillings and icing	60	23.2	19.3, 27.2	44	24.8	19.5, 29.9	16	19.1	15.4, 22.7
Crisps and savoury snacks	447	30.2	28.6, 31.6	294	30.2	28.5, 31.8	153	27.8	27.8, 32.9
Nuts and seeds	85	28.7	23.4, 33.9	60	27.6	21.2, 34.0	25	31.2	21.4, 41.1
Chocolate confectionery	378	39.3	35.7, 42.8	246	40.5	35.3, 45.8	132	36.9	34.0, 39.9
Biscuits	385	37.4	34.6, 40.2	256	36.3	33.7, 38.9	129	39.4	33.0, 45.9
Buns cakes & pastries	344	64.9	61.1, 68.8	222	66.4	61.6, 71.1	122	62.3	55.5, 68.9
Cheese	418	37.0	34.8, 39.1	261	38.2	35.3, 41.0	157	34.9	31.5, 38.4
Breakfast cereals (not high fibre)	285	39.8	38.0, 41.5	191	40.8	38.7, 42.9	94	37.7	34.8, 40.6
Sugar	335	10.0	9.3, 10.7	222	10.5	9.6, 11.4	113	9.1	7.9, 10.2
Cream	66	32.1	27.1, 37.1	43	30.5	24.7, 36.4	23	35.1	25.3, 44.9
Meat pies and pastries	141	115.0	104.1, 125.9	90	116.8	102.7, 130.8	51	111.8	94.0, 129.7
Sugar confectionery	229	42.2	36.7, 47.7	140	46.8	39.5, 54.1	89	35	26.8, 43.1
High-fibre breakfast cereals	221	53.7	48.1, 59.4	149	52.4	45.8, 59.1	72	56.4	45.6, 67.1
Preserves	95	20.0	17.8, 22.3	71	20.2	17.4, 23.0	24	19.5	16.0, 23.0
Sausages	240	112.5	105.1, 119.9	157	118.4	108.8, 127.9	83	101.4	89.9, 112.8
Burgers and kebabs purchased	151	138.5	127.0, 149.8	94	136.5	122.7, 150.4	57	141.6	121.3, 161.9
White bread	556	72.3	69.9, 74.8	357	72.9	69.7, 75.9	199	71.4	67.4, 75.4
Pizza	233	206.5	188.0, 224.9	158	213.4	189.0,237.8	75	191.9	166.3, 217.6
Coated chicken and turkey	209	118.8	111.5, 126.0	136	117.6	108.5, 126.8	73	120.9	108.6, 133.2
Beverages (ml)									
Other milk	88	288.9	254.0, 323.9	63	295.8	254.2, 337.4	25	271.7	203.2, 340.3
Whole milk	133	143.3	126.7, 159.8	99	139.8	121.5, 158.1	34	153.4	115.0, 191.7
Semi skimmed milk	420	116.9	109.9, 124.0	272	116.3	107.9, 124.8	148	118.1	105.3, 130.9
Carbonated soft drinks (not low energy)	401	337.4	326.4, 348.5	266	332.7	319.6, 345.9	135	346.8	326.5, 367.0
Fruit juice (100%)	315	241.9	227.4, 256.5	212	236.4	220.4, 252.3	103	253.4	222.9, 283.9
Citrus fruit not canned	115	95.1	84.7, 105.6	72	100.7	86.8, 114.7	43	85.8	70.1, 101.4

*No adjustments for under-reporting were made.
† Information about food group classification is given in online supplementary Appendix 1.

Table 4. Association between BMI and portion size of each of the twenty most energy-dense foods consumed by adolescents (Number of adolescents, change in BMI values and 95% confidence intervals)

			All adolescents*			Normal reporter†				Under-reporters†			
Food groups (10 g)	ED‡	n	Changes in BMI§	95% CI	P	n	Changes in BMI§	95% CI	P	n	Changes in BMI§	95% CI	P
Fat (Oils & spread)	7.2	636	0.920	-0.25, 2.1	0.86	171	0.102	-0.32, 0.52	0.63	465	0.168	-0.33,0.66	0.51
Sweet spreads fillings and icing	5.2	60	-0.175	-0.66, 0.31	0.47	26	-0.317	-1.4, 0.72	0.53	34	0.033	-0.65, 0.72	0.92
Crisps and savoury snacks	5.1	447	0.121	-0.13, 0.38	0.35	140	-0.003	-0.32, 0.31	0.98	307	0.152	-0.19, 0.49	0.38
Nuts and seeds	5.1	85	0.102	-0.16, 0.36	0.44	34	-0.111	-0.60, 0.38	0.65	51	0.164	-0.16, 0.50	0.32
Chocolate confectionery	5.0	378	0.025	-0.09, 0.14	0.66	128	0.062	-0.09, 0.22	0.43	250	0.011	-0.14, 0.16	0.88
Biscuits	4.6	385	0.053	-0.10, 0.21	0.50	118	0.283	0.01, 0.56	0.04‖	267	0.018	-0.17, 0.21	0.84
Buns cakes & pastries	4.0	344	-0.049	-0.18, 0.08	0.45	118	0.185	0.05, 0.33	0.01‖	226	-0.098	-0.26, 0.068	0.24
Cheese	3.9	418	-0.080	-0.26, 0.11	0.40	118	0.258	0.04, 0.52	0.05‖	300	-0.204	-0.44, 0.03	0.08
Breakfast cereals (not high fibre)	3.9	285	0.037	-0.29, 0.37	0.83	91	-0.010	-0.34, 0.32	0.95	194	0.744	-0.43, 0.57	0.77
Sugar	3.8	335	-0.260	-0.92, 0.39	0.43	82	0.253	-0.89, 1.4	0.66	253	-0.342	-1.1, 0.43	0.38
Cream	3.4	66	0.622	0.14, 1.11	0.01‖	22	0.747	0.02, 1.5	0.04‖	44	0.424	-0.29, 1.1	1.14
Meat pies and pastries	3.2	141	0.021	-0.01, 0.14	0.73	42	-0.112	-0.29, 0.07	0.21	99	0.089	-0.06, 0.24	0.23
Sugar confectionery	3.2	229	-0.055	-0.19, 0.08	0.41	83	-0.001	-0.12, 0.12	0.99	146	-0.112	-0.34, 0.11	0.29
Breakfast cereals high fibre	2.9	221	0.138	0.03, 0.25	0.01‖	64	0.070	-0.10, 0.21	0.33	157	0.165	0.02, .31	0.02‖
Preserves	2.6	95	-0.040	-0.79, 0.71	0.92	26	0.126	-0.81, 1.1	0.78	69	-0.247	-1.3, 0.79	0.64
Sausages	2.6	240	-0.061	-0.16, 0.04	0.22	74	0.080	-0.04, 0.20	0.19	166	-0.127	-0.27, 0.01	0.06
Burgers and kebabs	2.6	181	0.020	-0.08, 0.12	0.69	49	0.022	-0.10, 0.13	0.69	102	0.022	-0.12, 0.16	0.75
White bread	2.6	556	-0.012	-0.13, 0.11	0.85	152	-0.013	-0.18, 0.15	0.87	404	0.001	-0.15, 0.16	0.99
Pizza	2.5	233	-0.001	-0.04, 0.04	0.96	73	0.003	-0.04, 0.04	0.98	160	0.002	-0.05, 0.06	0.93
Coated chicken and turkey	2.5	209	0.024	-0.10, 0.12	0.64	62	0.090	-0.03, 0.21	0.15	147	-0.004	-0.14, 0.13	0.96

ED, energy density.
* Age-, sex- and misreporting-adjusted regression (model 2).
† Age- and sex-adjusted regression (model 3).
‡ED of food group.
§ Changes in BMI (kg/m2) per each 10 g.
‖ $P < 0 \cdot 05$.

Table 5. Association between BMI and portion size of the six most energy-dense beverages consumed by adolescents (Number of adolescents, change in BMI values and 95% confidence intervals)

Food groups (100 ml)	ED‡	All adolescents*				Normal reporter†				Under-reporters†			
		n	Changes in BMI†	95% CI	P	n	Changes in BMI†	95% CI	P	n	Changes in BMI†	95% CI	P
Other milk	0.9	88	-0.065	-0.11, -0.02	0.008‖	31	-0.020	-0.10, 0.10	0.670	57	-0.071	-0.13, -0.01	0.017‖
Whole milk	0.6	133	0.100	-0.01, 0.15	0.069	48	0.065	-0.03, 0.20	0.195	85	0.062	-0.05, 0.17	0.260
Semi skimmed milk	0.4	420	0.027	-0.02,0.10	0.301	108	0.015	0.06, 0.09	0.678	312	0.031	-0.04, 0.10	0.340
Caloric soft-drinks (carbonated)	0.4	401	0.038	0.00, 0.07	0.033‖	120	0.012	-0.04, 0.07	0.667	281	0.046	0.003, 0.09	0.037‖
Fruit juice (100%)	0.4	315	0.020	-0.015, 0.05	0.306	104	-0.010	-0.05, 0.04	0.689	211	0.027	-0.014, 0.07	0.190
Citrus fruit not canned	0.4	115	-0.028	-0.15, 0.10	0.648	32	0.055	0.09, 0.20	0.451	83	-0.040	-0.21, 0.13	0.640

ED, energy density.
* Age-, sex- and misreporting-adjusted regression (model).
† Age- and sex-adjusted regression (models).
‡ED of food group.
§ Changes in BMI (kg/m2) per each 10 g.
‖ $P < 0{\cdot}05$.

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