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Energy density of meals and snacks in the British diet in relation to overall diet quality, BMI and waist circumference: findings from the National Diet and Nutrition Survey

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Abstract

This cross-sectional study examined how energy density (ED) in meals and snacks is associated with overall diet quality, BMI and waist circumference (WC). On the basis of the data from 7-d weighed dietary record, all eating occasions were divided into meals or snacks based on time (meals: 06.00–10.00, 12.00–15.00 and 18.00–21.00 hours; snacks: others) or contribution to energy intake (EI) (meals: ≥15; snacks: <15 %) in 1451 British adults aged 19–64 years. Irrespective of the definition of meals and snacks, both meal ED and snack ED (kJ/g; calculated on the basis of solid food only) were inversely associated with overall diet quality assessed by the healthy diet indicator (regression coefficient (β) = −0·29 to −0·21 and −0·07 to −0·04, respectively) and Mediterranean diet score (β = −0·43 to −0·30 and −0·13 to −0·06, respectively) in both sexes ($P \leq 0{\cdot}002$), although the associations were stronger for meal ED. After adjustment for potential confounders, in both men and women, meal ED based on EI contribution showed positive associations with BMI (β = 0·34; 95 % CI 0·06, 0·62 and β = 0·31; 95 % CI 0·01, 0·61, respectively) and WC (β = 0·96; 95 % CI 0·27, 1·66 and β = 0·67; 95 % CI 0·04, 1·30, respectively). In addition, meal ED based on time was positively associated with WC in men (β = 0·59; 95 % CI 0·07, 1·10) and snack ED based on time was positively associated with BMI in women (β = 0·15; 95 % CI 0·04, 0·27). In analyses in which only acceptable EI reporters were included, similar results were obtained. In conclusion, the findings suggest stronger associations of meal ED with overall diet quality, BMI and WC compared with snack ED.

Key words: Meals: Snacks: Diet quality: Obesity

Traditionally, nutritional research has concentrated on the detailed examination of possible health roles and consequences of dietary components (foods and/or nutrients) considered in isolation. However, the effects of individual foods and nutrients on health are usually difficult to estimate, because they can be small[1]. Furthermore, nutrients and foods are consumed in combination, and their combined effects may be interactive or synergistic[2]. Thus, an understanding of how different combinations of foods in meals and snacks are associated with overall diet quality and health status (such as measures of body fatness) is important for, for example, the development of science-based recommendations of meals and snacks for consumers[3].

Nevertheless, only a limited number of studies have been conducted to date to examine meal and snack eating behaviours in relation to overall diet and health markers[4–7], mainly because there is no consensus about what constitutes a snack, a meal or an eating occasion[3]. Although some researchers have relied on respondents' self-identification of meals, snacks or eating occasions[4–6,8–14], others have attempted to use more objective criteria (based on clock time, energy content/contribution or both)[5–7,15–26]. An accurate distinction between meals and snacks is important, because they are hypothesised to have different effects on energy and nutrient intakes[7,27,28]. An understanding of the influence of different meal and snack definitions on the associations between dietary characteristics of meals and snacks with overall diet quality and measures of body fatness may help establish consensus on the most appropriate research definition for meals and snacks[3]. In addition, the association of meal and snack intake or pattern with measures of body fatness (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[29,30].

The aim of this cross-sectional study in British adults was to examine how different combinations of foods assessed by energy density (ED) in meals and snacks are associated with overall diet quality, BMI and waist circumference (WC), by

Abbreviations: ED, energy density; EER, estimated energy requirement; EI, energy intake; HDI, healthy diet indicator; MDS, Mediterranean diet score; NDNS, National Diet and Nutrition Survey; WC, waist circumference.

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focusing on the confounding of EI misreporting and the use of different definitions of meals and snacks. We applied ED here not only because there is strong evidence that diets high in ED are associated with increased body weight[31–37], as well as lower diet quality[34,35,38–40], but also because ED has the advantages of being similarly calculated based on data on dietary intake from meals and snacks.

Methods

Survey design

This cross-sectional study was based on the National Diet and Nutrition Survey (NDNS): Adults Aged 19 to 64 Years. Details of the rationale, design and methods of the survey have been described in detail elsewhere[41]. In brief, the sample was randomly selected from 152 randomly selected postal sectors within mainland Great Britain. Eligibility was defined as being aged 19–64 years and not pregnant or breast-feeding. One eligible adult per private household was selected at random. Data collection was conducted from July 2000 to June 2001. 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. Written informed consent was obtained from all subjects.

Anthropometric measurements

All anthropometric measurements were performed 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. WC was measured at the midpoint between the iliac crest and the lower rib (to the nearest 0·1 cm).

Dietary assessment

Dietary data were collected by a 7-d weighed dietary record. A detailed description of the procedure has been published elsewhere[41,42]. In brief, each subject was supplied with a set of digital food scales and recording diaries. The subject was given written and verbal instructions by trained interviewers on how to weigh and record items in the diary. When weighing was not possible (e.g. eating out; 47 % of total food items recorded), the subject was asked to record as much information as possible. 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 of foods, energy and selected nutrients were calculated based on the Food Standards Agency nutrient databank[43], which is based on *McCance & Widdowson's: The Composition of Foods* series[44] and manufactures' data where applicable. For all dietary variables, mean values over 7 d were used in the analysis. Values of food and nutrient intake were energy-adjusted using the density method (i.e. percentage of energy for energy-providing nutrients and amount per 10 MJ of energy for foods and other nutrients).

As measures of diet quality, the healthy diet indicator (HDI) and the Mediterranean diet score (MDS) were calculated, as described elsewhere[7]. The HDI includes six nutrients and one food group (SFA, PUFA, cholesterol, protein, dietary fibre, fruits and vegetables, and non-milk extrinsic sugar)[45,46]. When intake was within the recommended range according to WHO guidelines, a score of one was assigned to that component; otherwise, a score of 0 was assigned, with a total score ranging from 0 to 7. Hence, a higher score reflected a healthier dietary pattern. The MDS represents a Mediterranean-type diet and is based on the consumption of nine different components (vegetables; legumes; fruits, nuts and seeds; cereals; fish; the ratio of unsaturated fatty acids:SFA; meat; dairy products; and alcohol)[46,47]. A score of 1 was assigned to moderate alcohol intake or, depending on the component, intake above or below the sex-specific median. Scores for all nine components were summed and resulted in a total range from 0 to 9, 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 caloric and non-caloric beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk)[48], because EI from beverages is regulated differently from EI from foods[49]. In addition, this calculation method has been shown to provide the best correlations with measurements of obesity in several previous analyses[34–36].

Definition of meals and snacks

In the present study, eating occasions were defined as any occasion when any food or drink was consumed[7,9,10,16,26]. If two eating occasions occurred in ≤15 min, both events were counted as a single eating occasion; when two eating occasions were separated by >15 min , these were considered distinct eating occasions[7,16,17,19,26]. All eating occasions were further divided into either meals or snacks with the use of two different published definitions: on the basis of (1) clock time[20] and (2) contribution to total EI[21]. For the first definition, meals were defined as eating events reported during selected times of the day – that is, 06.00–10.00, 12.00–15.00 and 18.00–21.00 hours. All other eating occasions were considered snacks. For 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 based on all eating occasions except for those providing <210 kJ of energy[6,7,9,10,16,26]. 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 each respondent (i.e. occupational social class) was self-reported and categorised as manual or non-manual. Smoking status (never, former or current) was also self-reported. A 7-d physical activity diary was carried out concurrently with the dietary record. A detailed description of the procedure has been published elsewhere[41,42]. Briefly, the subject was shown by trained interviewers how to record the information, and was asked to record, to the nearest 10 min, how long they spent doing various activities on that day. Trained interviewers checked the completeness of records at least twice during the recording period. Subsequently, time spent daily in sleep, light-, moderate- and vigorous-intensity activities was computed for each day of recording. The number of hours spent per day on each activity was multiplied by the metabolic equivalent (MET) value of that activity (derived from a published table)[50], and all MET-h products were summed to produce a total MET-h score for the day. A mean daily value over 7 d was used in the analysis.

Evaluation of energy intake reporting

We calculated each subject's estimated energy requirement (EER) based on the information on age, weight, height and physical activity, with the use of equations published in the US Dietary Reference Intakes[51]. Physical activity category was determined for each subject based on the physical activity level calculated as total MET-h/d (from the 7-d physical activity diary) divided by 24. Subjects were identified as acceptable reporters, under-reporters or over-reporters of EI based on 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[15], acceptable reporters were defined as having EI:EER in the range 0·665–1·335, under-reporters as EI:EER < 0·665 and over-reporters as EI:EER > 1·335. A detailed description of the procedure has been published elsewhere[42].

Analytic sample

Of 3704 potentially eligible people identified for the study, 2251 (61 % of eligible sample) participated in the survey. For the present analysis, we excluded a total of 736 subjects with missing information on the variables used. We further excluded twenty-eight underweight subjects (BMI < 18·5 kg/m^2)[52] and thirty-six subjects without any snacking occasion (based on either definition) during the 7-d period. The final analysis sample comprised 1451 adults aged 19–64 years (659 men and 792 women; 39 % of eligible sample). Further exclusion of subjects who reported dieting or who reported that illness had affected their eating during the diet-recording period (n 386) did not alter the findings of the present study (data not shown). Although both dieting and illness are likely to have some influence on the quantity of diet, it is unknown whether or how these factors are associated with the quality of diet (i.e. energy-adjusted dietary intakes, as well as ED). To minimise the possibility of bias caused by excluding these subjects, they were included in the analysis.

Statistical analysis

All statistical analyses were performed for men and women separately, using SAS statistical software (version 9.4; SAS Institute Inc.). 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 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 and WC. Potential confounding factors considered were age, social class, smoking status, physical activity, meal frequency, snack frequency and EI from beverages (model 1). We further included EI:EER as a potential confounding factor (model 2). These potential confounding factors were selected *a priori* based on a comprehensive literature review of epidemiological studies on ED[31–37] and meal and snack eating behaviours[4–10,15–19,21,23,26] in relation to measures of body fatness. ED of meals and snacks was analysed continuously after confirming the linearity of relations using tertile categories. All the analyses were repeated after excluding under- and over-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[41] but also because we were only interested in relationships between variables, rather than estimates of prevalence[26,42]. All reported P values are two-tailed, and P values of <0·05 were considered to be statistically significant.

Power calculations were performed on the basis of sample size and the standard deviations of ED of total diet, BMI and WC in the present study. We had >80 % power to detect associations as small as 0·30 (men) and 0·32 (women) kg/m^2 increase of BMI and 0·75 (men) and 0·67 (women) cm increase of WC/kJ per g increase of ED of total diet, at $\alpha = 0{\cdot}05$. Thus, the present study had adequate power to detect a magnitude of associations similar to those reported in previous studies[35,36].

Results

Characteristics of subjects are shown in Table 1. The percentages of acceptable reporters and under-reporters were 64 and 36 % in men and 56 and 44 % in women, respectively (only three men (0·5 %) were classified as over-reporters). Compared with acceptable reporters, under-reporters had lower mean values for age, EI, ED, eating frequency, meal and snack frequency, and higher mean values for physical activity (women only), BMI and WC. Under-reporters were also more likely to be

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

	Men							Women						
	All (*n* 659)†		AR (*n* 422)		UR (*n* 234)			All (*n* 792)		AR (*n* 446)		UR (*n* 346)		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	Mean	SD	*P*‡
Age (years)	42·5	11·9	43·5	11·7	40·8	12·0	0·006	42·4	12·0	43·8	12·3	40·7	11·3	0·0004
Social class (%)							0·04							0·007
Manual	45·7		42·4		50·9			32·2		28·3		37·3		
Non-manual	54·3		57·6		49·2			67·8		71·8		62·7		
Smoking status (%)							0·11							0·02
Never	44·3		46·9		39·7			46·5		50·9		40·8		
Former	25·6		25·8		25·6			22·0		20·4		24·0		
Current	30·1		27·3		34·6			31·6		28·7		35·3		
Physical activity (MET-h/d)	46·0	10·0	45·4	9·5	46·8	10·4	0·09	42·3	4·1	42·0	3·8	42·7	4·4	0·008
BMI (kg/m^2)	27·3	4·4	26·6	3·7	28·6	5·1	<0·0001	26·8	5·6	25·6	4·7	28·3	6·3	<0·0001
WC (cm)	96·0	11·1	94·7	10·3	98·5	11·9	<0·0001	83·1	11·9	81·2	10·9	85·5	12·8	<0·0001
EI:EER	0·73	0·19	0·83	0·13	0·55	0·10	<0·0001	0·69	0·18	0·82	0·11	0·53	0·10	<0·0001
EI (kJ/d)	9882	2510	11 029	1939	7690	1617	<0·0001	6980	1744	8077	1256	5565	1171	<0·0001
Energy density (kJ/g)§	7·87	1·44	7·99	1·38	7·62	1·50	0·002	7·18	1·57	7·44	1·54	6·85	1·56	<0·0001
Eating frequency (times/d)	5·65	1·88	6·13	1·79	4·73	1·53	<0·0001	4·89	1·41	5·47	1·32	4·16	1·15	<0·0001
MF_{time} (times/d)‖	3·64	1·19	3·93	1·11	3·10	1·04	<0·0001	3·30	0·97	3·63	0·92	2·87	0·85	<0·0001
SF_{time} (times/d)‖	2·01	1·12	2·20	1·15	1·62	0·93	<0·0001	1·60	0·84	1·84	0·86	1·29	0·71	<0·0001
$MF_{energy\%}$ (times/d)¶	2·29	0·55	2·34	0·54	2·20	0·57	0·002	2·29	0·57	2·35	0·55	2·21	0·60	0·0008
$SF_{energy\%}$ (times/d)¶	3·35	2·03	3·79	1·99	2·52	1·66	<0·0001	2·61	1·53	3·12	1·55	1·95	1·22	<0·0001
Healthy diet indicator**	2·27	1·36	2·25	1·34	2·30	1·40	0·64	2·50	1·34	2·47	1·29	2·55	1·40	0·40
Mediterranean diet score††	4·43	1·69	4·45	1·64	4·43	1·77	0·89	4·39	1·67	4·39	1·71	4·38	1·63	0·95

AR, acceptable reporters; UR, under-reporters; MET, metabolic equivalent; WC, waist circumference; 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 0·665:1·335; UR were defined as subjects with EI:EER < 0·665.

† Including over-reporters of energy intake (*n* 3), defined as subjects with EI:EER > 1·335.

‡ *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.

§ Calculated based on foods only; excluding all caloric and non-caloric 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 (06.00–10.00, 12.00–15.00 and 18.00–21.00 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 day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.

** Possible score ranging from 0 to 7.

†† Possible score ranging from 0 to 9.

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employed in manual occupations and be former and current smokers (women only).

Characteristics of meals and snacks were generally similar in men (Table 2) and women (Table 3). On the basis of the time definition, >60 % of food EI, beverage EI and food weight came from meals and the balance from snacks. Conversely, when the EI contribution definition was applied, meals contributed >80 % of food EI and food weight consumed and <41 % of beverage EI with the balance derived from snacks. Irrespective of the definition, however, ED of snacks was higher than ED of meals. In terms of dietary composition, meals were higher in vegetables, legumes (except for the time definition in men), cereals, fish, meat, protein, total fat and SFA (except for the time definition in men), starch and dietary fibre. Conversely, snacks were higher in fruits, biscuits/cakes/pastries, dairy products, sugar/preserves/confectionery, carbohydrate (only the EI contribution definition), non-milk extrinsic sugar and alcohol.

The associations of ED of meals and snacks with total dietary intakes were generally similar in both men (online Supplementary Table S1) and women (online Supplementary Table S2). Irrespective of the definition of meals and snacks, higher meal ED and snack ED were associated with unfavourable profiles of individual components of the diet, including lower intakes of vegetables, fruits, protein and dietary fibre, and higher intakes of sugar/preserves/confectionery, total fat, non-milk extrinsic sugar (except for the EI-contribution-defined meals in men) and total energy (except for the EI-contribution-defined meals in men). However, the strength of the associations was generally stronger for meal ED compared with snack ED, which was clearly shown in the analysis of measures of diet quality (Table 4). Irrespective of the definition of meals and snacks, 1 unit increase of meal ED (kJ/g) was associated with 0·21–0·29 point decrease of HDI and 0·30–0·43 point decrease of MDS, whereas 1 unit increase of snack ED was associated with only 0·04–0·07 point decrease of HDI and 0·06–0·13 decrease of MDS ($P \leq 0{\cdot}002$).

Associations of ED of meals and snacks with measures of body fatness are shown in Table 5. After adjustment for potential confounding factors except for EI:EER (model 1), ED of meals, snacks and total diet showed no associations with BMI and WC in both men and women. However, in both men and women, further adjustment for EI:EER (model 2) resulted in positive associations between ED of meals based on EI contribution and BMI (regression coefficient (β) = 0·34; 95 % CI 0·06, 0·62 and β = 0·31; 95 % CI 0·01, 0·61, respectively) and WC (β = 0·96; 95 % CI 0·27, 1·66 and β = 0·67; 95 % CI 0·04, 1·30, respectively) and between ED of total diet and BMI (β = 0·25; 95 % CI 0·004, 0·50 and β = 0·46; 95 % CI 0·20, 0·73, respectively) and WC (β = 0·99; 95 % CI 0·38, 1·60 and β = 0·98; 95 % CI 0·42, 1·54, respectively). Further, ED of meals based on time was positively associated with WC in men (β = 0·59; 95 % CI 0·07, 1·10), whereas ED of snacks based on time was positively associated with BMI in women (β = 0·15; 95 % CI 0·04, 0·27). All the analyses were repeated after excluding under- and over-reporters, providing similar results in terms of characteristics of meals and snacks (online Supplementary Tables S3 and S4) and associations of ED of meals and snacks with total dietary intakes (online Supplementary Tables S5 and S6), and BMI and WC (online Supplementary Table S7).

Discussion

To our knowledge, this is the first study to examine how different combinations of foods in meals and snacks assessed by ED are associated with overall diet quality and measures of body fatness. Irrespective of the definition of meals and snacks, both meal and snack ED showed inverse associations with overall diet quality (assessed by HDI and MDS) in British adults. However, the associations were stronger for ED of meals. After adjustment for potential confounders, ED of meals based on EI contribution was positively associated with BMI and WC in both sexes, whereas ED of meals based on time was positively associated with WC in men and ED of snacks based on time was positively associated with BMI in women. In analyses in which only acceptable EI reporters were included, similar results were obtained. The present findings suggest stronger associations of ED of meals with overall diet quality, BMI and WC compared with ED of snacks.

In the present study, 19–30 % of EI was derived from snacks, depending on the definition of snacks and sex. These figures are within the range of those observed in Norway (17 % for men and 21 % for women)[11], Brazil (21 % for both sexes combined)[20], the USA (23 % for both men and women)[12] and Finland (36 % for men and 40 % for women)[13]. This suggests that a considerable proportion of total EI is derived from snacks in affluent countries, regardless of the definitions applied.

Only a very limited number of studies have compared the dietary composition of 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 compared with snacks[14,22–25]. Meals had a lower proportion of total sugars but not total carbohydrate[22] or had a higher density of dietary fibre compared with snacks[23,25]. These observations are generally similar to those obtained in the present study. Taken together, it is speculated that meals and snacks are differentially associated with overall diet quality and health status. In the present study, different combinations of foods in meals and snacks were assessed by ED of meals and ED of snacks, respectively, not only because there is strong evidence that diets high in ED are associated with increased body weight[31–37], as well as lower diet quality[34,35,38–40], but also because ED has the advantages of being similarly calculated based on data on dietary intake from meals and snacks. Higher meal ED was associated with lower diet quality (assessed by HDI and MDS), and was independent of the definition of meals. Higher snack ED was similarly associated with lower diet quality, but the associations were generally weaker. Using data from a 7-d food record, de Castro[53,54] showed that higher ED was associated with higher EI regardless of the time of day, which is generally consistent with the present finding that meal and snack ED was positively associated with total EI (except for the EI-contribution-defined meals in men). However, because the main determinants of the ED (of any foods, meals or snacks) are the water and fat contents, it is not surprising that ED is inversely associated with overall diet quality – that is, HDI and MDS, both of which largely depend on intakes of fats and vegetables (high in water), as well as dietary fibre[45–47]. The present results should be interpreted with this kind of circularity

Table 2. Characteristics of meals and snacks in men (*n* 659)
(Mean values and standard deviations)

			Meals and snacks determined based on time*					Meals and snacks determined based on EI contribution†				
	Total intake		Intake from meals		Intake from snacks			Intake from meals		Intake from snacks		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	*P*‡
Food EI (kJ/d)	8195	2250	5927	2085	2267	1514	<0·0001	6850	1815	1345	1037	<0·0001
Beverage EI (kJ/d)	1687	1058	1033	649	654	593	<0·0001	607	470	1080	891	<0·0001
Food weight consumed (g/d)	1063	304	781	299	282	199	<0·0001	898	239	165	138	<0·0001
Energy density (kJ/g)§	7·87	1·44	7·88	1·69	8·80	2·94	<0·0001	7·75	1·33	9·57	4·31	<0·0001
Food intake (g/10 MJ)												
Vegetables	110·2	93·6	115·8	105·2	86·7	141·7	<0·0001	135·3	111·3	37·8	136·1	<0·0001
Legumes	38·4	40·1	38·9	47·5	33·6	80·2	0·13	49·6	52·9	3·4	20·0	<0·0001
Fruits	98·2	117·9	96·6	132·6	123·2	247·2	0·005	62·6	99·9	243·2	374·5	<0·0001
Cereals	242·0	102·2	259·8	118·6	178·5	134·4	<0·0001	278·8	116·3	123·9	139·5	<0·0001
Biscuits, cakes and pastries	38·6	39·5	33·7	41·0	59·8	82·5	<0·0001	32·5	38·6	56·4	73·9	<0·0001
Fish	34·6	41·6	37·2	47·6	26·4	70·3	0·0002	43·0	50·7	6·4	33·1	<0·0001
Meat	203·5	95·4	206·0	107·8	168·6	162·7	<0·0001	258·9	123·2	32·6	67·6	<0·0001
Dairy products	285·5	186·9	282·0	190·5	355·5	371·7	<0·0001	174·6	141·6	711·4	674·7	<0·0001
Sugar, preserves and confectionery	33·7	34·3	32·2	37·0	43·5	55·1	<0·0001	19·5	23·1	78·0	89·3	<0·0001
Nutrient intake												
Protein (% of energy)	15·3	2·8	15·7	3·1	13·6	4·6	<0·0001	17·1	3·1	10·0	4·5	<0·0001
Fat (% of energy)	33·5	5·8	33·7	6·3	31·6	9·7	<0·0001	37·6	6·1	20·9	9·6	<0·0001
SFA (% of energy)	12·6	3·0	12·5	3·2	12·6	4·4	0·78	13·5	3·1	10·0	5·2	<0·0001
Carbohydrate (% of energy)	44·8	7·0	45·2	7·4	44·9	10·7	0·43	42·5	7·0	52·9	13·4	<0·0001
Starch (% of energy)	25·5	5·7	26·5	6·1	21·5	8·3	<0·0001	29·2	5·7	13·8	9·0	<0·0001
Non-milk extrinsic sugar (% of energy)	12·6	6·0	12·0	6·5	16·1	10·2	<0·0001	7·8	4·1	27·8	15·9	<0·0001
Alcohol (% of energy)	6·5	7·0	5·5	6·3	10·0	13·2	<0·0001	2·9	4·2	16·2	17·2	<0·0001
Dietary fibre (g/10 MJ)	16·0	5·4	16·6	5·9	13·8	7·4	<0·0001	17·6	5·2	11·2	9·0	<0·0001

EI, energy intake.
* Meals were defined as eating events reported during select times of the day (06.00–10.00, 12.00–15.00 and 18.00–21.00 hours); all other eating occasions were considered as snacks.
† A meal was defined as any eating episode comprising ≥15 % of total energy intake, regardless of the time of 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 based on foods only; excluding all caloric and non-caloric beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).

Table 3. Characteristics of meals and snacks in women (*n* 792)
(Mean values and standard deviations)

			Meals and snacks determined based on time*					Meals and snacks determined based on EI contribution†				
	Total intake		Intake from meals		Intake from snacks			Intake from meals		Intake from snacks		
	Mean	SD	Mean	SD	Mean	SD	*P*‡	Mean	SD	Mean	SD	*P*‡
Food EI (kJ/d)	5980	1614	4352	1492	1628	1069	<0·0001	4990	1289	989	704	<0·0001
Beverage EI (kJ/d)	1000	595	641	3800	359	319	<0·0001	405	287	595	461	<0·0001
Food weight consumed (g/d)	861	260	637	264	224	155	<0·0001	715	207	146	111	<0·0001
Energy density (kJ/g)§	7·18	1·57	7·26	1·78	8·15	3·43	<0·0001	7·19	1·45	8·10	4·26	<0·0001
Food intake (g/10 MJ)												
Vegetables	162·3	123·1	164·2	139·6	127·7	177·0	<0·0001	195·7	147·0	49·8	142·1	<0·0001
Legumes	35·6	3·9	35·7	46·2	28·7	65·7	0·01	44·5	49·8	4·3	27·3	<0·0001
Fruits	156·8	170·5	150·9	180·3	228·2	436·1	<0·0001	93·1	129·5	426·8	568·6	<0·0001
Cereals	241·1	103·0	261·2	117·6	168·7	157·7	<0·0001	272·2	117·5	120·8	138·8	<0·0001
Biscuits, cakes and pastries	41·7	38·3	36·3	38·9	66·1	82·2	<0·0001	35·7	39·3	63·1	73·4	<0·0001
Fish	44·7	58·7	45·7	62·0	33·3	89·4	0·0002	54·6	69·7	8·5	39·7	<0·0001
Meat	187·1	113·4	183·3	127·5	158·1	177·3	0·0005	234·2	139·8	19·1	53·6	<0·0001
Dairy products	366·7	221·7	368·6	240·7	446·2	465·8	<0·0001	219·8	165·6	945·5	716·7	<0·0001
Sugar, preserves and confectionery	31·7	34·4	30·5	38·2	43·9	62·2	<0·0001	19·8	23·9	72·6	93·0	<0·0001
Nutrient intake												
Protein (% of energy)	15·9	3·3	16·0	3·6	14·4	5·4	<0·0001	17·2	3·5	11·4	4·6	<0·0001
Fat (% of energy)	33·6	6·5	33·6	7·2	32·3	9·7	<0·0001	36·7	6·8	22·8	9·7	<0·0001
SFA (% of energy)	12·7	3·3	12·6	3·5	13·0	5·0	0·01	13·2	3·4	11·0	5·3	<0·0001
Carbohydrate (% of energy)	46·6	7·1	46·9	7·8	47·4	11·2	0·26	44·1	7·0	55·6	12·5	<0·0001
Starch (% of energy)	26·4	5·7	27·3	6·3	22·1	9·0	<0·0001	29·5	6·0	14·8	8·6	<0·0001
Non-milk extrinsic sugar (% of energy)	11·5	6·1	11·0	6·9	14·8	10·6	<0·0001	7·8	4·1	24·0	14·8	<0·0001
Alcohol (% of energy)	4·1	5·5	3·5	5·3	6·0	10·8	<0·0001	2·1	3·5	10·4	14·0	<0·0001
Dietary fibre (g/10 MJ)	18·7	7·0	19·3	8·2	16·3	8·8	<0·0001	19·8	6·7	15·1	11·5	<0·0001

EI, energy intake.
* Meals were defined as eating events reported during select times of the day (06.00–10.00, 12.00–15.00 and 18.00–21.00 hours); all other eating occasions were considered as snacks.
† A meal was defined as any eating episode comprising ≥15 % of total energy intake, regardless of the time of 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 based on foods only; excluding all caloric and non-caloric beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).

Table 4. Associations of energy density of meals and snacks with measures of diet quality*
(Regression coefficients (β) and 95 % confidence intervals)

	Meals and snacks determined based on time†						Meals and snacks determined based on EI contribution‡					
	Energy density of meals			Energy density of snacks			Energy density of meals			Energy density of snacks		
	β§	95 % CI§	*P*	β§	95 % CI§	*P*	β§	95 % CI§	*P*	β§	95 % CI§	*P*
Men (*n* 659)												
Healthy diet indicator‖	−0·25	−0·31, −0·19	<0·0001	−0·06	−0·09, −0·02	0·0008	−0·25	−0·33, −0·17	<0·0001	−0·07	−0·10, −0·05	<0·0001
Mediterranean diet score¶	−0·30	−0·38, −0·23	<0·0001	−0·13	−0·17, −0·09	<0·0001	−0·36	−0·46, −0·26	<0·0001	−0·09	−0·12, −0·07	<0·0001
Women (*n* 792)												
Healthy diet indicator‖	−0·21	−0·27, −0·16	<0·0001	−0·05	−0·08, −0·02	0·0003	−0·29	−0·36, −0·22	<0·0001	−0·04	−0·06, −0·01	0·002
Mediterranean diet score¶	−0·33	−0·39, −0·27	<0·0001	−0·06	−0·09, −0·02	0·0005	−0·43	−0·51, −0·34	<0·0001	−0·06	−0·08, −0·03	<0·0001

EI, energy intake.
* Energy density was calculated based on foods only, excluding all caloric and non-caloric beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk). Adjustment was made for age (years, continuous) and social class (manual or non-manual). 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 (06.00–10.00, 12.00–15.00 and 18.00–21.00 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 day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.
§ Regression coefficients mean the change of diet quality measures with 1 unit increase of energy density (kJ/g).
‖ Possible score ranging from 0 to 7.
¶ Possible score ranging from 0 to 9.

between ED and diet quality measures in mind. For measures of body fatness, only ED of meals based on EI contribution (as well as ED of total diet) showed consistent and positive associations with BMI and WC. Evidence from epidemiological studies have generally supported the positive association between ED of total diet and measures of body fatness[31–37]. The present findings suggest that decreasing the ED of meals rather than that of snacks would improve overall diet quality and measures of body fatness. However, as a few existing studies on meal and snack eating behaviours in relation to overall diet and measures of body fatness have been producing somewhat conflicting findings[4–7], more research, preferably with a prospective design, should be conducted before reaching a firm conclusion.

In the present study, the direction of the association of ED of meals and ED of snacks with BMI and WC radically changed after adjustment for EI:EER. Given that under-reporters were characterised by higher BMI and WC and lower ED and eating frequency, this may be because of the under-reporting of ED of meals and snacks concomitant with the under-reporting of EI by subjects with higher BMI and WC[26]. Thus, the present study highlights the key importance of adjusting for EI misreporting in studies of dietary variables associated with EI misreporting (ED in this case) in relation to measures of body fatness.

The strengths of this 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 measure 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 relation between meal and snack intake and overall diet quality and measures of body fatness.

At present, the only way to obtain unbiased information on energy requirements in free-living settings is to use doubly-labelled water[55]. This technique is expensive and impractical for application to large-scale epidemiological studies. Instead, we calculated EER with the use of published equations[51]. In the absence of measured total energy expenditure, these equations with high R^2 values (0·82 for men and 0·79 for women)[51] should serve as the best proxy, although the selection of physical activity category was based on self-report (i.e. 7-d physical activity diary), which may be susceptible to reporting bias. In addition, we do not know the sensitivity and specificity of the procedure for identifying EI misreporters used. 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 overall diet quality and measures of body fatness 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.

Table 5. Associations of energy density (ED) of meals and snacks with measures of body fatness*
(Regression coefficients (β) and 95 % confidence intervals)

	Men (*n* 659)						Women (*n* 792)					
	Model 1†			Model 2‡			Model 1†			Model 2‡		
	β§	95 % CI§	*P*	β§	95 % CI§	*P*	β§	95 % CI§	*P*	β§	95 % CI§	*P*
ED of meals determined based on time (kJ/g)‖												
BMI (kg/m^2)	0·05	−0·16, 0·26	0·63	0·16	−0·05, 0·37	0·14	−0·15	−0·40, 0·09	0·22	0·08	−0·16, 0·32	0·52
WC (cm)	0·35	−0·17, 0·87	0·19	0·59	0·07, 1·10	0·03	−0·11	−0·62, 0·39	0·67	0·30	−0·20, 0·80	0·25
ED of snacks determined based on time (kJ/g)‖												
BMI (kg/m^2)	−0·08	−0·19, 0·04	0·19	−0·02	−0·13, 0·09	0·74	0·09	−0·03, 0·21	0·13	0·15	0·04, 0·27	0·007
WC (cm)	0·06	−0·23, 0·34	0·70	0·19	−0·09, 0·47	0·19	0·03	−0·21, 0·27	0·79	0·15	−0·09, 0·38	0·22
ED of meals determined based on EI contribution (kJ/g)¶												
BMI (kg/m^2)	0·10	−0·18, 0·38	0·47	0·34	0·06, 0·62	0·02	0·00	−0·31, 0·30	0·98	0·31	0·01, 0·61	0·04
WC (cm)	0·44	−0·25, 1·13	0·21	0·96	0·27, 1·66	0·007	0·11	−0·53, 0·74	0·75	0·67	0·04, 1·30	0·04
ED of snacks determined based on EI contribution (kJ/g)¶												
BMI (kg/m^2)	−0·06	−0·14, 0·03	0·18	−0·06	−0·14, 0·02	0·15	0·04	−0·06, 0·14	0·47	0·09	−0·01, 0·18	0·07
WC (cm)	0·03	−0·18, 0·23	0·79	0·02	−0·17, 0·22	0·81	0·08	−0·12, 0·29	0·43	0·18	−0·02, 0·38	0·08
ED of total diet (kJ/g)												
BMI (kg/m^2)	0·05	−0·20, 0·29	0·72	0·25	0·004, 0·50	0·046	0·09	−0·17, 0·36	0·49	0·46	0·20, 0·73	0·0006
WC (cm)	0·54	−0·07, 1·14	0·08	0·99	0·38, 1·60	0·002	0·31	−0·25, 0·87	0·28	0·98	0·42, 1·54	0·0006

WC, waist circumference; EI, energy intake.
* Energy density was calculated based on foods only, excluding all caloric and non-caloric beverages (tea, coffee, water, alcoholic beverages, soft drinks, fruit juice and milk).
† Adjusted for age (years, continuous), social class (manual or non-manual), smoking status (never, former, or current), physical activity (metabolic equivalent-h/d, continuous), 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 ED of meals and ED 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 (06.00–10.00, 12.00–15.00 and 18.00–21.00 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 day or composition of foods and beverages consumed; all other eating episodes were classified as snacks.

Another limitation of the present study is the relatively low response rate (61 %), and only 39 % of the eligible sample was included in the present study. The subjects included in the present analysis (*n* 1451) differed somewhat from those excluded from the analysis (*n* 705–758 depending on variables). The excluded subjects were more likely to be younger, be in manual occupations and be current smokers (all $P < 0{\cdot}05$). However, a previous analysis concluded that there was no evidence to suggest serious non-response bias in NDNS[41]. In addition, although pregnant and lactating women were excluded from the sample of NDNS, postpartum and non-lactating women were included in the present analysis (because of a lack of information), which might cause bias with regard to WC and BMI. Furthermore, although we adjusted for a variety of potential confounding variables, residual confounding could not be ruled out.

Finally, because there is no consensus about what constitutes a snack or a meal, the present results should be interpreted cautiously and oversimplification should be avoided. As mentioned above, we could not conduct the present analysis based on self-identification of eating occasions, the most common definition of meals and snacks (because of a lack of information in NDNS), although it is subject to inconsistencies due to differences in individual perception[28]. 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[28]. Furthermore, 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 snack: approximately 22 % from two occasions)[12], but this may not be suitable in the present British population. Thus, results may possibly differ on the basis of other definitions. In any case, as research explicitly examining the impact of these different definitions is limited, further research using different definitions of meals and snacks is warranted.

In conclusion, in this cross-sectional study in British adults, ED of meals was associated with lower overall diet quality (assessed by HDI and MDS). ED of snacks was similarly associated with lower overall diet quality, but the associations were generally weaker. These were not dependent on the definition of meals and snacks. After adjustment for potential confounders, ED of meals based on EI contribution showed positive associations with BMI and WC in both sexes, whereas ED of meals based on time was positively associated with WC in men and ED of snacks based on time was positively associated with BMI in women. In analyses in which only acceptable EI reporters were included, similar results were obtained. The present findings suggest stronger associations of ED of meals with overall diet quality, BMI and WC than ED of snacks. Further research, particularly with a prospective design, is needed so that any firm conclusions can be drawn with regard to the effect of different combinations of foods in meals and snacks on overall diet quality and measures of body fatness.

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Supplementary material

For supplementary material/s referred to in this article, please visit http://dx.doi.org/doi:10.1017/S0007114516003573

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