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Associations between energy density of meals and snacks and overall diet quality and adiposity measures in British children and adolescents: the National Diet and Nutrition Survey

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Abstract

This cross-sectional study examined how energy density (ED) of meals and snacks are associated with overall diet quality and adiposity measures in 1617 British children aged 4–18 years from the 1997 National Diet and Nutrition Survey. On the basis of data from 7-d weighed dietary record, all eating occasions were divided into meals or snacks on the basis of time (meals: 06.00–09.00, 12.00–14.00 and 17.00–20.00 hours; snacks: all others) or contribution to energy intake (EI) (meals: ≥15 %; snacks: <15 %). ED of meals and snacks was calculated on the basis of food only. Overall diet quality was assessed using the Mediterranean diet score (range 0–8). Irrespective of the definition of meals and snacks, ≥67 % of EI was derived from meals, whereas ED of meals was lower than ED of snacks (mean: 8·50–8·75 *v*. 9·69–10·52 kJ/g). Both ED of meals and ED of snacks were inversely associated with total intakes of vegetables, fruits, dietary fibre and overall diet quality and positively associated with total intakes of fat. However, the associations were stronger for ED of meals. The change in the Mediterranean diet score with a 1-unit increase of ED (kJ/g) was −0·35 to −0·30 for ED of meals and −0·09 to −0·06 for ED of snacks (all $P<0·0001$). After adjustment for potential confounders, all measures of ED of meals and snacks did not show positive associations with adiposity measures. In conclusion, although both ED of meals and ED of snacks were associated with adverse profiles of overall diet quality (but not adiposity measures), stronger associations were observed for ED of meals.

Key words: Meals: Snacks: Energy density: Diet quality

Diet in childhood and adolescence has been suggested to have a potential lifelong effect on the development of many chronic diseases such as obesity[1] and CVD[2]. In addition, evidence suggests that dietary characteristics established during childhood and adolescence persist into adulthood at least to some extent[3,4]. Thus, investigation of dietary behaviours that contribute to healthier dietary intakes in children and adolescents is a high public health priority. In this regard, dietary energy density (ED) has received increased attention, because there is evidence that diets high in ED are associated with increased body weight[5–8] as well as lower diet quality[8–10] in young populations. Given that people consume combinations of foods as meals and snacks, understanding how ED of meals and ED of snacks, rather than ED of the total diet, are associated with overall diet quality and health status (such as adiposity measures) would be helpful for, for example, the development of science-based recommendations of meals and snacks for children and adolescents[11]. In a small study of 6- to 8-year-old children in Northern Ireland (*n* 48), ED of self-reported snacks was higher than that of self-reported meals[7].

Nevertheless, virtually no studies have been conducted among children and adolescents, mainly because there is no consensus about what constitutes a snack, a meal or an eating occasion not only in adults[11–17,21–23,25–29] but also in children[18–20,24,30–33]. Although some researchers have relied on respondents' self-identification of meals, snacks or eating occasions[12–20], others have attempted to use more objective criteria (based on clock time, energy content/contribution or both)[16,18,21–33]. An accurate distinction between meals and snacks is important, because they are hypothesised to have different effects on energy and nutrient intakes[30,34,35]. An understanding of the influence of different meal and snack definitions on the associations between dietary characteristics of meals and snacks and overall diet quality and adiposity may help establish consensus on the most appropriate research definition for meals and snacks[11]. In addition, the association of meal and snack intake or pattern with adiposity measures (as well as dietary intake) may be confounded by possible under-reporting of eating frequency (i.e. meal and/or snack intake) concomitant with the under-reporting of energy intake (EI) by obese or overweight subjects[36,37].

Abbreviations: ED, energy density; EER, estimated energy requirement; EI, energy intake; EI:EER, ratio of energy intake:estimated energy requirement; MDS, Mediterranean diet score; NDNS, National Diet and Nutrition Survey; WHtR, waist:height ratio.

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Therefore, the primary aim of the present cross-sectional study in British children and adolescents was to explore how ED of meals and ED of snacks are associated with overall diet quality and adiposity measures, by using different definitions of meals and snacks. The secondary aim was to examine the impact of EI misreporting on these associations.

Methods

Survey design

The present cross-sectional study was based on data from the National Diet and Nutrition Survey (NDNS): Young People Aged 4 to 18 Years. Data from the NDNS were obtained from the UK Data Archive, University of Essex. Complete details of the rationale, design and methods of the survey have been described elsewhere[38,39]. In brief, the sample was randomly selected from 132 randomly selected postal sectors within mainland Great Britain. Eligibility was defined as being aged 4–18 years. One eligible person per private household was selected at random. Data collection was carried out during a 12-month period (January to December 1997). This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the National Health Service Local Research Ethics Committee covering each of the postal sectors. Verbal informed consent was obtained from all subjects and their parents/guardians. Verbal consent was witnessed and formally recorded.

Anthropometric measurements

All anthropometric measurements were obtained in duplicate by trained fieldworkers, and the mean value of two measurements was used in the analysis. Height (to the nearest 0·1 cm) and weight (to the nearest 0·1 kg) were measured while subjects were barefoot and wearing light clothes only. BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared and converted to age- and sex-specific z-scores according to British growth reference data[40]. For subjects aged ≥11 years, waist circumference was also measured at the midpoint between the iliac crest and the lower rib (to the nearest 0·1 cm). Waist:height ratio (WHtR) was calculated as waist circumference divided by height.

Dietary assessment

Dietary data were collected using a 7-d weighed dietary record. A detailed description of the procedure has been published elsewhere[38,39]. In brief, the subject, the parent or both, depending on the age of the subject, were asked to maintain a weighed record of all food and drinks consumed by the subject, both in and out of home, over 7 consecutive days. They were supplied with a set of digital food scales and recording diaries; they were also given written and verbal instructions on how to weigh and record items in the diary by trained interviewers. When weighing was not possible (e.g. eating out), the subject was asked to record as much information as possible. Generally, children aged 10 years and over were able to complete the diary themselves, whereas for children aged <10 years the parent/guardian was expected to complete the diary. Trained interviewers visited the household at least twice during the recording period and checked the completeness of food recording. All the collected diaries were checked by trained nutritionists in terms of coding, recorded weights and descriptions of items consumed. Estimates of daily intake for foods, energy and selected nutrients were calculated on the basis of the Food Standards Agency nutrient databank[41], which is based on McCance and Widdowson's composition of foods series[42] and manufacturers' data where applicable. For all dietary variables, mean daily values over 7 d were used in the analysis. The dietary variables used in this analysis were as follows, which were created using the information on foods, energy and selected nutrients consumed: energy and weight consumed (total, food and beverage), twelve food groups (vegetables; legumes; fruits; nuts and seeds; cereals; biscuits, cakes and pastries; fish; meat; dairy products; soft drinks; sugar, preserves and confectionery; and tea, coffee and water) and ten nutrients (protein, fat, SFA, MUFA, PUFA, carbohydrate, starch, total sugar, non-milk extrinsic sugar and dietary fibre). Values of food and nutrient intake were energy adjusted using the density method (i.e. % of energy for energy-providing nutrients and amount per 10 MJ of energy for foods and other nutrients).

As a measure of diet quality, the Mediterranean diet score (MDS) was calculated. The MDS represents a Mediterranean-type diet and is based on the consumption of eight different components (vegetables, legumes, fruits, cereals, fish, the ratio of unsaturated fatty acids:SFA, meat and dairy products)[43,44]. To modify the score for children and adolescents, the alcohol consumption component was removed from the score[30,45]. We selected the MDS not only because of the fact that it is one of the most established measures of diet quality but also because it focuses largely on intake of food groups (i.e. food choice) rather than intake of nutrients. Several previous studies among British young populations have also applied the MDS to measure overall diet quality[30,45]. For each component, subjects with an intake (g/10 MJ) above or equal to the age group- and sex-specific median were assigned a score of 1 (a score of 0 to those below), except for meat and dairy products, for which the score was assigned in the reverse manner. Scores for all eight components were summed and resulted in a total range from 0 to 8, whereby a higher score reflected better adherence to a Mediterranean-type diet.

ED (kJ/g) was calculated as total EI from foods relative to total grams of foods consumed (i.e. based on solid foods only), excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk), because EI from beverages is regulated differently from EI from foods[46]. In addition, this calculation method has been shown to provide stronger associations with measurements of obesity than other methods in several 1previous analyses[7,8,47].

Definition of meals and snacks

In the present study, eating occasions were defined as any occasion when any food or drink was consumed[12,13,21,24,29–31].

If two eating occasions occurred in ≤15 min, both events were counted as a single eating occasion; when >15 min separated two eating occasions, these were considered distinct eating occasions[21–23,29,30]. All eating occasions were further divided into either meals or snacks using two different published definitions: on the basis of (1) clock time[31] and (2) contribution to total EI[24]. According to the first definition, meals were defined as eating events reported during selected times of the day – that is, 06.00–09.00, 12.00–14.00 and 17.00–20.00 hours. All other eating occasions were considered snacks. According to the second definition, a meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of day or composition of foods or beverages consumed. All other eating episodes were classified as a snack. For each participant, dietary intakes from meals and snacks were calculated. In addition, eating frequency and meal and snack frequency were calculated on the basis of all eating occasions except for those providing <210 kJ of energy[12,13,21,29,30]. It should be noted that no self-definition of eating occasions was included in the NDNS dietary record.

Assessment of non-dietary variables

The socio-economic status of the head of household (i.e. occupational social class) was reported and used as a proxy for children's social class. The following three categories were used: manual (i.e. skilled manual, partly skilled and unskilled occupations: social classes III manual, IV and V), non-manual (i.e. professional, managerial, technical and skilled non-manual occupations: social classes I, II and III non-manual) or unclassified[48,49].

Subjects aged ≥7 years were asked to maintain a 7-d physical activity diary concurrently with the dietary record. A detailed description of the procedure has been published elsewhere[38,39]. In brief, the subject was asked to provide information on the time spent being active from a list of prompted moderate, vigorous and very vigorous activities. Information on activities not already listed and sleep was also provided. Trained interviewers checked the completeness of records at least twice during the recording period. Subsequently, time spent daily in sleep as well as in very light, light, moderate, vigorous and very vigorous physical activities was computed for each day of recording. The number of hours spent per day on each activity was multiplied by the metabolic equivalent value of that activity (derived from a published table)[50], and all metabolic equivalent-h products were summed to produce a total metabolic equivalent-h score for the day. They were then divided by 24 h to give a physical activity level value, and were further classified into four categories (sedentary, low active, active and very active) according to the US dietary reference intakes[51]. For subjects aged ≤6 years, for whom an activity diary was not maintained, the 'active' level was assigned on the basis of results on total energy expenditure measured by the doubly labelled water method in the NDNS feasibility study[52].

Evaluation of energy intake reporting

We calculated each subject's estimated energy requirement (EER) using equations published from the US dietary reference intakes[51]. Subjects were identified as acceptable reporters, under-reporters or over-reporters of EI on the basis of their ratio of EI:EER, according to whether the individual's ratio was within, below or above the 95 % confidence limits of the expected ratio of 1·0. On the basis of a published equation[32], acceptable reporters were defined as having EI:EER in the range 0·72–1·28, under-reporters as EI:EER < 0·72 and over-reporters as EI:EER > 1·28. A detailed description of the procedure has been published elsewhere[39].

Analytic sample

Of 2672 potentially eligible participants identified for the study, 2127 (80 % of eligible sample) participated in the survey. For the present analysis, we excluded a total of 443 subjects with missing information on the variables used (*n* 182 for anthropometric data; *n* 426 for dietary data; *n* 125 for physical activity data; some subjects had more than one missing value). We further excluded forty-eight underweight subjects (i.e. BMI ≤ 3rd percentile of the age- and sex-specific growth reference data[40]) and nineteen subjects without any snacking occasion (based on either definition) during the 7-d period. The final analysis sample comprised 1617 subjects aged 4–18 years (61 % of eligible sample). The subjects included in the present analysis (*n* 1617) differed somewhat from those excluded from the analysis (*n* 491). The excluded subjects were more likely to be younger and of lower socio-economic status (all $P < 0·05$).

Statistical analysis

All statistical analyses were performed for children aged 4–10 years and adolescents aged 11–18 years separately, using SAS statistical software (version 9.2; SAS Institute Inc.). Separate analyses for boys and girls showed similar patterns of associations, and tests for interaction with sex were not significant (data not shown). We therefore present results for both sexes combined. Differences between acceptable reporters and under-reporters (but not over-reporters because of there being only a few of them) were tested by the independent *t* test (for continuous variables) and the χ^2 test (for categorical variables). Differences between intakes from meals and snacks were examined by the paired *t* test. Associations between ED of meals and snacks and overall dietary intakes and quality were investigated by linear regression analyses using the PROC REG procedure, with adjustment for age, sex and social class. Both ED of meals and ED of snacks based on the same definition were entered simultaneously into the regression model. Linear regression analyses (using the PROC REG procedure) were also performed to explore the associations between ED of meals and snacks (as well as ED of total diet) and BMI *z*-score and WHtR. The potential confounding factors considered were age, sex, social class, physical activity, meal frequency, snack frequency and EI from beverages (model 1). We further included EI:EER as a potential confounding factor (model 2). ED of meals and snacks was analysed continuously after confirming the linearity of relations using tertile categories. The analyses were conducted not only for the entire population but also for acceptable reporters.

Data have not been weighted to take into account known socio-demographic differences between responders and non-responders, not only because the impact of this adjustment, applied as a weighting factor, for nutritional variables was extremely small and not significant[38] but also because we were only interested in relationships between variables, rather than estimates of prevalence[29,30,39]. All reported P values are two-tailed, and P values of <0·01 were considered statistically significant to minimise the chance of a type 1 error arising from multiple testing.

Results

Characteristics of the subjects are shown in Table 1. The percentages of acceptable reporters and under-reporters were 80 and 19 % in children and 48 and 52 % in adolescents, respectively (only three children (0·7 %) and three adolescents (0·4 %) were classified as over-reporters). Compared with acceptable reporters, under-reporters had lower mean values of EI, ED, eating frequency, and meal and snack frequencies (except for no difference in frequency of meals based on EI contribution) and higher mean values of age (only adolescents), BMI z-score, WHtR (only adolescents available) and MDS (only adolescents). Under-reporters were also more likely to be in the unclassified social class (only children) and physically active.

Characteristics of meals and snacks were generally similar in children (Table 2) and adolescents (Table 3) irrespective of the definition of meals and snacks. Although mean values of EI and weight consumed were larger in meals, snacks contributed to considerable proportions of these (≥15 %), particularly beverage energy and weight, with a range from 31 % for beverage energy from the time-based snacks in children (mean: 276 out of 884 kJ/d) to 48 % for beverage weight from the EI-contribution-based snacks in adolescents (mean: 495 out of 1030 g/d). The mean ED of snacks was higher than that of meals. In terms of dietary composition, meals had higher mean values of vegetables, legumes, nuts/seeds (only the EI contribution definition), cereals, fish, meat, protein, total fat (except for the time definition in children), SFA (except for the time definition), MUFA and PUFA, starch, and dietary fibre. Conversely, snacks had higher mean values of fruits, biscuits/cakes/pastries, dairy products, soft drinks, sugar/preserves/confectionery, tea/coffee/water, carbohydrate, and total and non-milk extrinsic sugars.

The associations of ED of meals and snacks with total dietary intakes were generally similar in both children (Table 4) and adolescents (Table 5). When the time definition was applied, ED of meals and ED of snacks showed inverse associations with vegetables, fruits, cereals (except for snacks in children), meat, protein and dietary fibre and positive associations with biscuits/cakes/pastries (except for meals in adolescents), sugar/preserves/confectionery (except for snacks in children), total fat, SFA and MUFA (except for snacks in children), and non-milk extrinsic sugar. ED of meals was also associated inversely with legumes, fish (only children), dairy products (only adolescents), tea/coffee/water (only children) and carbohydrate and positively associated with soft drinks (only children), whereas ED of snacks was also associated inversely with fish (only adolescents), PUFA (only children) and starch (only adolescents).

When the EI contribution definition was applied, ED of meals and ED of snacks were inversely associated with vegetables, fruits, cereals (except for snacks in children), tea/coffee/water (except for snacks in children), protein (except for snacks in children) and dietary fibre and positively associated with total fat, SFA (except for snacks in children) and MUFA. ED of meals also showed inverse associations with legumes, fish, carbohydrate (only adolescents) and starch and positive associations with nuts/seeds (only adolescents), biscuits/cakes/pastries, soft drinks, sugar/preserves/confectionery, PUFA and non-milk extrinsic sugar. ED of snacks also showed inverse associations with carbohydrate (only adolescents) and total sugar and positive associations with meat (only adolescents) and starch (only children).

However, the strength of these associations was generally stronger in ED of meals than in ED of snacks. In accordance with this, although both ED of meals and ED of snacks were inversely associated with MDS, irrespective of the definition of meals and snacks, the associations for ED of meals were stronger (3·3–5·8 times) than those for ED of snacks. Only in adolescents, ED of meals based on both definitions and that of snacks based on time were positively associated with total EI.

Associations of ED of meals and snacks with adiposity measures are shown in Table 6. After adjustment for potential confounding factors except for EI:EER (model 1), all measures of ED showed no associations (except for inverse associations between ED of meals based on time and BMI z-score in children and between ED of snacks based on time and BMI z-score in adolescents). Further adjustment for EI:EER (model 2) did not change the results materially. All the analyses were repeated after excluding under- and over-reporters, providing similar results in terms of characteristics of meals and snacks (Supplementary Tables S1 and S2) and associations of ED of meals and snacks with total dietary intakes (Supplementary Tables S3 and S4) and adiposity measures (Supplementary Table S5).

Discussion

To our knowledge, this is the first study to examine how ED of meals and ED of snacks are associated with overall diet quality and adiposity measures. Irrespective of the definition of meals and snacks, both ED of meals and ED of snacks were inversely associated with total intakes of vegetables, fruits, dietary fibre and overall diet quality (assessed by MDS) and positively associated with total intakes of fat in British children and adolescents. However, the associations were stronger for ED of meals than for ED of snacks. After adjustment for potential confounders, all measures of ED did not show positive associations with adiposity measures. In analyses where only acceptable EI reporters were included, similar results were obtained. The present findings suggest stronger associations of ED of meals with overall diet quality but not adiposity measures compared with ED of snacks.

In the present study, 19–33 % of EI was derived from snacks, depending on the definition of snacks and age. These figures are broadly similar to those observed in Mexico (19 % for boys and girls aged 2–5 years and 16 % for those aged

Table 1. Characteristics of the subjects*
(Mean values and standard deviations or percentages)

	Children aged 4–10 years							Adolescents aged 11–18 years						
	All (*n* 808)†		AR (*n* 649)		UR (*n* 153)			All (*n* 809)†		AR (*n* 387)		UR (*n* 419)		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	Mean	SD	*P*‡
Age (years)	7·1	1·9	7·1	1·9	7·4	2·1	0·08	14·2	2·3	13·7	2·2	14·7	2·2	<0·0001
Sex (% boys)	53·2		54·9		45·8		0·04	48·5		53·0		43·9		0·01
Social class (%)							0·02							0·36
Manual	42·7		43·4		39·2			45·4		43·7		46·5		
Non-manual	49·6		50·4		47·7			46·0		48·6		43·9		
Unclassified	7·7		6·3		13·1			8·7		7·8		9·6		
Physical activity (%)§							<0·0001							<0·0001
Low active	5·7		6·0		3·9			6·3		9·0		3·6		
Active	87·5		89·1		81·1			75·5		80·6		70·9		
Very active	6·8		4·9		15·0			18·2		10·3		25·5		
BMI *z*-score	0·38	0·98	0·32	0·94	0·59	1·13	0·002	0·46	1·06	0·24	0·98	0·67	1·09	<0·0001
WHtR	–	–	–	–	–	–	–	0·46	0·06	0·45	0·05	0·46	0·06	0·0009
EI:EER	0·84	0·16	0·88	0·11	0·63	0·08	<0·0001	0·71	0·18	0·86	0·10	0·57	0·11	<0·0001
EI (kJ/d)	6711	1441	7002	1228	5291	1117	<0·0001	7959	2182	9204	1892	6767	1642	<0·0001
Energy density (kJ/g)‖	8·74	1·36	8·79	1·30	8·52	1·52	0·02	8·76	1·36	9·06	1·27	8·46	1·36	<0·0001
Eating frequency (times/d)	4·96	1·08	5·10	1·06	4·30	0·88	<0·0001	4·67	1·19	5·23	1·11	4·15	1·01	<0·0001
MF_{time} (times/d)¶	3·37	0·68	3·46	0·65	3·01	0·65	<0·0001	2·79	0·75	3·11	0·69	2·50	0·68	<0·0001
SF_{time} (times/d)¶	1·58	0·78	1·65	0·79	1·29	0·68	<0·0001	1·87	0·89	2·11	0·92	1·65	0·81	<0·0001
$MF_{energy\%}$ (times/d)**	2·57	0·63	2·56	0·64	2·60	0·54	0·45	2·47	0·58	2·57	0·56	2·38	0·58	<0·0001
$SF_{energy\%}$ (times/d)**	2·39	1·29	2·55	1·31	1·70	0·94	<0·0001	2·20	1·25	2·65	1·26	1·77	1·09	<0·0001
Mediterranean diet score††	3·99	1·54	3·95	1·53	4·20	1·53	0·08	4·00	1·49	3·82	1·46	4·18	1·50	0·0006

AR, acceptable reporters; UR, under-reporters; WHtR, waist:height ratio; EI:EER, ratio of energy intake:estimated energy requirement; EI, energy intake; MF_{time}, meal frequency (MF) determined on the basis of the time consumed; SF_{time}, snack frequency (SF) determined on the basis of the time consumed; $MF_{energy\%}$, MF determined on the basis of percentage contribution to total EI; $SF_{energy\%}$, SF determined on the basis of percentage contribution to total EI.
* AR were defined as subjects with EI:EER 0·72–1·28; UR were defined as subjects with EI:EER < 0·72.
† Including over-reporters of energy intake (*n* 6 in children and *n* 3 in adolescents), defined as subjects with EI:EER > 1·28.
‡ *P* values for differences between AR and UR based on the independent *t* test for continuous variables and the χ^2 test for categorical variables.
§ There were no subjects classified into the 'sedentary' level.
‖ Calculated on the basis of solid foods only; excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).
¶ Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.
** A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.
†† Possible score ranging from 0 to 8.

Table 2. Characteristics of meals and snacks in children aged 4–10 years (*n* 808)
(Mean values and standard deviations)

	Total intake		Meals and snacks based on time*					Meals and snacks based on EI contribution†				
			Intake from meals		Intake from snacks			Intake from meals		Intake from snacks		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	*P*‡
EI (kJ/d)												
Total energy	6711	1441	5025	1299	1686	922	<0·0001	5273	1261	1438	806	<0·0001
Food energy	5827	1329	4417	1184	1410	823	<0·0001	4742	1175	1085	654	<0·0001
Beverage energy	884	453	608	349	276	233	<0·0001	531	323	353	277	<0·0001
Weight consumed (g/d)												
Total weight (g/d)	1509	362	1100	305	409	212	<0·0001	1020	267	489	267	<0·0001
Food weight (g/d)	679	170	532	160	147	97	<0·0001	554	154	125	82	<0·0001
Beverage weight (g/d)	831	284	568	214	262	156	<0·0001	466	180	365	219	<0·0001
Energy density (kJ/g)§	8·74	1·36	8·51	1·43	10·47	3·30	<0·0001	8·75	1·39	9·69	3·61	<0·0001
Food intake (g/10 MJ)												
Vegetables	56·3	52·8	61·9	61·5	36·7	94·2	<0·0001	62·3	60·2	32·3	70·3	<0·0001
Legumes	35·5	36·4	39·6	42·1	22·2	56·3	<0·0001	41·9	43·6	10·0	34·3	<0·0001
Fruits	100·3	86·0	91·7	87·3	146·8	309·6	<0·0001	65·3	72·8	241·5	423·8	<0·0001
Nuts and seeds	1·6	5·1	1·6	5·6	1·7	10·5	0·66	1·8	6·0	0·9	5·6	0·003
Cereals	221·7	89·0	240·6	102·9	152·3	138·0	<0·0001	237·7	103·3	161·4	127·5	<0·0001
Biscuits, cakes and pastries	64·5	38·0	57·3	38·8	88·7	80·3	<0·0001	62·0	42·0	72·3	67·5	<0·0001
Fish	22·4	25·7	25·7	31·1	11·9	42·3	<0·0001	26·6	30·9	5·3	20·1	<0·0001
Meat	132·5	68·4	146·1	78·9	83·7	121·5	<0·0001	159·2	84·9	34·3	64·5	<0·0001
Dairy products	398·6	209·5	385·9	216·0	444·1	430·0	0·0001	308·2	188·2	727·3	528·0	<0·0001
Soft drinks	349·4	301·6	309·2	292·8	519·7	626·5	<0·0001	272·3	239·0	721·4	1015·6	<0·0001
Sugar, preserves and confectionery	54·4	36·5	42·4	34·1	97·0	87·1	<0·0001	40·7	32·2	107·2	116·4	<0·0001
Tea, coffee and water	183·7	229·3	169·6	211·6	259·7	525·4	<0·0001	117·6	159·4	530·6	1053·0	<0·0001
Nutrient intake												
Protein (% of energy)	12·7	1·9	13·4	2·1	10·5	3·7	<0·0001	13·4	2·2	10·2	3·3	<0·0001
Fat (% of energy)	35·6	4·0	35·6	4·4	35·3	7·3	0·28	37·1	4·5	29·5	7·4	<0·0001
SFA (% of energy)	14·7	2·3	14·4	2·5	15·5	4·1	<0·0001	14·7	2·5	14·3	4·3	0·007
MUFA (% of energy)	11·6	1·6	11·6	1·8	11·2	2·9	0·0004	12·3	1·9	8·8	2·5	<0·0001
PUFA (% of energy)	5·7	1·5	5·9	1·6	4·8	2·2	<0·0001	6·3	1·6	3·4	1·6	<0·0001
Carbohydrate (% of energy)	51·6	4·4	51·0	4·8	54·2	8·6	<0·0001	49·4	4·9	60·2	8·5	<0·0001
Starch (% of energy)	27·1	4·4	28·4	4·6	22·5	7·9	<0·0001	28·7	4·5	21·3	7·8	<0·0001
Total sugar (% of energy)	24·5	5·4	22·6	5·5	31·6	12·1	<0·0001	20·8	5·5	39·0	11·4	<0·0001
Non-milk extrinsic sugar (% of energy)	17·2	5·2	15·5	5·1	23·4	11·5	<0·0001	14·6	5·0	27·3	11·6	<0·0001
Dietary fibre (g/10 MJ)	14·0	3·6	14·6	3·9	12·3	6·2	<0·0001	14·4	3·8	12·6	6·8	<0·0001

EI, energy intake.
* Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.
† A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.
‡ *P* values for differences between meals and snacks based on the paired *t* test.
§ Calculated on the basis of solid foods only; excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).

Table 3. Characteristics of meals and snacks in adolescents aged 11–18 years (*n* 809)
(Mean values and standard deviations)

	Total intake		Meals and snacks based on time*					Meals and snacks based on EI contribution†				
			Intake from meals		Intake from snacks			Intake from meals		Intake from snacks		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	*P*‡
EI (kJ/d)												
Total energy	7959	2182	5337	1787	2623	1467	<0·0001	6426	1661	1533	1031	<0·0001
Food energy	6967	1916	4773	1626	2194	1264	<0·0001	5841	1520	1125	814	<0·0001
Beverage energy	993	641	564	366	429	408	<0·0001	585	401	408	388	<0·0001
Weight consumed (g/d)												
Total weight (g/d)	1837	611	1168	419	669	403	<0·0001	1220	362	617	420	<0·0001
Food weight (g/d)	807	230	574	203	232	154	<0·0001	685	187	121	97	<0·0001
Beverage weight (g/d)	1030	489	593	285	437	320	<0·0001	535	259	495	370	0·006
Energy density (kJ/g)§	8·76	1·36	8·50	1·53	10·30	2·91	<0·0001	8·65	1·33	10·52	3·88	<0·0001
Food intake (g/10 MJ)												
Vegetables	73·4	74·6	84·0	90·5	47·5	83·6	<0·0001	82·3	85·3	39·6	123·4	<0·0001
Legumes	37·4	44·0	43·5	55·3	22·2	50·5	<0·0001	43·9	52·0	7·7	34·4	<0·0001
Fruits	66·7	98·3	61·2	97·7	85·1	166·8	<0·0001	40·4	66·3	188·4	384·9	<0·0001
Nuts and seeds	1·4	5·7	1·1	6·2	2·1	11·7	0·02	1·5	6·5	0·8	4·3	0·005
Cereals	244·2	100·4	252·3	110·6	213·3	155·1	<0·0001	264·6	113·4	151·7	127·9	<0·0001
Biscuits, cakes and pastries	49·2	39·6	43·8	40·1	63·8	70·6	<0·0001	45·3	41·7	66·1	73·4	<0·0001
Fish	21·6	31·0	24·8	37·5	12·8	41·2	<0·0001	24·8	36·1	6·3	27·8	<0·0001
Meat	167·4	91·0	188·0	111·9	114·3	128·5	<0·0001	196·7	107·2	35·6	86·8	<0·0001
Dairy products	281·7	180·2	255·1	186·9	352·9	310·8	<0·0001	217·3	166·7	588·1	520·0	<0·0001
Soft drinks	360·0	319·5	336·0	321·4	442·0	509·9	<0·0001	268·9	251·0	802·6	971·9	<0·0001
Sugar, preserves and confectionery	49·8	38·6	41·0	40·3	76·3	73·0	<0·0001	38·2	36·7	101·7	139·2	<0·0001
Tea, coffee and water	357·3	382·0	308·7	390·8	547·8	757·9	<0·0001	177·6	225·1	1465·9	2483·6	<0·0001
Nutrient intake												
Protein (% of energy)	13·3	2·3	14·0	2·7	11·5	3·4	<0·0001	14·1	2·5	9·6	3·7	<0·0001
Fat (% of energy)	35·5	4·9	36·0	5·3	33·9	7·5	<0·0001	37·2	5·2	27·3	8·7	<0·0001
SFA (% of energy)	13·8	2·4	13·7	2·6	14·0	3·6	0·03	14·0	2·5	12·5	4·3	<0·0001
MUFA (% of energy)	11·8	2·1	12·0	2·3	11·0	3·0	<0·0001	12·5	2·3	8·4	3·2	<0·0001
PUFA (% of energy)	6·3	1·6	6·6	1·9	5·4	2·3	<0·0001	6·9	1·8	3·6	2·0	<0·0001
Carbohydrate (% of energy)	50·4	5·4	49·6	5·9	52·9	8·4	<0·0001	48·2	5·7	60·9	9·9	<0·0001
Starch (% of energy)	28·5	4·8	29·5	4·8	25·5	7·8	<0·0001	30·2	4·9	20·8	9·0	<0·0001
Total sugar (% of energy)	21·9	5·8	20·0	6·2	27·4	10·3	<0·0001	18·0	5·5	40·1	13·0	<0·0001
Non-milk extrinsic sugar (% of energy)	16·0	5·6	14·3	5·9	20·7	9·7	<0·0001	12·9	5·2	30·3	13·6	<0·0001
Dietary fibre (g/10 MJ)	14·6	4·3	15·4	4·9	12·8	5·5	<0·0001	15·2	4·3	12·3	8·2	<0·0001

EI, energy intake.
* Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.
† A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.
‡ *P* values for differences between meals and snacks based on the paired *t* test.
§ Calculated on the basis of solid foods only; excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).

Table 4. Associations of energy density of meals and snacks with total dietary intakes in children aged 4–10 years (*n* 808)*
(Regression coefficients (*β*) with their standard errors)

	Meals and snacks based on time†						Meals and snacks based on EI contribution‡					
	Energy density of meals			Energy density of snacks			Energy density of meals			Energy density of snacks		
	β§	SE§	*P*	*β*§	SE§	*P*	*β*§	SE§	*P*	*β*§	SE§	*P*
Food intake from meals and snacks (g/10 MJ)												
Vegetables	−15·48	1·15	<0·0001	−2·70	0·50	<0·0001	−15·75	1·18	<0·0001	−2·88	0·46	<0·0001
Legumes	−6·33	0·88	<0·0001	−0·85	0·38	0·03	−8·09	0·90	<0·0001	0·78	0·35	0·02
Fruits	−26·18	1·74	<0·0001	−7·05	0·75	<0·0001	−21·75	1·76	<0·0001	−9·64	0·68	<0·0001
Nuts and seeds	−0·21	0·13	0·09	0·03	0·06	0·54	−0·13	0·13	0·31	−0·04	0·05	0·42
Cereals	−10·52	2·20	<0·0001	−2·10	0·95	0·03	−13·69	2·25	<0·0001	−0·97	0·87	0·26
Biscuits, cakes and pastries	3·90	0·92	<0·0001	2·14	0·40	<0·0001	5·03	0·96	<0·0001	0·59	0·37	0·11
Fish	−2·61	0·64	<0·0001	−0·47	0·27	0·09	−3·21	0·65	<0·0001	−0·12	0·25	0·64
Meat	−10·51	1·64	<0·0001	−2·80	0·71	<0·0001	−14·64	1·69	<0·0001	0·10	0·65	0·88
Dairy products	−8·30	5·04	0·10	0·60	2·17	0·78	−2·84	5·20	0·59	−3·17	2·00	0·11
Soft drinks	22·56	7·57	0·003	0·94	3·26	0·77	27·58	7·79	0·0004	−1·60	3·00	0·59
Sugar, preserves and confectionery	3·95	0·91	<0·0001	0·70	0·39	0·07	6·75	0·92	<0·0001	−0·33	0·35	0·35
Tea, coffee and water	−17·19	5·64	0·002	−3·44	2·43	0·16	−18·33	5·81	0·002	−3·33	2·34	0·14
Nutrient intake from meals and snacks												
Protein (% of energy)	−0·50	0·04	<0·0001	−0·09	0·02	<0·0001	−0·61	0·04	<0·0001	−0·03	0·02	0·05
Fat (% of energy)	0·72	0·1	<0·0001	0·12	0·04	0·004	0·85	0·10	<0·0001	0·10	0·04	0·009
SFA (% of energy)	0·38	0·06	<0·0001	0·12	0·02	<0·0001	0·52	0·06	<0·0001	0·05	0·02	0·02
MUFA (% of energy)	0·26	0·04	<0·0001	0·03	0·02	0·09	0·28	0·04	<0·0001	0·05	0·02	0·001
PUFA (% of energy)	0·06	0·04	0·11	−0·05	0·02	0·003	0·01	0·04	0·79	0·00	0·01	0·86
Carbohydrate (% of energy)	−0·22	0·11	0·04	−0·03	0·05	0·59	−0·25	0·11	0·03	−0·07	0·04	0·13
Starch (% of energy)	−0·08	0·11	0·45	−0·08	0·05	0·09	−0·47	0·11	<0·0001	0·16	0·04	0·0002
Total sugar (% of energy)	−0·14	0·13	0·29	0·05	0·06	0·35	0·21	0·14	0·12	−0·23	0·05	<0·0001
Non-milk extrinsic sugar (% of energy)	0·56	0·13	<0·0001	0·17	0·05	0·002	0·83	0·13	<0·0001	−0·03	0·05	0·50
Dietary fibre (g/10 MJ)	−1·09	0·08	<0·0001	−0·23	0·03	<0·0001	−1·22	0·08	<0·0001	−0·15	0·03	<0·0001
Mediterranean diet score‖	−0·32	0·04	<0·0001	−0·08	0·02	<0·0001	−0·35	0·04	<0·0001	−0·06	0·01	<0·0001
Total EI (kJ/d)	42·7	31·6	0·18	24·8	13·6	0·07	60·5	32·6	0·06	−1·1	12·6	0·93

EI, energy intake.
* Energy density was calculated on the basis of solid foods only, excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk). Adjustment was made for age (years, continuous), sex (boys or girls) and social class (manual, non-manual or unclassified). Both energy density of meals and energy density of snacks based on the same definition were entered simultaneously into the regression model.
† Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.
‡ A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.
§ Regression coefficients mean the change of dietary variables with 1-unit increase of energy density (kJ/g).
‖ Possible score ranging from 0 to 8.

Table 5. Associations of energy density of meals and snacks with total dietary intakes in adolescents aged 11–18 years (*n* 809)*
(Regression coefficients (*β*) with their standard errors)

	Meals and snacks based on time†						Meals and snacks based on EI contribution‡					
	Energy density of meals			Energy density of snacks			Energy density of meals			Energy density of snacks		
	β§	SE§	*P*	*β*§	SE§	*P*	*β*§	SE§	*P*	*β*§	SE§	*P*
Food intake from meals and snacks (g/10 MJ)												
Vegetables	−18·41	1·52	<0·0001	−4·82	0·77	<0·0001	−22·72	1·74	<0·0001	−2·93	0·58	<0·0001
Legumes	−7·35	1·02	<0·0001	−1·03	0·52	0·05	−10·00	1·18	<0·0001	−0·09	0·39	0·82
Fruits	−23·37	2·05	<0·0001	−9·12	1·05	<0·0001	−20·15	2·35	<0·0001	−9·23	0·79	<0·0001
Nuts and seeds	0·31	0·14	0·02	0·05	0·07	0·49	0·46	0·16	0·004	0·00	0·05	0·97
Cereals	−7·36	2·31	0·002	−8·72	1·18	<0·0001	−16·09	2·70	<0·0001	−3·90	0·91	<0·0001
Biscuits, cakes and pastries	1·45	0·91	0·11	2·60	0·47	<0·0001	4·22	1·08	<0·0001	0·08	0·36	0·82
Fish	−0·64	0·74	0·39	−1·04	0·38	0·006	−4·14	0·86	<0·0001	−0·04	0·29	0·90
Meat	−8·47	2·12	<0·0001	−4·04	1·08	0·0002	−16·34	2·45	<0·0001	2·31	0·82	0·005
Dairy products	−11·57	4·27	0·007	1·43	2·18	0·51	−11·24	4·97	0·02	−4·20	1·67	0·012
Soft drinks	16·71	7·61	0·03	9·08	3·88	0·02	27·42	8·87	0·002	4·55	2·98	0·13
Sugar, preserves and confectionery	4·40	0·88	<0·0001	1·64	0·45	0·0003	6·23	1·04	<0·0001	−0·16	0·35	0·65
Tea, coffee and water	−16·62	8·55	0·05	−8·96	4·37	0·04	−28·39	9·92	0·004	−9·21	3·33	0·006
Nutrient intake from meals and snacks												
Protein (% of energy)	−0·55	0·05	<0·0001	−0·16	0·03	<0·0001	−0·76	0·06	<0·0001	−0·05	0·02	0·004
Fat (% of energy)	0·94	0·11	<0·0001	0·33	0·06	<0·0001	1·32	0·12	<0·0001	0·22	0·04	<0·0001
SFA (% of energy)	0·44	0·05	<0·0001	0·16	0·03	<0·0001	0·59	0·06	<0·0001	0·09	0·02	<0·0001
MUFA (% of energy)	0·38	0·05	<0·0001	0·12	0·02	<0·0001	0·52	0·05	<0·0001	0·10	0·02	<0·0001
PUFA (% of energy)	0·06	0·04	0·10	0·02	0·02	0·38	0·12	0·05	0·008	0·01	0·02	0·38
Carbohydrate (% of energy)	−0·37	0·12	0·003	−0·13	0·06	0·05	−0·55	0·14	0·0002	−0·18	0·05	0·0003
Starch (% of energy)	−0·20	0·11	0·07	−0·27	0·06	<0·0001	−0·71	0·13	<0·0001	−0·01	0·04	0·82
Total sugar (% of energy)	−0·17	0·14	0·22	0·15	0·07	0·04	0·16	0·16	0·31	−0·17	0·05	0·002
Non-milk extrinsic sugar (% of energy)	0·49	0·13	0·0002	0·33	0·07	<0·0001	0·78	0·15	<0·0001	0·05	0·05	0·34
Dietary fibre (g/10 MJ)	−1·22	0·09	<0·0001	−0·32	0·05	<0·0001	−1·37	0·11	<0·0001	−0·23	0·04	<0·0001
Mediterranean diet score‖	−0·30	0·03	<0·0001	−0·09	0·02	<0·0001	−0·34	0·04	<0·0001	−0·07	0·01	<0·0001
Total EI (kJ/d)	160·9	45·4	0·0004	102·2	23·2	<0·0001	243·7	53·4	<0·0001	14·4	17·9	0·42

EI, energy intake.

* Energy density was calculated on the basis of solid foods only, excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk). Adjustment was made for age (years, continuous), sex (boys or girls) and social class (manual, non-manual or unclassified). Both energy density of meals and energy density of snacks based on the same definition were entered simultaneously into the regression model.

† Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.

‡ A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.

§ Regression coefficients mean the change of dietary variables with 1-unit increase of energy density (kJ/g).

‖ Possible score ranging from 0 to 8.

Table 6. Associations of energy density (ED) of meals and snacks with adiposity measures*
(Regression coefficients (*β*) with their standard errors)

	Model 1†			Model 2‡		
	β§	SE§	*P*	*β*§	SE§	*P*
Children aged 4–10 years (*n* 808)						
ED of meals based on time (kJ/g)‖						
BMI *z*-score	–0·06	0·02	0·02	–0·05	0·02	0·03
ED of snacks based on time (kJ/g)‖						
BMI *z*-score	0·01	0·01	0·40	0·01	0·01	0·34
ED of meals based on EI contribution (kJ/g)¶						
BMI *z*-score	–0·04	0·03	0·08	–0·04	0·03	0·09
ED of snacks based on EI contribution (kJ/g)¶						
BMI *z*-score	–0·01	0·01	0·56	0·00	0·01	0·74
ED of total diet (kJ/g)						
BMI *z*-score	–0·05	0·03	0·07	–0·04	0·03	0·10
Adolescents aged 11–18 years (*n* 809)						
ED of meals based on time (kJ/g)‖						
BMI *z*-score	0·00	0·03	0·90	0·04	0·03	0·14
WHtR	0·001	0·001	0·54	0·002	0·001	0·17
ED of snacks based on time (kJ/g)‖						
BMI *z*-score	–0·04	0·01	0·006	–0·03	0·01	0·03
WHtR	–0·001	0·001	0·16	–0·001	0·001	0·29
ED of meals based on EI contribution (kJ/g)¶						
BMI *z*-score	–0·04	0·03	0·16	0·00	0·03	0·91
WHtR	–0·001	0·002	0·55	0·000	0·002	0·90
ED of snacks based on EI contribution (kJ/g)¶						
BMI *z*-score	–0·01	0·01	0·40	0·00	0·01	0·68
WHtR	0·000	0·001	0·39	0·001	0·001	0·26
ED of total diet (kJ/g)						
BMI *z*-score	–0·05	0·08	0·10	0·00	0·03	0·95
WHtR	–0·001	0·002	0·74	0·001	0·002	0·60

EI, energy intake; WHtR, waist:height ratio.
* Energy density was calculated on the basis of solid foods only, excluding all energy-containing and non-energy-containing beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).
† Adjusted for age (years, continuous), sex (boys or girls) social class (manual, non-manual or unclassified), physical activity (low active, active or very active), meal frequency based on the same definition (times/d, continuous), snack frequency based on the same definition (times/d, continuous) and EI from beverages (kJ/d, continuous). Both energy density of meals and energy density of snacks based on the same definition were entered simultaneously into the regression model.
‡ Adjusted for variables used in model 1 and ratio of EI:estimated energy requirement (continuous). Both energy density of meals and energy density of snacks based on the same definition were entered simultaneously into the regression model.
§ Regression coefficients mean the change of adiposity measures with 1-unit increase of energy density (kJ/g).
‖ Meals were defined as eating events reported during select times of the day (06.00–09.00, 12.00–14.00 and 17.00–20.00 hours); all other eating occasions were considered as snacks.
¶ A meal was defined as any eating episode comprising ≥15 % of total EI, regardless of the time of the day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.

6–13 years)[19], the USA (27 % for those aged 2–18 years)[20] and the UK (30 % for those aged 13–16 years)[33], although the definitions of snacks varied across studies. This suggests that a considerable proportion of total EI is derived from snacks in affluent countries, whatever definitions are applied.

Only a limited number of studies in adults have compared the dietary composition between meals and snacks. Although the definitions of meals and snacks varied across studies, a consistent finding is that meals provide a higher proportion of EI from fat or protein than snacks[15,25–28]. With respect to carbohydrates, meals had a lower proportion of total sugars but not total carbohydrate[25] or had a higher density of dietary fibre compared with snacks[26,28]. These observations are generally similar to those obtained in the present young population. Taken together, these data clearly show that meals and snacks have different impacts on overall diet quality and health status. In the present study, we used ED of meals and ED of snacks as measures of dietary characteristics of meals and snacks, respectively, not only because there is evidence that diets high in ED are associated with increased body weight[5–8] as well as lower diet quality[8–10] but also because ED has the advantages of being similarly calculated on the basis of data on dietary intake from meals and snacks. ED of meals was associated with less favourable dietary intake patterns, including lower intakes of vegetables, fruits and dietary fibre, higher intakes of fat and lower diet quality (assessed by MDS). This was not dependent on the definition of meals and snacks. ED of snacks was similarly associated with less favourable dietary intake patterns, but the associations were generally weaker. For adiposity measures, there were no positive associations for all measures of ED. The present findings suggest greater importance of diet quality (assessed by ED) of meals than that of snacks for improving overall diet quality but not adiposity measures. In a previous analysis of the same British children and adolescents, higher frequency of snacks was associated with lower overall diet quality, including higher intakes of soft drinks, confectionery and total sugar, lower intakes of cereals, fish, meat, protein, PUFA, starch and dietary fibre and a lower MDS, but not adiposity measures, irrespective of the definition of snacks (although associations for frequency of meals varied depending on the definition of meals and sex)[30]. Thus, although the quality (combination of foods) rather than the frequency of consumption is important for meals, the reverse is the case with snacks for better overall diet quality, at least for British children and adolescents. Further research in different populations is warranted.

The strengths of the present study include the use of objective and published definitions of meals and snacks based on detailed dietary information obtained from a 7-d weighed dietary record, measured anthropometric data and the use of individualised measures of EER to identify EI misreporters. However, there are also several limitations. First, the cross-sectional nature of the study does not permit the assessment of causality owing to the uncertain temporality of the association. Only a prospective study would provide better understanding of the relationship between meal and snack intakes and overall diet quality and adiposity measures.

We used BMI *z*-score and WHtR as proxy measures of body fatness. As BMI reflects not only body fatness but also relative length of legs, body frame size and fat-free body mass[53], subjects with similar BMI (*z*-score) do not necessarily have the same amount of body fat. A more valid measure of body fat mass (e.g. dual-energy X-ray absorptiometry) may be needed for further investigation.

Another limitation of the present study is that only 61 % of the eligible sample was included in the present study, although the response rate was relatively high (80 %). The excluded subjects differed somewhat from those included in the present analysis, as mentioned above. However, a previous analysis concluded that there was no evidence to suggest serious non-response bias in the NDNS[38]. In addition, although we adjusted for a variety of potential confounding variables, residual confounding could not be ruled out. In particular, adjustment for physical activity may be insufficient in the analysis of children as all subjects aged ≤6 years were categorised into the same category because of a lack of information. In addition, we could not control for puberty status or parental weight status because of a lack of information, which may cause potential confounding by unknown or unmeasured factors.

There is currently no consensus about what constitutes an eating occasion, a meal or a snack. In this regard, we could not conduct the present analysis on the basis of self-identification of eating occasions, the most common definition of meals and snacks (because of a lack of information in the NDNS), although it is subject to inconsistencies due to differences in individual perception[35]. In addition, meals and snacks based on time may be problematic, because eating patterns vary according to lifestyle (e.g. shift workers, individuals who consistently eat their meals at non-traditional times of day) as well as the cultural environment[35]. Furthermore, definition of meals and snacks based on EI contribution (≥15 or <15 %) was made on the basis of the US national averages of the distribution of energy from (self-defined) meals compared with (self-defined) snacks (breakfast: approximately 16 %; lunch: approximately 25 %; dinner: approximately 37 %; and snacks: approximately 22 % from two occasions)[14], but this may not be suitable for the present British population. Thus, results may possibly differ on the basis of other definitions. In any case, as studies explicitly examining the impact of these different definitions are limited, it is currently difficult to decide which definition might be most appropriate for meals and snacks, and further research using different definitions of meals and snacks is needed before reaching a consensus on what defines meals and snacks.

Finally, we assessed misreporting of EI against calculated EER using published equations[51]. In the absence of measured total energy expenditure, these equations with high R^2 values (≥0·95)[51] should serve as the best proxy. Nevertheless, the selection of physical activity category was based on self-report (i.e. 7-d physical activity diary) in subjects aged ≥7 years and fixed in subjects aged ≤6 years, which may be susceptible to systematic error. In addition, we do not know the sensitivity and specificity of the procedure used for identifying EI misreporters. However, even though some misclassification of subjects according to EI reporting status did occur in this study, we are confident of our conclusions, because the associations of ED of meals and snacks with dietary intakes and adiposity measures observed in the entire populations were similarly observed in acceptable reporters. Nonetheless, it should be stressed that the role of misreporting was mainly evaluated only in terms of under-reporting because over-reporting occurred in such a low number of cases that no conclusions could be drawn in this regard.

In conclusion, in this cross-sectional study in British children and adolescents, ED of meals was associated with less favourable dietary intake patterns, including lower intakes vegetables, fruits and dietary fibre, higher intakes of fat and lower diet quality (assessed by MDS). ED of snacks was similarly associated with less favourable dietary intake patterns, but the associations were generally weaker. After adjustment for potential confounders, ED of meals and snacks did not show positive associations with adiposity measures. These were not dependent on the definition of meals and snacks. In analyses where only acceptable EI reporters were included, similar results were obtained. The present findings suggest stronger associations of ED of meals with overall diet quality but not adiposity measures compared with ED of snacks. Further research, particularly with a prospective design, is needed so that firm conclusions can be drawn with regard to the effect of ED of meals and snacks on overall diet quality and adiposity measures.

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Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114516003731

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