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ORIGINAL ARTICLE

Eating frequency in relation to body mass index and waist circumference in British adults

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BACKGROUND: Inconsistent associations between eating frequency (EF) and adiposity may be mainly due to measurement errors of EF.
OBJECTIVE: This cross-sectional study examined the association of EF with body mass index (BMI) and waist circumference (WC), by focusing on the confounding of energy misreporting and the effect of exclusion of underreporters (URs).
DESIGN: Dietary intake was assessed using a 7-day weighed dietary record in 1487 British adults aged 19–64 years. EF was calculated based on all eating occasions (EF_{all}), after excluding those providing no energy (EF_{energy}), and after excluding those providing <210 kJ of energy ($EF_{\geqslant 210\,kJ}$). Energy misreporting was assessed as reported energy intake divided by estimated energy requirement (EI:EER).
RESULTS: The mean values (1st and 99th percentiles) of EF_{all}, EF_{energy} and $EF_{\geqslant 210\,kJ}$ were, respectively, 7.8 (3.1, 15.3), 7.2 (2.9, 12.7), and 5.6 (2.3, 10.7) times/day in men and 7.6 (3.0, 13.9), 6.7 (2.7, 12.1), and 4.8 (1.9, 9.1) times/day in women. In the univariate analyses of the entire male population, $EF_{\geqslant 210\,kJ}$, but not EF_{all} and EF_{energy}, was inversely associated with BMI and WC. After full adjustment (including EI:EER), all three measures of EF were positively associated with BMI and WC. In the univariate analyses of the entire female population, all three measures of EF were inversely associated with BMI and WC. After full adjustment, $EF_{\geqslant 210\,kJ}$ was positively associated with BMI and WC while EF_{all} and EF_{energy} showed null associations. When URs (EI:EER <0.665) were excluded, the multivariate analyses showed that EF_{all} and EF_{energy} were positively associated with BMI in men while $EF_{\geqslant 210\,kJ}$ was positively associated with BMI and WC in both sexes.
CONCLUSIONS: We showed positive associations of EF with BMI and WC. Adjustment for EI:EER and the exclusion of URs, as well as definitions of EF, radically affected the results of the analysis.

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Keywords: eating frequency; diet; body mass index; waist circumference; underreporting; epidemiology

INTRODUCTION

Many epidemiologic studies have investigated the association between eating frequency (EF) and adiposity measures, but the results are far from consistent, with a mixture of inverse,[1–7] null,[8–13] and positive[14–18] associations. This is an issue that is beset by substantial methodological problems. First, while the assessment of EF has often relied on a series of self-report questions,[2,5–7,11,14,15,18] none of them have examined or reported the validity of the questions. Only a few studies[1,4,9,10] have assessed EF on the basis of information on actual dietary habits (using dietary record or 24-h recall) over a sufficient number of days to take into account that day-to-day variation in an individual's EF is relatively large.[19] Second, interpreting the literature on EF is complicated by the fact that there is no consensus about what constitutes a snack, a meal, or an eating occasion. While some researchers have relied on respondents' self-identification of meals, snacks, or eating occasions,[2,5–7,11–15,18] others have attempted to use more objective criteria.[1,3,4,8–10,16,17] To date, only two studies have investigated the influence of different definitions of EF on the association between EF and adiposity measures.[12,13] Third, given insufficient or no adjustment for potential confounding factors in many studies,[1,9,10,14–17] at least some of the findings observed previously may be due to confounding. In particular, the apparent inverse or no relation between EF and adiposity measures in most studies is likely to be an artifact that can in part be attributed to the underreporting of EF concomitant with the underreporting of energy intake (EI) by obese or overweight subjects.[20,21] However, many studies have not taken into account such a potential reporting bias.[2,4,5,7–9,11,14,15,18] In fact, a very limited number of studies[16,17] (but not all)[1,3,6,10,12,13] suggest that EF is positively, rather than inversely, associated with adiposity measures after accounting for EI reporting bias. This positive association seems plausible given that EF is almost always positively associated with EI.[1,2,6,8,10,12,13,15,17] Nevertheless, half of these studies[1,3,13,17] have used a fixed cut-off value to identify low-energy reporters, without taking into account the physical activity level of each subject, which may result in misclassification of up to 50% of low-energy reporters.[22,23] As a consequence of these methodological limitations, the discrepant findings are not surprising, which clearly bring into question the direction of the relationship between EF and adiposity measures and whether a relationship even exists. Thus, more robust data analyses are needed to clarify this issue.

The aim of this cross-sectional study in British adults was to examine the relationship of EF with body mass index (BMI) and waist circumference (WC), by focusing on the confounding of

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energy misreporting and the effect of exclusion of underreporters (URs). EF was objectively defined with the use of three different published methods, based on dietary information obtained from a 7-day weighed dietary record. Energy misreporting was assessed by comparing EI with individualized measure of estimated energy requirement (EER).

SUBJECTS AND METHODS

Survey design

This cross-sectional study was based on the National Diet and Nutrition Survey: Adults aged 19–64 years. Data from the National Diet and Nutrition Survey were obtained from the UK Data Archive, University of Essex. Details of the rationale, design, and methods of the survey have been described in detail elsewhere.[24] Briefly, 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 during a 12-month period (July 2000–June 2001).

Ethical approval for the survey was obtained from both a Multi-center Research Ethics Committee and the National Health Service Local Research Ethics Committee covering each of the postal sectors. All subjects gave written informed consent to participate in the survey.

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-day weighed dietary record. A detailed description of the procedure has been published elsewhere.[24,25] Briefly, each subject was supplied with a set of digital food scales and recording diaries. The subject was given by trained interviewers both written and verbal instructions on how to weigh and record items in the diary. When weighing was not possible (for example, 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 for foods, energy, and selected nutrients were calculated based on the Food Standards Agency nutrient databank,[26] which is based on McCance and Widdowson's composition of foods series[27] and manufactures' data where applicable. For all dietary variables, mean daily values over 7 days were used in the analysis. Values of nutrient intake were energy-adjusted using the density method (that is, % of energy for energy-providing nutrients and amount per 10 MJ of energy for dietary fiber).

Establishing the number of eating occasions

Data from the 7-day dietary record were also used to calculate the average number of eating occasions per day, that is, EF. Eating occasions were defined as any occasion when any food or drink was consumed.[12,13,17] If two eating occasions occurred in $\leqslant$15 min, both events were counted as a single eating occasion; when >15 min separated two eating occasions, these occasions were considered distinct eating occasions.[1,4,10,17] EF was calculated with the use of three different published methods:[3,4,12,13,17] EF based on all eating occasions (EF_{all}); EF based on all eating occasions except for those providing no energy (EF_{energy}); and EF based on all eating occasions except for those providing <210 kJ of energy ($EF_{\geqslant 210\,kJ}$).

Assessment of non-dietary variables

The socio-economic status of each respondent (that is, occupational social class) was self-reported and categorized as manual (that is, skilled manual, partly skilled, and unskilled occupations: social classes III manual, IV, and V) or non-manual (that is, professional, managerial, technical, and skilled non-manual occupations: social classes I, II, and III non-manual). Smoking status (never, former, or current) was also self-reported.

A 7-day physical activity diary was carried out concurrently with the dietary record. A detailed description of the procedure has been published elsewhere.[24,25] 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),[28] and all MET-h products were summed to produce a total MET-h score for the day. A mean daily value over 7 days was used in the analysis.

Evaluation of EI reporting

We calculated each subject's EER with the use of equations published from the US Dietary Reference Intakes.[29] Physical activity category was determined for each subject based on the physical activity level calculated as total MET-h/day (from the 7-day physical activity diary) divided by 24. Subjects were identified as acceptable reporters (ARs), URs, or over-reporters of EI based on their ratio of EI to EER (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. Based on a published equation,[16] ARs were defined as having EI:EER in the range 0.665 to 1.335, URs as EI:EER <0.665, and overreporters as EI:EER >1.335. A detailed description of the procedure has been published elsewhere.[25]

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 28 underweight subjects (BMI $<18.5\,kg\,m^{-2}$).[30] The final analysis sample comprised 1487 adults aged 19–64 years (678 men and 809 women; 40% of eligible sample). Further exclusion of subjects who reported dieting or that illness had affected their eating during the diet recording period ($n=397$) did not alter the findings of the present study (data not shown); therefore, these subjects were included in the analysis.

Statistical analysis

All statistical analyses were performed for men and women separately, using SAS statistical software (version 9.2, SAS Institute, Cary, North Carolina). Differences between ARs and URs (but not overreporters because of there being only a few of them) were tested by the independent *t*-test (for continuous variables) and by the χ^2 test (for categorical variables). Associations of EF with EI:EER and EI were investigated through Pearson correlation analyses. Linear regression analyses were performed to explore the associations of EF (independent variables) with BMI and WC (dependent variables). EF was analyzed continuously after confirming the linearity of relations using tertile, quartile, and quintile categories. With the use of the PROC REG procedure, we calculated the crude (that is, model 1) and adjusted (that is, models 2 and 3) regression coefficients (with s.e.) of variation of BMI and WC by one increase of EF. Potential confounding factors included in the multivariate models (model 2) were age (years, continuous), social class (manual or non-manual), smoking status (never, former, or current), physical activity (metabolic equivalent-h/day, continuous), and intakes of protein (% of energy, continuous), fat (% of energy, continuous), total sugar (% of energy, continuous), alcohol (% of energy, continuous), and dietary fiber (g/10 MJ, continuous). We further included EI:EER (continuous) as a potential confounding factor (model 3). The analyses were conducted not only for the entire population but also for ARs only or URs only.

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[24] but also because we were only interested in relationships between variables, rather than estimates of prevalence.[25] All reported *P*-values are 2-tailed, and *P*-values of <0.05 were considered statistically significant.

RESULTS

Underreporting of EI compared with EER was on average 27% in men and 31% in women (Table 1). The mean values of BMI and WC were, respectively, 27.3 kg m^{-2} and 96.0 cm in men and 26.8 kg m^{-2} and 83.1 cm in women. The mean values (1st, 5th, 95th, and 99th percentiles) of EF_{all}, EF_{energy}, and $EF_{\geqslant 210\ kJ}$ were, respectively, 7.8 (3.1, 4.0, 11.9, and 15.3), 7.2 (2.9, 3.6, 11.1, and 12.7), and 5.6 (2.3, 3.0, 9.1, and 10.7) times/day in men and 7.6 (3.0, 4.1, 11.3, and 13.9), 6.7 (2.7, 3.7, 10.0, and 12.1), and 4.8 (1.9, 2.7, 7.3, and 9.1) times/day in women. There were strong correlations among three measures of EF in both men (Pearson *r*: 0.91 between EF_{all} and EF_{energy}; Pearson *r*: 0.69 between EF_{all} and $EF_{\geqslant 210\ kJ}$; Pearson *r*: 0.76 between EF_{energy} and $EF_{\geqslant 210\ kJ}$) and women (Pearson *r*: 0.85 between EF_{all} and EF_{energy}; Pearson *r*: 0.55 between EF_{all} and $EF_{\geqslant 210\ kJ}$; Pearson *r*: 0.63 between EF_{energy} and $EF_{\geqslant 210\ kJ}$; all $P < 0.0001$).

The percentage of ARs and URs were 63 and 37% in men and 55 and 45% in women, respectively (only 3 men (0.4%) was classified as overreporters). In both men and women, compared with ARs, URs had a lower mean value of age, EI, and all three measures of EF and a higher mean value of physical activity, BMI, WC, and energy-adjusted intakes of protein and starch. They were also more likely to be employed in manual occupations and be current smokers. In women only, URs had lower mean intakes of fat and total sugar and a higher mean intake of dietary fiber.

All three measures of EF were significantly positively correlated with both EI:EER and EI in both men and women (Table 2). Significant (but weaker) correlations were also observed not only in the analysis of ARs only but also in the analysis of URs only.

Table 3 shows the associations of EF with adiposity measures in men. In the univariate analyses (model 1) for all men, $EF_{\geqslant 210\ kJ}$, but not EF_{all} and EF_{energy}, was inversely associated with BMI and WC. Adjustment for age, social class, smoking status, physical activity, and intakes of protein, fat, total sugar, alcohol, and dietary fiber (model 2) showed no relations of all three EF measures to BMI and WC. Further adjustment for EI:EER (model 3) resulted in positive associations between all three measures of EF and BMI and WC. In analyses in which only ARs were included, EF_{all} and EF_{energy} were positively associated with BMI whereas $EF_{\geqslant 210\ kJ}$ was positively associated with BMI and WC after adjustment for potential confounding factors including EI:EER (model 3). In the analysis of URs only, there was no association between EF and BMI and WC in any models.

The associations between EF and adiposity measures in women are presented in Table 4. In the univariate analyses (model 1) for all women, all three measures of EF were inversely associated with BMI and WC. After adjustment for potential confounding factors except for EI:EER (model 2), the inverse associations for EF_{all} and EF_{energy} remained while there were no associations for $EF_{\geqslant 210\ kJ}$. Further adjustment for EI:EER (model 3) resulted in positive associations between $EF_{\geqslant 210\ kJ}$ and BMI and WC, with there being no associations for EF_{all} and EF_{energy}. In the analysis of ARs, only $EF_{\geqslant 210\ kJ}$ showed positive associations with BMI and WC after adjustment for potential confounding factors including EI:EER (model 3). In the analysis of URs, EF_{all} was inversely associated with WC while $EF_{\geqslant 210\ kJ}$ was positively associated with BMI after full adjustment (model 3).

DISCUSSION

To our knowledge, this is the first study to examine associations between different measures of EF and adiposity measures, after taking into account the confounding of energy misreporting and the effect of exclusion of subjects with implausible EI (based on individualized measures of EER). In the crude analyses (model 1), all $EF_{\geqslant 210\ kJ}$, EF_{energy} (women only), and EF_{all} (women only) were

Table 1. Characteristics of subjects[a]

	Men				Women			
	All (n = 678)[b]	*ARs* (n = 426)	*URs* (n = 249)	P[c]	*All* (n = 809)	*ARs* (n = 447)	*URs* (n = 362)	P[c]
EI:EER	0.73 (0.19)	0.83 (0.13)	0.54 (0.10)	< 0.0001	0.69 (0.18)	0.82 (0.11)	0.53 (0.11)	< 0.0001
Age (y)	42.4 (12.0)	43.5 (11.7)	40.6 (12.2)	0.002	42.4 (11.9)	43.8 (12.3)	40.6 (11.3)	0.0002
Social class (%)				0.02				0.005
Manual	46.2	42.5	51.8		32.4	28.2	37.6	
Non-manual	53.8	57.5	48.2		67.6	71.8	62.4	
Smoking status (%)				0.06				0.02
Never	44.3	47.2	39.4		46.7	51.0	41.4	
Former	25.4	25.6	25.3		21.6	20.4	23.2	
Current	30.4	27.2	35.3		31.6	28.6	35.4	
Physical activity (MET-h/day)	46.1 (10.2)	45.4 (9.5)	47.1 (10.7)	0.03	42.3 (4.1)	42.0 (3.8)	42.7 (4.4)	0.01
BMI (kg m^{-2})	27.3 (4.4)	26.6 (3.7)	28.5 (5.0)	< 0.0001	26.8 (5.6)	25.6 (4.7)	28.2 (6.2)	< 0.0001
WC (cm)	96.0 (11.0)	94.7 (10.3)	98.2 (11.9)	< 0.0001	83.1 (11.9)	81.2 (10.9)	85.4 (12.8)	< 0.0001
EI (kJ/day)	9837 (2523)	11038 (1937)	7666 (1621)	< 0.0001	6932 (1769)	8073 (1258)	5523 (1202)	< 0.0001
Protein intake (% of energy)	15.3 (2.9)	14.9 (2.5)	16.0 (3.4)	< 0.0001	15.9 (3.3)	14.9 (2.6)	17.2 (3.6)	< 0.0001
Fat intake (% of energy)	33.4 (5.9)	33.6 (5.7)	33.1 (6.2)	0.33	33.6 (6.6)	34.1 (6.1)	33.1 (7.1)	0.02
Carbohydrate intake (% of energy)	44.7 (7.1)	44.6 (6.8)	44.9 (7.6)	0.64	46.5 (7.1)	46.9 (6.3)	46.0 (8.0)	0.10
Total sugar intake (% of energy)	19.1 (6.3)	19.4 (5.8)	18.6 (6.9)	0.11	20.0 (6.6)	21.1 (6.0)	18.7 (7.0)	< 0.0001
Starch intake (% of energy)	25.6 (5.8)	25.2 (5.3)	26.3 (6.6)	0.02	26.5 (5.8)	25.8 (5.1)	27.3 (6.4)	0.0001
Alcohol intake (% of energy)	6.7 (7.3)	7.0 (7.1)	6.1 (7.7)	0.13	4.0 (5.5)	4.2 (5.5)	3.8 (5.6)	0.25
Dietary fiber intake (g/10 MJ)	16.0 (5.5)	15.9 (5.1)	16.2 (6.1)	0.58	18.7 (7.1)	18.0 (6.2)	19.6 (8.0)	0.002
EF_{all} (times/day)	7.8 (2.5)	8.4 (2.3)	6.7 (2.2)	< 0.0001	7.6 (2.2)	8.2(2.1)	6.9 (2.2)	< 0.0001
EF_{energy} (times/day)	7.2 (2.3)	7.7 (2.2)	6.1 (2.0)	< 0.0001	6.7 (2.0)	7.3 (1.8)	6.0 (1.9)	< 0.0001
$EF_{\geqslant 210kJ}$ (times/day)	5.6 (1.9)	6.1 (1.8)	4.7(1.5)	< 0.0001	4.8 (1.4)	5.5 (1.3)	4.1 (1.2)	< 0.0001

Abbreviations: ARs, acceptable reporters; BMI, body mass index; EF_{all}, eating frequency (EF) based on all occasions; EF_{energy}, EF based on all occasions except for those providing no energy; $EF_{\geqslant 210\ kJ}$, EF based on all occasions except for those providing < 210 kJ of energy; EI, energy intake; EI:EER, ratio of energy intake to estimated energy requirement; MET, metabolic equivalent; URs, underreporters; WC, waist circumference. [a]Values are mean (s.d.) unless otherwise indicated. ARs were defined as subjects with EI:EER 0.665 to 1.335; URs defined as subjects with EI:EER < 0.665. [b]Including overreporters of energy intake ($n = 3$), defined as subjects with EI:EER > 1.335. [c]*P*-values for differences between ARs and URs based on the independent *t*-test for continuous variables and the χ^2 test for categorical variables.

Table 2. Correlation of eating frequency with EI:EER and EI[a]

	All		ARs		URs	
	EI:EER	*EI (kJ/day)*	*EI:EER*	*EI (kJ/day)*	*EI:EER*	*EI (kJ/day)*
Men	*n = 678*[b]		*n = 426*		*n = 249*	
EF_{all} (times/day)	0.43 (0.37, 0.49)	0.43 (0.37, 0.49)	0.28 (0.19, 0.36)	0.29 (0.20, 0.38)	0.35 (0.23, 0.45)	0.33 (0.21, 0.43)
EF_{energy} (times/day)	0.45 (0.38, 0.50)	0.45 (0.38, 0.51)	0.32 (0.23, 0.40)	0.33 (0.24, 0.41)	0.34 (0.23, 0.45)	0.33 (0.21, 0.43)
$EF_{\geqslant 210\,kJ}$ (times/day)	0.52 (0.46, 0.57)	0.53 (0.48, 0.58)	0.37 (0.29, 0.45)	0.43 (0.34, 0.50)	0.42 (0.31, 0.51)	0.38 (0.26, 0.48)
Women	*n = 809*		*n = 447*		*n = 362*	
EF_{all} (times/day)	0.36 (0.30, 0.41)	0.33 (0.27, 0.39)	0.19 (0.10, 0.28)	0.15 (0.06, 0.24)	0.25 (0.16, 0.35)	0.23 (0.12, 0.32)
EF_{energy} (times /day)	0.42 (0.36, 0.48)	0.39 (0.33, 0.45)	0.21 (0.12, 0.30)	0.15 (0.06, 0.24)	0.33 (0.24, 0.42)	0.30 (0.21, 0.39)
$EF_{\geqslant 210\,kJ}$ (times/day)	0.58 (0.54, 0.63)	0.57 (0.52, 0.61)	0.31 (0.23, 0.39)	0.29 (0.20, 0.37)	0.50 (0.41, 0.57)	0.49 (0.41, 0.57)

Abbreviations: ARs, acceptable reporters; EF_{all}, eating frequency (EF) based on all occasions; EF_{energy}, EF based on all occasions except for those providing no energy; $EF_{\geqslant 210\,kJ}$, EF based on all occasions except for those providing < 210 kJ of energy; EI, energy intake; EI:EER, ratio of energy intake to estimated energy requirement; URs, underreporters. [a]Values are Pearson correlation coefficients (95% confidence intervals). All correlations were statistically significant ($P < 0.01$). ARs were defined as subjects with EI:EER 0.665 to 1.335; URs defined as subjects with EI:EER < 0.665. [b]Including overreporters of EI ($n = 3$), defined as subjects with EI:EER > 1.335.

inversely associated with BMI and WC. However, after full adjustment (including EI:EER, model 3), a completely different picture emerged, showing positive associations of all three EF measures with BMI and WC in men and those of $EF_{\geqslant 210\,kJ}$ with BMI and WC (and null associations for EF_{all} and EF_{energy}) in women. When URs were excluded, the multivariate analyses (model 3) showed that EF_{all} and EF_{energy} were positively associated with BMI only in men while $EF_{\geqslant 210\,kJ}$ was positively associated with BMI and WC in both men and women. Thus, adjustment for EI:EER and the exclusion of URs, as well as the definition of EF, radically changed results of the present analysis.

In the present study, the prevalence of EI misreporters (that is, URs and overreporters) was 37% in men and 45% in women, which was relatively similar to that observed in previous studies using similar dietary assessment methodologies (37%[31] and 38%).[22] The results are also consistent with numerous previous studies,[32–38] which have shown that URs had considerably different characteristic compared with ARs. The differences between URs and ARs suggest that data exclusions may actually introduce a selection bias, so that exclusion of misreporters is not recommended.[39] Moreover, the reduced sample sizes resulting from exclusion of misreporters and stratification do limit statistical power, especially in the (smaller) groups of ARs (and URs).[39] In fact, some of the associations observed in the entire population after adjustment for EI:EER could not be found in the analysis of ARs. Furthermore, EF was significantly correlated with EI:EER not only in the entire population but also in ARs only (and URs only). This may explain why many of the significant associations observed in the analysis of ARs emerged only after further adjustment for EI:EER. Taken together, exclusion of energy misreporters may simply reduce the possibility to obtain true significant associations not only because of the reduced sample size but also because of the persistent presence of confounding of energy misreporting in ARs. Thus, the present study highlights that adjustment for EI:EER is a viable and justifiable alternative to omitting a substantial proportion of subjects (misreporters).

Epidemiologic studies of EF in relation to adiposity measures in free-living adults have yielded inconsistent findings. While EF was not prospectively associated with subsequent weight change in a national representative sample in the US,[8] an increasing number of eating occasions in addition to three standard meals was associated with a higher risk of weight gain in US men.[18] For cross-sectional studies where implausible energy reporters were excluded from the analysis, some researchers have showed a positive association between EF and adiposity measures[16,17] while others showed inverse[1,3,6] or null[10,12,13] associations. A mixture of positive,[2,4,5,7] null,[8,9,11] and positive[14,15] associations has also been observed in other cross-sectional studies with no or insufficient adjustment for potential confounding factors or without taking into account dietary intake misreporting. We found positive associations between EF and BMI and WC after adjustment for EI misreporting, which is consistent with several previous studies.[14–18] These discrepant findings may be, at least partly, explained by differences in the characteristics and lifestyles of the populations, definitions of EF, dietary assessment methods, adiposity measures, and potential confounding factors considered, in addition to underreporting of EF by obese or overweight subjects.

Our main finding that EF was positively associated with BMI and WC seems plausible given the positive correlation between EF and EI, which has also been observed in many previous studies.[1,2,6,8,10,12,13,15,17] The correlation was the strongest for $EF_{\geqslant 210\,kJ}$, the weakest for EF_{all}, and moderate for EF_{energy}, which is again reasonable because $EF_{\geqslant 210\,kJ}$ was used to avoid giving undue weight to eating occasions that, for example, only included water, low-calorie beverages, or small quantities of foods. The strongest correlation between $EF_{\geqslant 210\,kJ}$ and EI may also explain why we observed positive associations of $EF_{\geqslant 210\,kJ}$, but not EF_{all} and EF_{energy}, with BMI and WC in women, as well as the strongest associations between $EF_{\geqslant 210\,kJ}$ and BMI and WC, compared with those for EF_{all} and EF_{energy}, in men. In any case, the positive correlation between EF and EI suggests that subjects in this study did not compensate for more frequent eating episodes by reducing the quantity of energy consumed per eating occasion.

The strengths of this study include the use of objective definitions of EF based on data obtained from a 7-day weighed dietary record, measured anthropometric data, and the use of individualized 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. Many health organizations, diet books, and Internet sites recommend eating small, frequent meals for weight loss. Because of this, overweight and obese subjects may increase their EF, although it is unlikely in the present study that they eat small meals given the positive correlation between EF and EI observed. Alternatively, overweight and obese subjects may simply have reduced their EF in an attempt to lose weight. If so, the strength of the positive association between EF and adiposity measures would be underestimated. In any case, only a prospective study taking into account dietary misreporting would provide better understanding of the relation between EF and adiposity measures.

At present, the only way to obtain unbiased information on energy requirements in free-living settings is to use doubly

Table 3. Associations of eating frequency with adiposity measures in men[a]

	Model 1[b]			Model 2[c]			Model 3[d]		
	β[e]	s.e.[e]	P	β[e]	s.e.[e]	P	β[e]	s.e.[e]	P
All (n = *678*)[f]									
EF_{all} (times/day)									
BMI (kg m^{-2})	−0.06	0.07	0.36	0.02	0.07	0.74	0.24	0.08	**0.002**
WC (cm)	−0.12	0.17	0.48	0.02	0.18	0.89	0.47	0.19	**0.01**
EF_{energy} (times/day)									
BMI (kg m^{-2})	−0.09	0.07	0.22	0.03	0.08	0.68	0.28	0.08	**0.0009**
WC (cm)	−0.18	0.19	0.34	0.06	0.19	0.77	0.58	0.21	**0.006**
$EF_{\geqslant 210\,kJ}$ (times/day)									
BMI (kg m^{-2})	−0.28	0.09	**0.002**	−0.07	0.10	0.49	0.35	0.12	**0.004**
WC (cm)	−0.56	0.22	**0.01**	−0.06	0.26	0.81	0.87	0.30	**0.003**
ARs (n = *426*)									
EF_{all} (times/day)									
BMI (kg m^{-2})	0.07	0.08	0.35	0.15	0.08	0.06	0.19	0.08	**0.03**
WC (cm)	0.06	0.21	0.78	0.27	0.22	0.21	0.35	0.23	0.12
EF_{energy} (times/day)									
BMI (kg/m^2)	0.07	0.08	0.42	0.19	0.09	**0.03**	0.23	0.09	**0.01**
WC (cm)	0.03	0.23	0.88	0.36	0.24	0.14	0.47	0.25	0.07
$EF_{\geqslant 210\,kJ}$ (times/day)									
BMI (kg m^{-2})	−0.03	0.10	0.76	0.28	0.12	**0.02**	0.37	0.13	**0.004**
WC (cm)	−0.27	0.28	0.32	0.57	0.32	0.08	0.80	0.35	**0.02**
URs (n = *249*)									
EF_{all} (times/day)									
BMI (kg m^{-2})	0.07	0.15	0.65	0.19	0.15	0.21	0.29	0.16	0.08
WC (cm)	0.16	0.35	0.65	0.46	0.35	0.19	0.64	0.37	0.09
EF_{energy}(times/day)									
BMI (kg/m^2)	0.01	0.16	0.95	0.21	0.17	0.21	0.31	0.18	0.08
WC (cm)	0.06	0.37	0.86	0.55	0.38	0.15	0.76	0.40	0.06
$EF_{\geqslant 210\,kJ}$ (times/day)									
BMI (kg m^{-2})	−0.31	0.21	0.13	0.00	0.25	1.00	0.16	0.28	0.56
WC (cm)	−0.44	0.49	0.37	0.45	0.57	0.44	0.86	0.64	0.18

Abbreviations: ARs, acceptable reporters; BMI, body mass index; EF_{all}, eating frequency (EF) based on all occasions; EF_{energy}, EF based on all occasions except for those providing no energy; $EF_{\geqslant 210\,kJ}$, EF based on all occasions except for those providing < 210 kJ of energy; EI:EER, ratio of energy intake to estimated energy requirement; URs, underreporters. [a]ARs were defined as subjects with EI:EER 0.665 to 1.335; URs defined as subjects with EI:EER < 0.665. Statistically significant values are presented in bold. [b]Crude model. [c]Adjusted for age (years, continuous), social class (manual or non-manual), smoking status (never, former, or current), physical activity (metabolic equivalent-h/day, continuous), protein intake (% of energy, continuous), fat intake (% of energy, continuous), total sugar intake (% of energy, continuous), alcohol intake (% of energy, continuous), and dietary fiber intake (g/10 MJ, continuous). [d]Adjusted for variables used in model 2 and EI:EER (continuous). [e]Regression coefficients mean the change of body fatness measures with one additional eating occasion per day. [f]Including overreporters of energy intake ($n = 3$), defined as subjects with EI:EER >1.335.

labeled water as a biomarker.[32] This technique is expensive and impractical for application to large-scale epidemiologic studies. Instead, we calculated EER with the use of published equations.[29] In the absence of measured total energy expenditure, these equations with high R^2 values (0.82 for men and 0.79 for women)[29] should serve as the best proxy, although the selection of physical activity category was based on self-report (that is, 7-day physical activity diary), which may be susceptible to reporting bias. Additionally, it should be stressed that the role of misreporting was mainly evaluated only in terms of under-reporting because overreporting occurred in such a low number of cases that no conclusions could be drawn in this regard.

Another limitation of the present study is the relatively low response rate (61%), and only 40% of the eligible sample was included in the present study. The subjects included in the present analysis ($n = 1487$) 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 $P < 0.05$). However, a previous analysis concluded that there was no evidence to suggest serious non-response bias in National Diet and Nutrition Survey.[24] Further, although we adjusted for a variety of potential confounding variables, residual confounding could not be ruled out. Finally, because only about 5% of subjects reported < 3 times of eating occasions per day in this study, the present finding should not be interpreted as conclusive evidence that eating less frequently (for example, 1 or 2 meals per day) is an effective way to prevent obesity but that higher frequency of eating may be a contributing factor to obesity. Thus, the practical implications that come out of the present study would be that eating three times per day (for example, breakfast, lunch, and dinner without any kind of snacking) may be important to prevent obesity and any additional eating episode (for example, any kind of snacking or meal) may contribute to obesity. Nonetheless, oversimplification should be avoided because there is no consensus about what constitutes a snack, a meal, or an eating occasion.

In conclusion, in this cross-sectional study in British adults, we showed positive associations of EF with BMI and WC and addressed the effect of adjustment for EI:EER with and without the inclusion of URs, which radically affected the results of the analysis. This suggests the importance of adjustment for EI:EER, rather than excluding URs, which may lead to bias. Further research, particularly with a prospective design, is needed, taking into account dietary misreporting so that any firm conclusions can be drawn with regard to the effect of EF on adiposity measures. Generally, the routine application of some procedures

Table 4. Associations of eating frequency with adiposity measures in women[a]

	Model 1[b]			*Model 2*[c]			*Model 3*[d]		
	β^e	*s.e.*[e]	P	β^e	*s.e.*[e]	P	β^e	*s.e.*[e]	P
All (n = 809)									
EF_{all} (times/day)									
BMI (kg m^{-2})	−0.35	0.09	< **0.0001**	−0.29	0.09	**0.002**	−0.07	0.09	0.48
WC (cm)	−0.75	0.19	< **0.0001**	−0.70	0.19	**0.0003**	−0.31	0.20	0.12
EF_{energy} (times/day)									
BMI (kg m^{-2})	−0.36	0.10	**0.0002**	−0.34	0.10	**0.001**	−0.04	0.11	0.72
WC (cm)	−0.72	0.21	**0.0007**	−0.81	0.22	**0.0002**	−0.30	0.23	0.20
$EF_{\geqslant 210\,kJ}$ (times/day)									
MI (kg m^{-2})	−0.42	0.14	**0.002**	−0.28	0.17	0.09	0.60	0.19	**0.002**
WC (cm)	−0.77	0.29	**0.009**	−0.56	0.35	0.11	1.02	0.41	**0.01**
ARs (n = 447)									
EF_{all} (times/day)									
BMI (kg m^{-2})	−0.05	0.11	0.65	−0.02	0.11	0.84	0.05	0.11	0.67
WC (cm)	−0.07	0.25	0.78	0.00	0.25	0.99	0.12	0.25	0.63
EF_{energy} (times/day)									
BMI (kg m^{-2})	0.00	0.12	1.00	−0.02	0.13	0.86	0.06	0.13	0.63
WC (cm)	0.13	0.28	0.65	0.00	0.29	0.99	0.14	0.29	0.63
$EF_{\geqslant 210\,kJ}$ (times/day)									
BMI (kg m^{-2})	0.06	0.17	0.73	0.31	0.20	0.11	0.61	0.21	**0.004**
WC (cm)	0.14	0.39	0.72	0.70	0.44	0.11	1.22	0.47	**0.01**
URs (n = 362)									
EF_{all} (times/day)									
BMI (kg m^{-2})	−0.36	0.15	**0.01**	−0.29	0.15	0.06	−0.17	0.16	0.28
WC (cm)	−1.03	0.30	**0.0006**	−1.02	0.31	**0.001**	−0.73	0.31	**0.02**
EF_{energy} (times/day)									
BMI (kg m^{-2})	−0.33	0.17	0.51	−0.32	0.18	0.07	−0.12	0.19	0.51
WC (cm)	−0.99	0.35	**0.005**	−1.15	0.35	**0.001**	−0.70	0.37	0.06
$EF_{\geqslant 210\,kJ}$ (times/day)									
BMI (kg m – ^{2})	−0.07	0.28	0.79	−0.05	0.33	0.89	0.76	0.38	**0.04**
WC (cm)	−0.48	0.57	0.40	−0.58	0.66	0.38	1.24	0.75	0.10

Abbreviations: ARs, acceptable reporters; BMI, body mass index; EF_{all}, eating frequency (EF) based on all occasions; EF_{energy}, EF based on all occasions except for those providing no energy; $EF_{\geqslant 210\,kJ}$, EF based on all occasions except for those providing < 210 kJ of energy; EI:EER, ratio of energy intake to estimated energy requirement; URs, underreporters. [a]ARs were defined as subjects with EI:EER 0.665 to 1.335; URs defined as subjects with EI:EER <0.665. Statistically significant values are presented in bold. [b]Crude model. [c]Adjusted for age (year, continuous), social class (manual or non-manual), smoking status (never, former, or current), physical activity (metabolic equivalent-h/day, continuous), protein intake (% of energy, continuous), fat intake (% of energy, continuous), total sugar intake (% of energy, continuous), alcohol intake (% of energy, continuous), and dietary fiber intake (g/10 MJ, continuous). [d]Adjusted for variables used in model 2 and EI:EER (continuous). [e]Regression coefficients mean the change of body fatness measures with one additional eating occasion per day.

to identify and separately treat those who report data of poor validity would improve the precision and accuracy of results in studies of EF.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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