

Eating Frequency Is Positively Associated with Overweight and Central Obesity in US Adults^{1–3}

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Abstract

Background: Evidence of the association between eating frequency (EF) and adiposity is inconsistent.

Objective: With the use of data from the NHANES 2003–2012, this cross-sectional study examined the associations between EF, meal frequency (MF), and snack frequency (SF) and overweight/obesity and central obesity.

Methods: Dietary intake was assessed with the use of two 24-h dietary recalls in 18,696 US adults ≥ 20 y of age. All eating occasions providing ≥ 50 kcal of energy were divided into meals or snacks on the basis of contribution to energy intake ($\geq 15\%$ or $<15\%$), self-report, and time (0600–1000, 1200–1500, 1800–2100, or other). Multivariable logistic regression was used to compute ORs and 95% CIs.

Results: When analyzed without adjustment for the ratio of energy intake to estimated energy requirement (EI:EER), all measures of EF, MF, and SF showed inverse or null associations. After adjustment for EI:EER, however, EF was positively associated with overweight/obesity (body mass index ≥ 25 kg/m²) and central obesity (waist circumference ≥ 102 cm in men and ≥ 88 cm in women). Compared with the lowest category (≤ 3 times/d), the OR (95% CI) for overweight/obesity in the highest category (≥ 5 times/d) was 1.54 (1.23, 1.93) in men (P -trend = 0.003) and 1.45 (1.17, 1.81) in women (P -trend = 0.001). The corresponding value for central obesity was 1.42 (1.15, 1.75) in men (P -trend = 0.002) and 1.29 (1.05, 1.59) in women (P -trend = 0.03). The self-report-based MF and time-based MF were positively associated with overweight/obesity, central obesity, or both, although MF based on energy contribution showed no associations. There were positive associations for all SF measures in men and for the energy-contribution-based SF in women.

Conclusions: This cross-sectional study suggests that higher EF, MF, and SF are associated with an increased likelihood of overweight/obesity and central obesity in US adults. Prospective studies are needed to confirm the associations observed in this study. *J Nutr* 2015;145:2715–24.

Keywords: eating frequency, meal frequency, snack frequency, body mass index, waist circumference, epidemiology, NHANES, misreporting

Introduction

Many epidemiologic studies have investigated the association between eating frequency (EF)⁶ and adiposity measures, but the results are highly inconsistent, with a mixture of inverse (1–7), null (8–13), and positive (14–20) associations. This is an issue that is beset by substantial methodologic problems. First, the assessment of EF has often relied on a series of self-report questions (2, 5–7, 11, 14, 15, 18, 19), the validity of which has not been examined or reported. Only a few studies have assessed EF on the basis of information on actual dietary habits (with the

use of a dietary record or 24-h recall) (1, 4, 9, 10, 20). Second, 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

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³ Supplemental Tables 1–3 are available from the “Online Supporting Material” link in the online posting of the article and from the same link in the online table of contents at <http://jn.nutrition.org>.

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⁶ Abbreviations used: EER, estimated energy requirement; EF, eating frequency; EF_{all}, eating frequency based on all eating occasions; EF_{energy}, eating frequency based on all eating occasions except for those providing no energy; EF _{≥ 50 kcal}, eating frequency based on all eating occasions except for those providing <50 kcal of energy; EI, energy intake; EI:EER, ratio of energy intake to estimated energy requirement; MF, meal frequency; MF_{energy%}, meal frequency determined based on percentage contribution to total energy intake; MF_{self-report}, meal frequency determined based on self-report; MF_{time}, meal frequency determined based on the time the meal was consumed; SF, snack frequency; SF_{energy%}, snack frequency determined based on percentage contribution to total energy intake; SF_{self-report}, snack frequency determined based on self-report; SF_{time}, snack frequency determined based on the time the snack was consumed; WC, waist circumference.

in part can be attributed to the underreporting of EF concomitant with the underreporting of energy intake (EI) by obese or overweight subjects (21, 22). 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, 19, 20) (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, 20). Third, 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. Whereas 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, 19, 20). Further, potentially different effects of meal frequency (MF) and snack frequency (SF) have not been investigated with the use of different definitions of meal and snack. As a consequence of these methodologic limitations, the discrepant findings are not surprising and merit more robust data analyses to resolve this issue.

The objective of this cross-sectional study in a representative sample of US adults based on data from the NHANES was to examine the relation between EF, MF, and SF and overweight/obesity and central obesity, by focusing on the influence of adjustment for the ratio of energy intake to estimated energy requirement (EI:EER) and the use of different definitions of eating occasions, meals, and snacks.

Methods

Survey design and analytic sample. The present cross-sectional analysis was based on public domain data from NHANES, a continuing population-based survey that uses a complex, stratified multistage probability sample design to create a representative sample of the noninstitutionalized civilian US population (23, 24). The survey examines ~5000 persons each year and the data are released every 2 y. The unweighted response rates for the examined participants for NHANES 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 were 76%, 77%, 75%, 77%, and 70%, respectively (25). The NHANES protocol was approved by the National Center for Health Statistics Research Ethics Review Board, and written informed consent was obtained from all participants. The documentation and data for each of the surveys used were downloaded from the NHANES website (26).

The analytic sample was limited to adults aged ≥ 20 y with 2 complete and reliable self-reported 24-h dietary recall data determined by the National Center for Health Statistics ($n = 21,921$). After excluding pregnant ($n = 618$) and lactating ($n = 153$) respondents, as well as those with missing information on the variables of interest ($n = 2185$), the final analytic sample included 18,965 respondents from NHANES 2003–2012.

Anthropometric measurements. Body weight and height were measured by trained interviewers who used standardized procedures with calibrated equipment. BMI (kilograms per meter squared) was calculated as weight (kilograms) divided by height (meters) squared. Waist circumference (WC) was measured by trained personnel using a soft tape placed horizontally just above the iliac crest at minimal respiration. Overweight/obesity was defined as BMI ≥ 25 (27). Central obesity was defined as WC ≥ 102 cm in men and ≥ 88 cm in women (27).

Dietary assessment. All surveys collected dietary information with the use of two 24-h dietary recalls. The first recall was conducted by face-to-face interview, with the second recall being conducted by telephone 3–10 d after the first recall on a different day of the week (but not necessarily,

for example, 1 weekday and 1 weekend day). The dietary data were collected with the use of an automated 5-step multiple pass approach, namely, the USDA Automated Multiple-Pass Method (26–31). Participants were asked to report the time each food and beverage was consumed and to classify each eating occasion from a predefined list of categories, which were used to define meals and snacks, as described later. Estimates of intakes of energy and selected nutrients from all reported foods and beverages were calculated by using the USDA Food and Nutrient Database for Dietary Studies (26). The mean of dietary intake over the 2 d for each participant was used for the present analysis. Values of nutrient intake were energy-adjusted with the use of the density method (i.e., percentage of energy for energy-providing nutrients and amount per 1000 kcal of energy for dietary fiber).

Definition of EF, MF, and SF. Data from the two 24-h dietary recalls were also used to calculate the mean number of eating occasions per day, i.e., EF. Eating occasions were defined as any occasion during which any food or drink was consumed (12, 13, 17, 20). In previous studies, if 2 eating occasions occurred in ≤ 15 min, the 2 events were counted as a single eating occasion; when >15 min separated 2 eating occasions, these were considered distinct eating occasions (1, 4, 10, 17, 20). In the present study, however, all foods and beverages reported at one discrete clock time were considered to be part of one eating occasion, because almost all eating episodes ($>99.5\%$) occurred ≥ 15 min apart in NHANES (32). EF was calculated with the use of 3 different published methods (3, 4, 12, 13, 17, 20): eating frequency based on all eating occasions (EF_{all}), eating frequency based on all eating occasions except for those providing no energy (EF_{energy}), and eating frequency based on all eating occasions except for those providing <50 kcal of energy ($EF_{\geq 50kcal}$).

All eating occasions were divided into either meals or snacks with the use of 3 different published definitions: on the basis of 1) contribution to total EI (33), 2) self-reported name of eating occasion (32), and 3) clock time (34). For the first definition, a meal was defined as any eating episode comprising $\geq 15\%$ of total EI, regardless of the time of day or composition of the foods or beverages consumed. All other eating episodes were classified as a snack. This definition was made based on the national averages of the distribution of energy from (self-defined) meals compared with (self-defined) snacks (33), which is consistent with a recent analysis based on NHANES (breakfast, $\sim 16\%$; lunch, $\sim 25\%$; dinner, $\sim 37\%$; and snack, $\sim 22\%$ from 2 occasions) (32). For each participant, meal frequency determined based on percentage contribution to total energy intake ($MF_{energy\%}$) and snack frequency determined based on percentage contribution to total energy intake ($SF_{energy\%}$) were thus calculated. For the second definition, any eating occasions with the self-reported name of “breakfast,” “brunch,” “lunch,” “supper,” and “dinner” or their equivalents in Spanish were considered to be meals. All other self-reported eating events were considered to be snacks. For each participant, meal frequency determined based on self-report ($MF_{self-report}$) and snack frequency determined based on self-report ($SF_{self-report}$) were thus calculated. For the third definition, meals were defined as eating events reported during select times of the day, that is, 0600–1000, 1200–1500, and 1800–2100. All other eating occasions were considered snacks. This definition was used in a recent analysis based on a national survey in Brazil (34) and is not largely discrepant with the time of (self-reported) meals in NHANES (breakfast, ~ 0800 ; lunch, ~ 1230 ; and dinner, ~ 1820) (32). For each participant, meal frequency determined based on the time the meal was consumed (MF_{time}) and snack frequency determined based on the time the snack was consumed (SF_{time}) were thus calculated. MF and SF derived from EF_{all} , those derived from EF_{energy} , and those derived from $EF_{\geq 50kcal}$ were strongly correlated with each other (Pearson r : ≥ 0.92 and ≥ 0.91 , respectively). Thus, we report only MF and SF calculated based on all eating occasions providing ≥ 50 kcal of energy; consequently, the sum of MF and SF for each definition is equal to $EF_{\geq 50kcal}$.

Assessment of nondietary variables. Consistent with NHANES sample-selection methods, age was categorized as 20–39, 40–59, and ≥ 60 y. Race-ethnicity was categorized as non-Hispanic white, non-Hispanic black, Mexican American, and other. As indicators of socioeconomic status, we considered family income as a percentage of the federal poverty threshold and years of education. The family poverty income ratio

was categorized as <130%, 130–349%, and $\geq 350\%$. The educational level was categorized as <12 y, 12 y, some college, and college degree or more. Information on smoking status (never, former, or current) and any recreational physical activity (yes or no) was also collected.

Evaluation of EI reporting. Misreporting of EI was evaluated based on EI:EER (16). EER was calculated with the use of sex- and age-specific equations for use in populations with a range of weight statuses, published from the US DRI, based on sex, age, body height and weight, and physical activity (35). Because of a lack of an objective measure of physical activity in the present study, we assumed a “low active” level of physical activity (i.e., physical activity level ≥ 1.4 to <1.6) (35) for all subjects during this calculation.

Statistical analysis. Statistical analyses were performed for men and women separately with the use of SAS statistical software, version 9.2. All of the analyses used the NHANES-provided sampling weights that were calculated to take into account unequal probabilities of selection resulting from the sample design, nonresponse, and planned oversampling of selected subgroups, so that the results are representative of the US community-dwelling population (24, 36). For EF, MF, and SF, sample-weighted means (\pm SEs) were generated with the use of the PROC SURVYMEANS procedure. Differences in these variables across categories of each of the characteristics were examined based on Wald's *F* test derived from linear regression analysis with the use of the PROC SURVEYREG procedure. Associations between EF, MF, SF, BMI, and WC and EI and EI:EER were investigated using linear regression analyses with the use of the PROC SURVEYREG procedure. Multivariable logistic regression was used to explore the associations between EF, MF, and SF and overweight/obesity and central obesity. For this analysis, EF_{all} and EF_{energy} were categorized into the following 5 groups: ≤ 3.5 , 4, 4.5, 5, and ≥ 5.5 times/d; EF _{≥ 50 kcal} into the following 5 groups: ≤ 3 , 3.5, 4, 4.5, and ≥ 5 times/d; all measures of MF into the following 4 groups: ≤ 2 , 2.5, 3, and ≥ 3.5 times/d; SF_{energy%} and SF_{self-report} into the following 5 groups: ≤ 0.5 , 1, 1.5, 2 or 2.5, and ≥ 3 times/d; and SF_{time} into the following 4 groups: ≤ 0.5 , 1, 1.5, and ≥ 2 times/d (because only 5.6% of subjects had ≥ 3 times/d). With the use of the PROC SURVEYLOGISTIC procedure, we calculated multivariate-adjusted ORs and 95% CIs for overweight/obesity and central obesity for each category of EF, MF, and SF, with the lowest category as the reference. Tests for trend were conducted by assigning each subject the median value for the category and modeling this value as a continuous variable. Potential confounding factors considered (model 1) were age group (20–39, 40–59, or ≥ 60 y), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), years of education (<12 y, 12 y, some college, or college degree or more), family poverty income ratio (<130%, 130–349%, or $\geq 350\%$), smoking status (never, former, or current), any recreational physical activity (yes or no), survey cycle (2003–2004, 2005–2006, 2007–2008, 2009–2010, or 2011–2012), protein intake (percentage of energy, continuous), fat intake (percentage of energy, continuous), total sugar intake (percentage of energy, continuous), alcohol intake (percentage of energy, continuous), and dietary fiber intake (g/1000 kcal, continuous). We further included EI:EER (continuous) as a potential confounding factor (in model 2). EI was not included as a potential confounding factor not only because we considered it to be a potential causal factor but also because there was a strong correlation between EI and EI:EER (Pearson *r*: 0.88). All reported *P* values are 2-tailed, and *P* < 0.05 was considered to be statistically significant.

Results

Dietary characteristics and adiposity measures of the subjects are presented in Table 1. The prevalence of overweight/obesity was higher in men, whereas that of central obesity was higher in women. Mean EF_{all} and EF_{energy} were higher in women, but mean EF _{≥ 50 kcal} was higher in men. Although women had higher mean values of MF_{energy%} and MF_{self-report}, there was no sex difference in MF_{time}. In contrast, men had higher mean values of

TABLE 1 Dietary characteristics and adiposity measures of adults aged ≥ 20 y participating in NHANES 2003–2012¹

	Men (<i>n</i> = 9397)	Women (<i>n</i> = 9568)	<i>P</i> ²
EF _{all} , times/d	4.78 \pm 0.02	4.85 \pm 0.02	0.004
EF _{energy} , times/d	4.75 \pm 0.02	4.83 \pm 0.02	0.005
EF _{≥ 50kcal} , times/d	4.32 \pm 0.02	4.26 \pm 0.02	0.01
MF _{energy%} , ^{3,4} times/d	2.65 \pm 0.01	2.68 \pm 0.01	0.009
SF _{energy%} , ^{3,4} times/d	1.67 \pm 0.02	1.58 \pm 0.02	0.0002
MF _{self-report} , ^{3,5} times/d	2.64 \pm 0.01	2.66 \pm 0.01	0.02
SF _{self-report} , ^{3,5} times/d	1.68 \pm 0.02	1.60 \pm 0.02	0.0002
MF _{time} , ^{3,6} times/d	2.94 \pm 0.02	2.94 \pm 0.02	0.64
SF _{time} , ^{3,6} times/d	1.39 \pm 0.01	1.32 \pm 0.01	0.0002
EI, kcal/d	2507 \pm 15	1774 \pm 9	<0.0001
EI:EER	0.89 \pm 0.005	0.82 \pm 0.004	<0.0001
Protein intake, % of energy	16.1 \pm 0.07	15.8 \pm 0.08	0.0003
Fat intake, % of energy	33.7 \pm 0.12	33.7 \pm 0.14	0.92
Carbohydrate intake, % of energy	47.8 \pm 0.17	49.9 \pm 0.18	<0.0001
Total sugar intake, % of energy	21.0 \pm 0.16	22.7 \pm 0.16	<0.0001
Alcohol intake, % of energy	3.6 \pm 0.10	2.1 \pm 0.08	<0.0001
Dietary fiber intake, g/1000 kcal	7.7 \pm 0.07	8.7 \pm 0.08	<0.0001
BMI, kg/m ²	28.6 \pm 0.11	28.6 \pm 0.12	0.87
WC, cm	101.2 \pm 0.31	95.1 \pm 0.30	<0.0001
Overweight/obesity, ⁷ %	72.9 \pm 0.9	63.3 \pm 0.9	<0.0001
Central obesity, ⁸ %	44.5 \pm 0.9	63.0 \pm 0.9	<0.0001

¹ Values are means \pm SEs for continuous variables and percentages \pm SEs for categorical variables. All values are weighted to reflect the survey design characteristics. Analyses are based on subjects with complete data on two 24-h dietary recalls, as well as complete information on the variables of interest. All dietary variables are based on mean values of two 24-h dietary recalls. EF_{all}, eating frequency based on all occasions; EF_{energy}, eating frequency based on all occasions except for those providing no energy; EF _{≥ 50 kcal}, eating frequency based on all occasions except for those providing <50 kcal of energy; EI, energy intake; EI:EER, ratio of energy intake to estimated energy requirement; MF_{energy%}, meal frequency determined based on percentage contribution to total energy intake; MF_{self-report}, meal frequency determined based on self-report; MF_{time}, meal frequency determined based on the time the meal was consumed; SF_{energy%}, snack frequency determined based on percentage contribution to total energy intake; SF_{self-report}, snack frequency determined based on self-report; SF_{time}, snack frequency determined based on the time the snack was consumed; WC, waist circumference.

² Values for differences between men and women based on the independent *t* test for continuous variables and on the chi-square test for categorical variables.

³ Based on all occasions except for those providing <50 kcal of energy.

⁴ A meal was defined as any eating episode comprising $\geq 15\%$ of total energy intake, regardless of the time of day or composition of foods and beverages consumed; all other eating episodes were classified as a snack.

⁵ Self-reports of breakfast, brunch, lunch, supper, and dinner or their equivalents in Spanish were considered to be meals; all other self-reported eating events were considered to be snacks.

⁶ Meals were defined as eating events reported during select times of the day (0600–1000, 1200–1500, and 1800–2100); all other eating occasions were considered to be snacks.

⁷ Defined as BMI ≥ 25 kg/m².

⁸ Defined as WC ≥ 102 cm for men and ≥ 88 cm for women.

all measures of SF. The majority of subjects were classified into 3–6 times/d for EF, 2–4 times/d for MF, and 0.5–3.5 times/d for SF, although the distributions differed considerably by the definitions used (Supplemental Table 1). There were strong correlations between the 3 measures of EF in both sexes (Supplemental Table 2). Correlations between the 3 measures of MF were modest, whereas those between the 3 measures of SF were modest to strong. Correlations between MF and SF based on the same definition were low to modest.

EF _{≥ 50 kcal}, MF_{energy%}, and SF_{energy%} according to categories of subjects characteristics are shown in Table 2. EF _{≥ 50 kcal} and

TABLE 2 Eating frequency, meal frequency, and snack frequency according to demographic and lifestyle characteristics of adults aged ≥ 20 y participating in NHANES 2003–2012¹

	Men (<i>n</i> = 9397)				Women (<i>n</i> = 9568)			
	<i>n</i>	EF _{≥ 50kcal} , times/d	MF _{energy%} , ^{2,3} times/d	SF _{energy%} , ^{2,3} times/d	<i>n</i>	EF _{≥ 50kcal} , times/d	MF _{energy%} , ^{2,3} times/d	SF _{energy%} , ^{2,3} times/d
Age group, y								
20–39	3135	4.28 \pm 0.04	2.60 \pm 0.01	1.68 \pm 0.03	3022	4.20 \pm 0.03	2.63 \pm 0.01	1.57 \pm 0.03
40–59	3079	4.41 \pm 0.03	2.65 \pm 0.01	1.76 \pm 0.03	3302	4.34 \pm 0.03	2.68 \pm 0.01	1.66 \pm 0.03
≥ 60	3183	4.24 \pm 0.04	2.74 \pm 0.01	1.50 \pm 0.03	3244	4.23 \pm 0.03	2.75 \pm 0.01	1.47 \pm 0.03
<i>P</i> ⁴		0.002	<0.0001	<0.0001		0.001	<0.0001	<0.0001
Race/ethnicity								
Non-Hispanic white	4759	4.41 \pm 0.03	2.67 \pm 0.01	1.74 \pm 0.03	4676	4.34 \pm 0.02	2.7 \pm 0.01	1.63 \pm 0.02
Non-Hispanic black	1880	3.98 \pm 0.04	2.57 \pm 0.02	1.41 \pm 0.04	2047	3.95 \pm 0.03	2.59 \pm 0.02	1.36 \pm 0.03
Mexican American	1547	4.15 \pm 0.05	2.63 \pm 0.02	1.52 \pm 0.04	1518	4.06 \pm 0.03	2.66 \pm 0.02	1.40 \pm 0.04
Other	1211	4.14 \pm 0.04	2.59 \pm 0.02	1.55 \pm 0.04	1327	4.23 \pm 0.04	2.65 \pm 0.02	1.58 \pm 0.04
<i>P</i> ⁴		<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
Education								
<12 y	2476	4.05 \pm 0.05	2.59 \pm 0.02	1.46 \pm 0.05	2339	3.99 \pm 0.04	2.65 \pm 0.02	1.33 \pm 0.03
12 y	2255	4.23 \pm 0.04	2.66 \pm 0.02	1.57 \pm 0.04	2198	4.14 \pm 0.04	2.66 \pm 0.02	1.48 \pm 0.03
Some college	2530	4.35 \pm 0.04	2.64 \pm 0.02	1.71 \pm 0.03	2960	4.32 \pm 0.03	2.68 \pm 0.01	1.63 \pm 0.03
College degree or more	2136	4.52 \pm 0.04	2.69 \pm 0.01	1.83 \pm 0.04	2071	4.46 \pm 0.03	2.72 \pm 0.02	1.74 \pm 0.03
<i>P</i> ⁴		<0.0001	0.0009	<0.0001		<0.0001	0.04	<0.0001
Family poverty income ratio, %								
<130	2566	4.15 \pm 0.04	2.62 \pm 0.02	1.53 \pm 0.04	3018	4.12 \pm 0.04	2.63 \pm 0.02	1.49 \pm 0.03
130–349	3598	4.23 \pm 0.03	2.65 \pm 0.01	1.58 \pm 0.03	3628	4.18 \pm 0.03	2.69 \pm 0.01	1.50 \pm 0.02
≥ 350	3233	4.46 \pm 0.03	2.66 \pm 0.01	1.79 \pm 0.03	2922	4.40 \pm 0.03	2.70 \pm 0.01	1.70 \pm 0.03
<i>P</i> ⁴		<0.0001	0.13	<0.0001		<0.0001	0.006	<0.0001
Smoking status								
Never	4139	4.31 \pm 0.03	2.66 \pm 0.01	1.66 \pm 0.03	5850	4.27 \pm 0.02	2.7 \pm 0.01	1.57 \pm 0.02
Former	2956	4.41 \pm 0.03	2.72 \pm 0.02	1.69 \pm 0.03	1964	4.32 \pm 0.04	2.71 \pm 0.02	1.61 \pm 0.04
Current	2302	4.23 \pm 0.04	2.56 \pm 0.02	1.67 \pm 0.04	1754	4.17 \pm 0.05	2.59 \pm 0.02	1.58 \pm 0.05
<i>P</i> ⁴		<0.0001	<0.0001	0.65		0.10	<0.0001	0.66
Any recreational physical activity								
Yes	5248	4.41 \pm 0.03	2.68 \pm 0.01	1.74 \pm 0.03	4819	4.36 \pm 0.03	2.70 \pm 0.01	1.66 \pm 0.02
No	4149	4.16 \pm 0.03	2.61 \pm 0.01	1.55 \pm 0.03	4749	4.12 \pm 0.02	2.66 \pm 0.01	1.47 \pm 0.02
<i>P</i> ⁴		<0.0001	0.0004	<0.0001		<0.0001	0.008	<0.0001
Survey cycle								
2003–2004	1765	4.25 \pm 0.05	2.68 \pm 0.03	1.57 \pm 0.05	1738	4.18 \pm 0.04	2.68 \pm 0.02	1.5 \pm 0.04
2005–2006	1745	4.34 \pm 0.05	2.61 \pm 0.02	1.72 \pm 0.04	1683	4.18 \pm 0.03	2.67 \pm 0.02	1.51 \pm 0.04
2007–2008	1954	4.26 \pm 0.06	2.62 \pm 0.01	1.63 \pm 0.05	2043	4.27 \pm 0.05	2.67 \pm 0.02	1.60 \pm 0.04
2009–2010	2077	4.39 \pm 0.04	2.67 \pm 0.02	1.73 \pm 0.03	2215	4.36 \pm 0.04	2.69 \pm 0.01	1.67 \pm 0.04
2011–2012	1856	4.36 \pm 0.04	2.67 \pm 0.02	1.68 \pm 0.05	1889	4.31 \pm 0.05	2.70 \pm 0.02	1.61 \pm 0.04
<i>P</i> ⁴		0.13	0.02	0.10		0.003	0.65	0.01

¹ Values are means \pm SEs. All values are weighted to reflect the survey design characteristics. Analyses are based on subjects with complete data on two 24-h dietary recalls, as well as complete information on the variables of interest. All dietary variables are based on mean values of two 24-h dietary recalls. EF _{≥ 50 kcal}, eating frequency based on all occasions except for those providing <50 kcal of energy; MF_{energy%}, meal frequency determined based on percentage contribution to total energy intake; SF_{energy%}, snack frequency determined based on percentage contribution to total energy intake.

² Based on all occasions except for those providing <50 kcal of energy.

³ A meal was defined as any eating episode comprising $\geq 15\%$ of total energy intake, regardless of the time of day or composition of foods and beverages consumed; all other eating episodes were classified as a snack.

⁴ Based on Wald's *F* test derived from linear regression analysis.

SF_{energy%} differed between age groups, with higher values in the middle-age group (40–59 y) than in the other age groups, whereas MF_{energy%} was positively associated with age groups. All EF _{≥ 50 kcal}, MF_{energy%}, and SF_{energy%} differed between race/ethnic groups, with higher values in non-Hispanic whites and lower values in non-Hispanic blacks than in other groups. Years of education and family poverty income ratio were positively associated with all EF _{≥ 50 kcal}, MF_{energy%}, and SF_{energy%} (except for no association between family poverty income ratio and MF_{energy%} in men). EF _{≥ 50 kcal} and MF_{energy%} (but not SF_{energy%})

differed between smoking status categories, with higher values in former smokers and lower values in current smokers compared with never smokers. Subjects with any recreational physical activity had higher values of all EF _{≥ 50 kcal}, MF_{energy%}, and SF_{energy%}. For survey cycles, MF_{energy%} differed only in men, with a higher value in 2003–2004 and a lower value in 2005–2006, whereas EF _{≥ 50 kcal} and SF_{energy%} differed only in women, with higher values in 2009–2010 and lower values in 2003–2004 than in other cycles. Similar associations of these characteristics with other measures of EF, MF, and SF were also

observed (data not shown). When no potential confounders were adjusted for, all measures of EF, MF, and SF were strongly positively associated with both EI and EI:EER in both sexes (Supplemental Table 3). Although BMI and WC were inversely associated with EI in men only, they were inversely associated with EI:EER in both sexes.

The associations between EF, MF, and SF and overweight/obesity and central obesity in men are shown in Table 3. After adjustment for potential confounding factors except for EI:EER (model 1), all measures of EF, MF, and SF showed inverse or null associations with the risk of overweight/obesity and central obesity. However, further adjustment for EI:EER (model 2) resulted in positive associations between all EF_{all} , $EF_{energy\%}$, and $EF_{\geq 50kcal}$ and both overweight/obesity and central obesity. For MF, after full adjustment including EI:EER (model 2), $MF_{energy\%}$ was not associated with overweight/obesity and central obesity, whereas $MF_{self-report}$ and MF_{time} showed positive associations (except for no association between MF_{time} and overweight/obesity). After full adjustment (model 2), all $SF_{energy\%}$, $SF_{self-report}$, and SF_{time} were also positively associated with overweight/obesity and central obesity, except for no association between SF_{time} and overweight/obesity.

The associations between EF, MF, and SF and overweight/obesity and central obesity in women are presented in Table 4. In multivariate analyses without adjustment for EI:EER (model 1), all measures of EF, MF, and SF were inversely associated with the risk of overweight/obesity, central obesity, or both, except for no associations for $MF_{energy\%}$ and $MF_{self-report}$. Further adjustment for EI:EER (model 2), however, resulted in positive associations between $EF_{\geq 50kcal}$ and overweight/obesity and central obesity, with there being no associations for EF_{all} and $EF_{energy\%}$. For MF, after full adjustment including EI:EER (model 2), $MF_{energy\%}$ was not associated with overweight/obesity and central obesity, whereas $MF_{self-report}$ and MF_{time} showed positive associations (except for no association between MF_{time} and central obesity). After full adjustment (model 2), higher $SF_{energy\%}$ was associated with higher risks of overweight/obesity and central obesity, whereas there were no associations for $SF_{self-report}$ and SF_{time} .

Discussion

To our knowledge, this is the first study to examine associations between different measures of EF, MF, and SF and adiposity measures by focusing on the influence of adjustment for EI:EER. In the multivariate analyses without taking into account EI:EER, all measures of EF, MF, and SF showed inverse or null associations with overweight/obesity and central obesity in both sexes. However, after full adjustment including EI:EER, a completely different picture emerged. We found positive associations between all EF_{all} , $EF_{energy\%}$, and $EF_{\geq 50kcal}$ and overweight/obesity and central obesity in men and those for $EF_{\geq 50kcal}$ (and null associations for EF_{all} and $EF_{energy\%}$) in women. $MF_{self-report}$ and MF_{time} were also positively associated with overweight/obesity, central obesity, or both, whereas there were no associations for $MF_{energy\%}$. Additionally, all $SF_{energy\%}$, $SF_{self-report}$, and SF_{time} were positively associated with overweight/obesity, central obesity, or both in men, with there being positive associations for $SF_{energy\%}$ (but not $SF_{self-report}$ and SF_{time}) in women. Thus, adjustment for EI:EER changed the results of the present analysis more radically than the definition of EF, MF, and SF.

Epidemiologic studies of EF in relation to adiposity measures in free-living adults have yielded inconsistent findings. Although EF was not prospectively associated with subsequent weight

change in a national representative sample in the United States (8), an increasing number of eating occasions in addition to 3 standard meals was associated with a higher risk of weight gain in US men (18). For cross-sectional studies in which implausible energy reporters were excluded from the analysis or EI misreporting was taken into account, some research showed a positive association between EF and adiposity measures (16, 17, 19, 20), whereas others showed inverse (1, 3, 6) or null (10, 12, 13) associations. A mixture of inverse (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. Our observed positive associations between EF and overweight/obesity and central obesity after adjustment for EI misreporting are consistent with a prospective study (18) and several cross-sectional studies with (16, 17, 19, 20) or without (14, 15) taking into account EI misreporting. One cross-sectional study in US adults (19) showed that after excluding implausible energy reporters, SF (as defined mainly based on self-report and energy content) was positively associated with BMI, although there was no association for MF. These results are thus not fully consistent with our present observations. These discrepant findings may be explained at least partly by differences in the characteristics and lifestyles of the populations, definitions of EF, MF, and SF, dietary assessment methods, adiposity measures, and potential confounding factors considered, in addition to underreporting of EF, MF, and SF by obese or overweight subjects.

Our main finding that all measures of EF were positively associated with overweight/obesity and central obesity seems plausible, given the observed positive association between EF and EI (1, 2, 6, 8, 10, 12, 13, 15, 17, 20). As opposed to experimental trials that would hold EI constant while increasing EF, the increased EF may have led to an increased EI in these samples of free-living men and women. The association was the strongest for $EF_{\geq 50kcal}$ and the weakest for EF_{all} , and was moderate for $EF_{energy\%}$, which is again plausible because $EF_{\geq 50kcal}$ was used to avoid giving undue weight to eating occasions that, e.g., only included water, low-calorie beverages, or small quantities of foods. The strongest association between $EF_{\geq 50kcal}$ and EI may also explain why we observed positive associations between $EF_{\geq 50kcal}$, but not EF_{all} and $EF_{energy\%}$, and overweight/obesity and central obesity in women. The positive associations between $MF_{self-report}$, $SF_{self-report}$, MF_{time} , SF_{time} , and $SF_{energy\%}$ and overweight/obesity and central obesity also seem plausible because of the positive associations with EI. Conversely, $MF_{energy\%}$ was rather weakly (but significantly) associated with EI, showing no association with overweight/obesity and central obesity. In any case, the positive association between EF, MF, and SF 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.

In the present study, the direction of the association between EF, MF, and SF and overweight/obesity and central obesity radically changed after adjustment for EI:EER. Given the positive association between EF, MF, and SF and EI:EER and the inverse association between BMI and WC and EI:EER, this may be due to the underreporting of EF, MF, and SF concomitant with the underreporting of EI by subjects with higher BMI and WC, which has also been suggested in a previous study in British adults (20). Thus, the present study highlights the importance of critical evaluation of and adjustment for EI misreporting in studies of EF, MF, and SF in relation to adiposity measures.

TABLE 3 Associations between eating frequency, meal frequency, and snack frequency and the risk of overweight/obesity and central obesity in 9397 men aged ≥ 20 y participating in NHANES 2003–2012¹

	Category 1 (lowest)	Category 2	Category 3	Category 4	Category 5	P-trend
EF _{all} , times/d	≤ 3.5	4	4.5	5	≥ 5.5	—
Subjects, <i>n</i>	2435	1507	1511	1299	2645	—
Overweight/obesity, ² <i>n</i>	1796	1114	1093	944	1903	—
Model 1: OR (95% CI) ³	1 (reference)	1.01 (0.79, 1.28)	0.86 (0.69, 1.06)	0.86 (0.68, 1.09)	0.87 (0.72, 1.05)	0.13
Model 2: OR (95% CI) ⁴	1 (reference)	1.25 (0.97, 1.61)	1.08 (0.87, 1.34)	1.17 (0.92, 1.49)	1.45 (1.20, 1.76)	0.0006
Central obesity, ⁵ <i>n</i>	1106	671	676	615	1152	—
Model 1: OR (95% CI) ³	1 (reference)	0.93 (0.76, 1.15)	0.91 (0.75, 1.11)	1.03 (0.85, 1.26)	0.88 (0.73, 1.06)	0.24
Model 2: OR (95% CI) ⁴	1 (reference)	1.14 (0.92, 1.41)	1.15 (0.94, 1.41)	1.40 (1.15, 1.70)	1.42 (1.18, 1.72)	0.0001
EF _{energy} , times/d	≤ 3.5	4	4.5	5	≥ 5.5	—
Subjects, <i>n</i>	2475	1532	1516	1283	2591	—
Overweight/obesity, ² <i>n</i>	1829	1134	1098	934	1855	—
Model 1: OR (95% CI) ³	1 (reference)	1.02 (0.81, 1.30)	0.85 (0.68, 1.06)	0.85 (0.67, 1.08)	0.85 (0.70, 1.03)	0.07
Model 2: OR (95% CI) ⁴	1 (reference)	1.28 (0.99, 1.64)	1.07 (0.86, 1.34)	1.16 (0.91, 1.48)	1.43 (1.17, 1.73)	0.002
Central obesity, ⁵ <i>n</i>	1132	684	679	610	1115	—
Model 1: OR (95% CI) ³	1 (reference)	0.92 (0.74, 1.13)	0.91 (0.75, 1.11)	1.01 (0.83, 1.23)	0.86 (0.71, 1.03)	0.15
Model 2: OR (95% CI) ⁴	1 (reference)	1.12 (0.91, 1.39)	1.16 (0.94, 1.42)	1.37 (1.12, 1.67)	1.39 (1.15, 1.68)	0.0003
EF _{≥ 50 kcal} , times/d	≤ 3	3.5	4	4.5	≥ 5	—
Subjects, <i>n</i>	1806	1623	1725	1576	2667	—
Overweight/obesity, ² <i>n</i>	1337	1224	1275	1147	1867	—
Model 1: OR (95% CI) ³	1 (reference)	1.11 (0.89, 1.38)	0.93 (0.73, 1.17)	0.98 (0.78, 1.22)	0.78 (0.63, 0.98)	0.005
Model 2: OR (95% CI) ⁴	1 (reference)	1.37 (1.09, 1.72)	1.32 (1.03, 1.70)	1.45 (1.15, 1.83)	1.54 (1.23, 1.93)	0.003
Central obesity, ⁵ <i>n</i>	849	759	803	711	1098	—
Model 1: OR (95% CI) ³	1 (reference)	0.86 (0.73, 1.01)	0.92 (0.75, 1.12)	0.96 (0.77, 1.20)	0.74 (0.61, 0.89)	0.009
Model 2: OR (95% CI) ⁴	1 (reference)	1.05 (0.89, 1.25)	1.30 (1.06, 1.61)	1.43 (1.14, 1.80)	1.42 (1.15, 1.75)	0.002
MF _{energy} , ^{6,7} times/d	≤ 2	2.5	3	≥ 3.5	—	—
Subjects, <i>n</i>	2215	3091	2818	1273	—	—
Overweight/obesity, ² <i>n</i>	1636	2283	2026	905	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.92 (0.78, 1.08)	0.84 (0.70, 1.00)	0.78 (0.63, 0.97)	—	0.007
Model 2: OR (95% CI) ⁴	1 (reference)	0.99 (0.83, 1.17)	0.97 (0.81, 1.17)	0.92 (0.74, 1.15)	—	0.48
Central obesity, ⁵ <i>n</i>	1037	1379	1262	542	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.91 (0.77, 1.07)	0.89 (0.73, 1.07)	0.72 (0.60, 0.88)	—	0.003
Model 2: OR (95% CI) ⁴	1 (reference)	0.99 (0.83, 1.18)	1.04 (0.86, 1.27)	0.86 (0.71, 1.05)	—	0.71
SF _{energy} , ^{6,7} times/d	≤ 0.5	1	1.5	2 or 2.5	≥ 3	—
Subjects, <i>n</i>	2362	1902	1667	2164	1302	—
Overweight/obesity, ² <i>n</i>	1736	1415	1221	1562	916	—
Model 1: OR (95% CI) ³	1 (reference)	1.08 (0.88, 1.31)	1.08 (0.87, 1.34)	1.04 (0.85, 1.27)	0.88 (0.69, 1.13)	0.20
Model 2: OR (95% CI) ⁴	1 (reference)	1.32 (1.08, 1.61)	1.41 (1.13, 1.77)	1.50 (1.24, 1.81)	1.74 (1.33, 2.29)	0.0001
Central obesity, ⁵ <i>n</i>	1108	874	761	940	537	—
Model 1: OR (95% CI) ³	1 (reference)	0.95 (0.80, 1.13)	0.95 (0.78, 1.14)	0.91 (0.76, 1.08)	0.85 (0.70, 1.05)	0.14
Model 2: OR (95% CI) ⁴	1 (reference)	1.17 (0.97, 1.40)	1.24 (1.02, 1.51)	1.32 (1.10, 1.58)	1.64 (1.30, 2.08)	<0.0001
MF _{self-report} , ^{6,8} times/d	≤ 2	2.5	3	≥ 3.5	—	—
Subjects, <i>n</i>	2349	2468	3736	844	—	—
Overweight/obesity, ² <i>n</i>	1681	1809	2752	608	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.96 (0.75, 1.21)	0.88 (0.74, 1.04)	0.90 (0.70, 1.15)	—	0.14
Model 2: OR (95% CI) ⁴	1 (reference)	1.15 (0.89, 1.48)	1.22 (1.03, 1.46)	1.41 (1.10, 1.82)	—	0.003
Central obesity, ⁵ <i>n</i>	1051	1094	1737	338	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.96 (0.80, 1.16)	0.91 (0.79, 1.05)	0.82 (0.65, 1.04)	—	0.09
Model 2: OR (95% CI) ⁴	1 (reference)	1.17 (0.98, 1.41)	1.28 (1.09, 1.49)	1.29 (1.01, 1.65)	—	0.004
SF _{self-report} , ^{6,8} times/d	≤ 0.5	1	1.5	2 or 2.5	≥ 3	—
Subjects, <i>n</i>	2046	1862	1869	2385	1235	—
Overweight/obesity, ² <i>n</i>	1546	1389	1368	1696	851	—
Model 1: OR (95% CI) ³	1 (reference)	1.03 (0.80, 1.33)	0.91 (0.73, 1.15)	0.83 (0.68, 1.00)	0.80 (0.62, 1.03)	0.02
Model 2: OR (95% CI) ⁴	1 (reference)	1.21 (0.93, 1.57)	1.14 (0.90, 1.45)	1.14 (0.94, 1.38)	1.44 (1.11, 1.85)	0.02
Central obesity, ⁵ <i>n</i>	975	875	846	1014	510	—
Model 1: OR (95% CI) ³	1 (reference)	1.03 (0.84, 1.27)	0.95 (0.77, 1.19)	0.88 (0.73, 1.06)	0.84 (0.67, 1.05)	0.051
Model 2: OR (95% CI) ⁴	1 (reference)	1.21 (0.98, 1.49)	1.19 (0.95, 1.48)	1.21 (0.99, 1.47)	1.45 (1.14, 1.85)	0.01

(Continued)

TABLE 3 Continued

	Category 1 (lowest)	Category 2	Category 3	Category 4	Category 5	P-trend
MF _{time} , ^{6,9} times/d	≤2	2.5	3	≥3.5	—	—
Subjects, <i>n</i>	2496	1764	1938	3199	—	—
Overweight/obesity, ² <i>n</i>	1808	1310	1431	2301	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.02 (0.82, 1.28)	0.96 (0.78, 1.16)	0.83 (0.69, 1.00)	—	0.03
Model 2: OR (95% CI) ⁴	1 (reference)	1.13 (0.89, 1.42)	1.15 (0.93, 1.42)	1.18 (0.98, 1.42)	—	0.12
Central obesity, ⁵ <i>n</i>	1115	814	882	1409	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.06 (0.86, 1.30)	0.94 (0.79, 1.11)	0.92 (0.79, 1.09)	—	0.20
Model 2: OR (95% CI) ⁴	1 (reference)	1.17 (0.95, 1.44)	1.14 (0.95, 1.36)	1.32 (1.11, 1.56)	—	0.002
SF _{time} , ^{6,9} times/d	≤0.5	1	1.5	≥2	—	—
Subjects, <i>n</i>	2486	2166	2024	2721	—	—
Overweight/obesity, ² <i>n</i>	1861	1595	1501	1893	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.95 (0.77, 1.16)	0.98 (0.83, 1.15)	0.83 (0.68, 1.00)	—	0.04
Model 2: OR (95% CI) ⁴	1 (reference)	1.06 (0.86, 1.31)	1.18 (0.98, 1.42)	1.14 (0.93, 1.39)	—	0.14
Central obesity, ⁵ <i>n</i>	1171	989	938	1122	—	—
Model 1: OR (95% CI) ³	1 (reference)	0.92 (0.76, 1.10)	1.02 (0.85, 1.23)	0.87 (0.73, 1.04)	—	0.24
Model 2: OR (95% CI) ⁴	1 (reference)	1.01 (0.83, 1.23)	1.22 (1.00, 1.47)	1.17 (0.98, 1.41)	—	0.03

¹ Analyses are based on subjects with complete data on two 24-h dietary recalls, as well as complete information on the variables of interest. All dietary variables are based on mean values of two 24-h dietary recalls. EF_{all}, eating frequency based on all occasions; EF_{energy}, eating frequency based on all occasions except for those providing no energy; EF_{≥50kcal}, eating frequency based on all occasions except for those providing <50 kcal of energy; MF_{energy%}, meal frequency determined based on percentage contribution to total energy intake; MF_{self-report}, meal frequency determined based on self-report; MF_{time}, meal frequency determined based on the time the meal was consumed; SF_{energy%}, snack frequency determined based on percentage contribution to total energy intake; SF_{self-report}, snack frequency determined based on self-report; SF_{time}, snack frequency determined based on the time the snack was consumed.

² Defined as BMI ≥25 kg/m².

³ Adjusted for age group (20–39, 40–59, or ≥60 y), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), years of education (<12 y, 12 y, some college, or college degree or more), family poverty income ratio (<130%, 130–349%, or ≥350%), smoking status (never, former, or current), any recreational physical activity (yes or no), survey cycle (2003–2004, 2005–2006, 2007–2008, 2009–2010, or 2011–2012), protein intake (percentage of energy, continuous), fat intake (percentage of energy, continuous), total sugar intake (percentage of energy, continuous), alcohol intake (percentage of energy, continuous), and dietary fiber intake (g/1000 kcal, continuous).

⁴ Adjusted for variables used in model 1 and ratio of energy intake to estimated energy requirement (continuous).

⁵ Defined as waist circumference ≥102 cm.

⁶ Based on all occasions except for those providing <50 kcal of energy.

⁷ 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 a snack.

⁸ Self-reports of breakfast, brunch, lunch, supper, and dinner or their equivalents in Spanish were considered to be meals; all other self-reported eating events were considered to be snacks.

⁹ Meals were defined as eating events reported during select times of the day (0600–1000, 1200–1500, and 1800–2100); all other eating occasions were considered to be snacks.

The strengths of this study include the use of a variety of published definitions of EF, MF, and SF based on detailed dietary information obtained from two 24-h dietary recalls, measured anthropometric data, and the use of individualized measures of EER to assess misreporting of EI in a large representative sample of US adults. However, there are also several limitations. The cross-sectional nature of the study did 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 MF (and EF), although it is unlikely in the present study that they ate small meals, given the positive associations between MF (and EF) and EI observed. Alternatively, overweight and obese subjects simply may have reduced their MF and SF (and EF) in an attempt to lose weight. If so, the strength of the positive associations between EF, MF, and SF and adiposity measures would be underestimated. In any case, only a prospective study taking into account dietary misreporting would provide better understanding of the relations between EF, MF, and SF and adiposity measures.

At present, the only way to obtain unbiased information on energy requirements in free-living settings is to use doubly labeled water (37). This technique is expensive and impractical for the application to large-scale epidemiologic studies. Instead, in the

present study, EER was calculated with the use of equations from the US DRI, which was developed based on a large number of measurements of total energy expenditure by the doubly labeled water method and are highly accurate ($R^2 = 0.82$ for men and 0.79 for women) (35). In the absence of actual measured total energy expenditure, these equations should serve as the best proxy. Because of constraints within the data set, we did not have a validated and individualized measure of physical activity. Instead, we assumed a “low active” level of physical activity for all subjects during the calculation of EER. This seems adequate for most US adults, based on accelerometer-based data in NHANES 2003–2006 (38, 39), although in some very active individuals, EER would be underestimated, having the effect of overestimating EI. Furthermore, although we adjusted for a variety of potential confounding variables, residual confounding could not be ruled out. Finally, because only EF of meals contributing to ≥15% of total EI (i.e., MF_{energy%}) showed null associations with overweight/obesity and central obesity (with positive associations for all other measures of EF, MF, and SF), the present finding should not be interpreted as conclusive evidence that eating less frequently (e.g., 1 or 2 large meals/d) is an effective way to prevent obesity but that higher SF or EF of additional small meals may be a contributing factor to obesity. Nonetheless, oversimplification should be avoided because there is no consensus about what

TABLE 4 Associations between eating frequency, meal frequency, and snack frequency and the risk of overweight/obesity and central obesity in 9568 women aged ≥ 20 y participating in NHANES 2003–2012¹

	Category 1 (lowest)	Category 2	Category 3	Category 4	Category 5	P-trend
EF _{all} , times/d	≤ 3.5	4	4.5	5	≥ 5.5	—
Subjects, <i>n</i>	2283	1470	1488	1356	2971	—
Overweight/obesity, ² <i>n</i>	1683	1037	1066	926	1877	—
Model 1: OR (95% CI) ³	1 (reference)	1.03 (0.82, 1.31)	1.05 (0.84, 1.31)	0.88 (0.72, 1.08)	0.74 (0.62, 0.88)	<0.0001
Model 2: OR (95% CI) ⁴	1 (reference)	1.18 (0.93, 1.51)	1.35 (1.07, 1.70)	1.19 (0.96, 1.46)	1.17 (0.97, 1.40)	0.40
Central obesity, ⁵ <i>n</i>	1653	1034	1042	917	1860	—
Model 1: OR (95% CI) ³	1 (reference)	0.98 (0.79, 1.21)	0.95 (0.76, 1.19)	0.91 (0.74, 1.11)	0.75 (0.64, 0.88)	<0.0001
Model 2: OR (95% CI) ⁴	1 (reference)	1.10 (0.89, 1.38)	1.19 (0.94, 1.50)	1.19 (0.97, 1.47)	1.13 (0.95, 1.34)	0.31
EF _{energy} , times/d	≤ 3.5	4	4.5	5	≥ 5.5	—
Subjects, <i>n</i>	2321	1486	1491	1364	2906	—
Overweight/obesity, ² <i>n</i>	1712	1047	1070	930	1830	—
Model 1: OR (95% CI) ³	1 (reference)	1.03 (0.81, 1.29)	1.05 (0.83, 1.33)	0.91 (0.74, 1.12)	0.72 (0.61, 0.85)	<0.0001
Model 2: OR (95% CI) ⁴	1 (reference)	1.18 (0.93, 1.49)	1.35 (1.06, 1.73)	1.22 (0.99, 1.51)	1.14 (0.95, 1.37)	0.56
Central obesity, ⁵ <i>n</i>	1682	1046	1048	918	1812	—
Model 1: OR (95% CI) ³	1 (reference)	0.96 (0.78, 1.19)	0.95 (0.75, 1.20)	0.92 (0.76, 1.12)	0.72 (0.62, 0.85)	<0.0001
Model 2: OR (95% CI) ⁴	1 (reference)	1.09 (0.88, 1.35)	1.19 (0.93, 1.51)	1.20 (0.98, 1.47)	1.09 (0.92, 1.29)	0.52
EF _{≥ 50 kcal} , times/d	≤ 3	3.5	4	4.5	≥ 5	—
Subjects, <i>n</i>	1928	1645	1746	1558	2691	—
Overweight/obesity, ² <i>n</i>	1424	1165	1218	1060	1722	—
Model 1: OR (95% CI) ³	1 (reference)	0.94 (0.76, 1.17)	0.95 (0.75, 1.20)	0.84 (0.69, 1.02)	0.77 (0.63, 0.93)	0.002
Model 2: OR (95% CI) ⁴	1 (reference)	1.19 (0.94, 1.50)	1.32 (1.03, 1.70)	1.29 (1.03, 1.60)	1.45 (1.17, 1.81)	0.001
Central obesity, ⁵ <i>n</i>	1402	1143	1216	1061	1684	—
Model 1: OR (95% CI) ³	1 (reference)	0.90 (0.72, 1.12)	1.05 (0.85, 1.29)	0.90 (0.74, 1.10)	0.74 (0.61, 0.89)	0.0002
Model 2: OR (95% CI) ⁴	1 (reference)	1.10 (0.88, 1.39)	1.40 (1.12, 1.74)	1.31 (1.06, 1.62)	1.29 (1.05, 1.59)	0.03
MF _{energy} , ^{6,7} times/d	≤ 2	2.5	3	≥ 3.5	—	—
Subjects, <i>n</i>	2032	3229	2999	1308	—	—
Overweight/obesity, ² <i>n</i>	1407	2265	2049	868	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.03 (0.86, 1.24)	0.89 (0.76, 1.03)	0.92 (0.74, 1.15)	—	0.14
Model 2: OR (95% CI) ⁴	1 (reference)	1.09 (0.91, 1.30)	0.97 (0.83, 1.13)	1.06 (0.85, 1.32)	—	0.92
Central obesity, ⁵ <i>n</i>	1357	2245	2048	856	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.14 (0.95, 1.37)	1.00 (0.86, 1.16)	0.95 (0.76, 1.20)	—	0.38
Model 2: OR (95% CI) ⁴	1 (reference)	1.20 (1.00, 1.44)	1.09 (0.93, 1.28)	1.09 (0.85, 1.38)	—	0.73
SF _{energy} , ^{6,7} times/d	≤ 0.5	1	1.5	2 or 2.5	≥ 3	—
Subjects, <i>n</i>	2625	1864	1644	2174	1261	—
Overweight/obesity, ² <i>n</i>	1899	1323	1122	1459	786	—
Model 1: OR (95% CI) ³	1 (reference)	1.02 (0.85, 1.22)	0.99 (0.81, 1.20)	0.88 (0.74, 1.04)	0.78 (0.62, 0.98)	0.01
Model 2: OR (95% CI) ⁴	1 (reference)	1.21 (0.99, 1.46)	1.22 (0.99, 1.51)	1.29 (1.06, 1.56)	1.43 (1.13, 1.82)	0.004
Central obesity, ⁵ <i>n</i>	1881	1313	1109	1435	768	—
Model 1: OR (95% CI) ³	1 (reference)	0.94 (0.76, 1.16)	0.97 (0.78, 1.20)	0.82 (0.68, 0.99)	0.75 (0.61, 0.92)	0.002
Model 2: OR (95% CI) ⁴	1 (reference)	1.08 (0.87, 1.35)	1.17 (0.93, 1.47)	1.14 (0.93, 1.41)	1.28 (1.03, 1.58)	0.03
MF _{self-report} , ^{6,8} times/d	≤ 2	2.5	3	≥ 3.5	—	—
Subjects, <i>n</i>	2076	2575	4141	776	—	—
Overweight/obesity, ² <i>n</i>	1485	1834	2741	529	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.01 (0.88, 1.17)	0.90 (0.76, 1.07)	0.84 (0.63, 1.12)	—	0.10
Model 2: OR (95% CI) ⁴	1 (reference)	1.29 (1.11, 1.50)	1.34 (1.13, 1.58)	1.39 (1.04, 1.86)	—	0.003
Central obesity, ⁵ <i>n</i>	1464	1811	2722	509	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.06 (0.88, 1.28)	0.93 (0.78, 1.10)	0.79 (0.59, 1.06)	—	0.06
Model 2: OR (95% CI) ⁴	1 (reference)	1.32 (1.08, 1.60)	1.32 (1.11, 1.56)	1.24 (0.92, 1.66)	—	0.02
SF _{self-report} , ^{6,8} times/d	≤ 0.5	1	1.5	2 or 2.5	≥ 3	—
Subjects, <i>n</i>	2192	2002	1862	2391	1121	—
Overweight/obesity, ² <i>n</i>	1599	1396	1309	1581	704	—
Model 1: OR (95% CI) ³	1 (reference)	0.97 (0.80, 1.17)	0.93 (0.78, 1.12)	0.93 (0.79, 1.11)	0.68 (0.55, 0.85)	0.001
Model 2: OR (95% CI) ⁴	1 (reference)	1.06 (0.87, 1.30)	1.12 (0.91, 1.36)	1.27 (1.06, 1.53)	1.14 (0.89, 1.45)	0.18
Central obesity, ⁵ <i>n</i>	1559	1393	1308	1555	691	—
Model 1: OR (95% CI) ³	1 (reference)	0.99 (0.83, 1.19)	1.03 (0.84, 1.25)	0.94 (0.79, 1.13)	0.67 (0.55, 0.82)	<0.0001
Model 2: OR (95% CI) ⁴	1 (reference)	1.08 (0.90, 1.28)	1.21 (0.99, 1.48)	1.24 (1.03, 1.51)	1.05 (0.84, 1.32)	0.51

(Continued)

TABLE 4 Continued

	Category 1 (lowest)	Category 2	Category 3	Category 4	Category 5	P-trend
MF _{time} , ^{6,9} times/d	≤2	2.5	3	≥3.5	—	—
Subjects, <i>n</i>	2365	1813	2109	3281	—	—
Overweight/obesity, ² <i>n</i>	1702	1306	1440	2141	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.05 (0.84, 1.32)	0.97 (0.79, 1.20)	0.87 (0.73, 1.04)	—	0.052
Model 2: OR (95% CI) ⁴	1 (reference)	1.21 (0.96, 1.53)	1.22 (0.98, 1.50)	1.27 (1.05, 1.53)	—	0.04
Central obesity, ⁵ <i>n</i>	1656	1304	1428	2118	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.19 (0.97, 1.45)	0.96 (0.77, 1.19)	0.88 (0.75, 1.04)	—	0.02
Model 2: OR (95% CI) ⁴	1 (reference)	1.35 (1.09, 1.67)	1.17 (0.94, 1.46)	1.23 (1.04, 1.47)	—	0.13
SF _{time} , ^{6,9} times/d	≤0.5	1	1.5	≥2	—	—
Subjects, <i>n</i>	2676	2283	2010	2599	—	—
Overweight/obesity, ² <i>n</i>	1893	1618	1380	1698	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.05 (0.87, 1.25)	0.91 (0.75, 1.11)	0.80 (0.67, 0.95)	—	0.003
Model 2: OR (95% CI) ⁴	1 (reference)	1.11 (0.93, 1.33)	1.05 (0.86, 1.28)	1.07 (0.90, 1.26)	—	0.59
Central obesity, ⁵ <i>n</i>	1894	1582	1353	1677	—	—
Model 1: OR (95% CI) ³	1 (reference)	1.08 (0.91, 1.29)	0.91 (0.75, 1.10)	0.84 (0.71, 0.98)	—	0.007
Model 2: OR (95% CI) ⁴	1 (reference)	1.14 (0.96, 1.37)	1.02 (0.84, 1.24)	1.09 (0.92, 1.28)	—	0.56

¹ Analyses are based on subjects with complete data on two 24-h dietary recalls, as well as complete information on the variables of interest. All dietary variables are based on mean values of two 24-h dietary recalls. EF_{all}, eating frequency based on all occasions; EF_{energy}, eating frequency based on all occasions except for those providing no energy; EF_{≥50kcal}, eating frequency based on all occasions except for those providing <50 kcal of energy; MF_{energy%}, meal frequency determined based on percentage contribution to total energy intake; MF_{self-report}, meal frequency determined based on self-report; MF_{time}, meal frequency determined based on the time the meal was consumed; SF_{energy%}, snack frequency determined based on percentage contribution to total energy intake; SF_{self-report}, snack frequency determined based on self-report; SF_{time}, snack frequency determined based on the time the snack was consumed.

² Defined as BMI ≥25 kg/m².

³ Adjusted for age group (20–39, 40–59, or ≥60 y), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), years of education (<12 y, 12 y, some college, or college degree or more), family poverty income ratio (<130%, 130–349%, or ≥350%), smoking status (never, former, or current), any recreational physical activity (yes or no), survey cycle (2003–2004, 2005–2006, 2007–2008, 2009–2010, or 2011–2012), protein intake (percentage of energy, continuous), fat intake (percentage of energy, continuous), total sugar intake (percentage of energy, continuous), alcohol intake (percentage of energy, continuous), and dietary fiber intake (g/1000 kcal, continuous).

⁴ Adjusted for variables used in model 1 and ratio of energy intake to estimated energy requirement (continuous).

⁵ Defined as waist circumference ≥88 cm.

⁶ Based on all occasions except for those providing <50 kcal of energy.

⁷ 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 a snack.

⁸ Self-reports of breakfast, brunch, lunch, supper, and dinner or their equivalents in Spanish were considered to be meals; all other self-reported eating events were considered to be snacks.

⁹ Meals were defined as eating events reported during select times of the day (0600–1000, 1200–1500, and 1800–2100); all other eating occasions were considered to be snacks.

constitutes a snack, a meal, or an eating occasion. Results possibly may differ on the basis of other definitions. In this context, MF and SF based on time may be the most problematic, because eating patterns vary according to lifestyle (e.g., shift workers, individuals who consistently eat their meals at nontraditional times of day) as well as the cultural environment (40). Nevertheless, a repeated analysis after excluding night/evening/rotating workers (*n* = 1674) and thus including only regular day workers and nonworkers (*n* = 10,043) from NHANES 2005–2010, where the information is available, revealed similar associations between MF_{time} and SF_{time} and overweight/obesity and central obesity, except for no association between MF_{time} and central obesity in men (data not shown).

In conclusion, in this cross-sectional study in a representative sample of US adults based on NHANES 2003–2012, we showed positive associations between different measures of EF, MF, and SF and overweight/obesity and central obesity, except for null associations for MF_{energy%}, and addressed the effect of adjustment for EI:EER, which affected the results of the analysis to a greater extent than did definitions of EF, MF, and SF. This suggests that adjustment for EI:EER is important, rather than excluding energy misreporters, which may lead to bias. Prospective studies are needed to confirm the associations observed in this cross-sectional study.

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KM and MBEL designed the research; KM performed the statistical analysis; KM and MBEL wrote the paper; and KM had primary responsibility for the final content. Both authors read and approved the final manuscript.

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