

Associations between eating frequency and energy intake, energy density, diet quality and body weight status in adults from the USA

Yong Zhu¹ and James H. Hollis^{2*}

¹Department of Epidemiology, The University of Iowa, Iowa City, IA 52242, USA

²Department of Food Science and Human Nutrition, Iowa State University, Ames, IA 50011, USA

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Abstract

To investigate associations between eating frequency and energy intake, energy density, diet quality and body weight status in adults from the USA, combined data from the 2009–2010 and 2011–2012 National Health and Nutrition Examination Survey (NHANES) were used in this study. The first 24-h dietary recall data from eligible participants (4017 men and 3774 women) were used to calculate eating frequency, as well as energy intake, energy density and the Healthy Eating Index 2010 (HEI-2010), as a measure of diet quality. BMI and waist circumference were obtained from the NHANES body measures data. Adjusting for confounding socio-demographic characteristics and lifestyle factors, a higher eating frequency was significantly associated with higher energy intake in both men and women (both $P < 0.001$). A higher eating frequency was also significantly associated with lower energy density in both men and women, regardless of whether beverage or water intake was included in the calculation of energy density (all $P < 0.01$). Moreover, there was a significant positive association between eating frequency and the HEI-2010 total score in both men and women (both $P < 0.001$). Eating frequency was inversely associated with BMI in women ($P = 0.003$), as well as waist circumference in both men ($P = 0.032$) and women ($P = 0.010$). Results from the present study suggested that adults with a higher eating frequency in the USA had a healthier diet with lower energy density and better diet quality, and eating frequency was inversely associated with body weight status.

Key words: National Health and Nutrition Examination Survey; Eating frequency; Energy density; Diet quality

Owing to the recent and rapid rise in the number of overweight and obese people, it is thought that changing environmental factors such as dietary choices or lifestyle habits are the predominant cause for this epidemic. One potentially key environmental change that has occurred in concert with the obesity epidemic is an increase in eating frequency (the number of eating occasions)⁽¹⁾. However, the association between eating frequency and energy intake, energy density, diet quality, BMI and waist circumference in a population-based nationally representative study has not been well studied.

Increasing eating frequency could possibly influence energy intake through improved appetite control. To date, the relationship between eating frequency and energy intake is not clear, with results reporting that increased eating frequency is associated with reduced food intake⁽²⁾, whereas another study found that increased eating frequency is associated with increased food intake⁽³⁾. It has also been suggested that eating frequency could affect diet-induced thermogenesis, although the results are inconsistent. Although a short-term (<24 h) study has suggested that increased eating frequency results in increased thermogenesis⁽⁴⁾, other studies have reported that

increasing eating frequency decreases thermogenesis^(5,6) or has no effect⁽⁷⁾. Longer-term studies (7 d) using doubly labelled water have consistently reported no effects of eating frequency on energy expenditure^(8,9).

Similar to short-term studies of the components of energy balance, studies that have investigated the association between eating frequency and body weight status also provide inconsistent data. Epidemiological studies have reported an inverse association^(2,10,11), no association^(3,12) or a positive association⁽¹³⁾ between eating frequency and body weight status. These discrepant findings may be due to differences in the definition of eating frequency, differences in the measurement of eating frequency or the lack of adjustment for potential confounders^(14,15). Only a limited number of randomised-controlled trials have been conducted thus far; they have reported that manipulating eating frequency had no effect on weight loss after intervention of 8 weeks⁽¹⁶⁾ or 6 months⁽¹⁷⁾. These studies focused on weight loss efficacy and were not representative of the wider population. Consequently, the results may be of limited relevance for efforts to optimise the diet for the general public. Further research, especially using

Abbreviations: HEI-2010, Healthy Eating Index 2010; NHANES, National Health and Nutrition Examination Survey.

* **Corresponding author:** J. H. Hollis, email jhollis@iastate.edu

nationally representative data, is warranted to investigate the relationship between eating frequency and diet and body weight status.

Methods

Data source and study population

Data from the 2009–2010 and 2011–2012 National Health and Nutrition Examination Survey (NHANES) were combined and used in this study. The NHANES is a survey conducted by the National Center for Health Statistics for the assessment of health and nutritional status of non-institutionalised residents in the USA; selected participants were invited for the interview and physical examinations⁽¹⁸⁾. At the mobile examination centre, participants were asked to provide a 24-h dietary recall; a second dietary recall was obtained by telephone interview 3–10 d later. The NHANES dietary recall was administered using the United States Department of Agriculture (USDA) Automated Multiple-Pass Method⁽¹⁹⁾, and participants were provided with a standard set of measuring guides to help estimate food portion sizes. Dietary recall data were processed using the USDA's Food and Nutrient Database for Dietary Studies; details of sampling methodology, survey instruments, study protocols and data sets are available on the NHANES website⁽¹⁸⁾. The NHANES study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the National Center for Health Statistics Research Ethics Review Board. Written informed consent was obtained from all the participants.

Participants aged ≥ 20 years with a complete first 24-h dietary recall were initially included in this study (n 10 563). Of these, 2772 participants were excluded if they met one or more of the following criteria: were pregnant or lactating (168 participants), were on a special diet either to lose weight or for some other health-related reason (1520 participants) or had missing data on any covariates or outcome variables (1310 participants). The final sample size of the present study included 7791 eligible adults (4017 men and 3774 women).

Exposure and outcome variables

Self-reported time of consumption of each food or beverage in response to the question 'what time did you begin to eat/drink the meal/food?' in the first 24-h dietary recall was used to estimate eating frequency. An eating occasion was defined such that it contained at least 210 kJ and the time interval between eating occasions was more than 15 min⁽²⁰⁾. This definition was chosen because recent studies that examined various definitions of eating occasion revealed it was the one that best predicted variance in total energy intake⁽²¹⁾ or provided the strongest correlation with total energy intake⁽²²⁾.

Total energy intake from the first dietary recall, BMI and waist circumference were directly obtained from the NHANES data set. Energy density was calculated by dividing total energy of dietary items by total weight of dietary items^(23–25). Three types of energy density were examined in this study: using foods only, using foods and beverages excluding water and using

foods and beverages including water. Milk and milk drinks, fruit juice, vegetable juice, alcoholic beverages and non-alcoholic beverages (coffee, tea, soft drinks, etc.) were considered as beverages⁽²⁵⁾.

Diet quality was estimated as the Healthy Eating Index 2010 (HEI-2010)⁽²⁶⁾. The HEI-2010 was developed as a parameter for compliance with the *2010 Dietary Guidelines for Americans*; it consists of nine adequacy food components and three moderation food components; the total score ranges from 0 to 100, a higher score indicates better diet quality or better compliance with the dietary guidelines⁽²⁶⁾.

Covariates

Socio-demographic characteristics including age, race/ethnicity and ratio of family income:poverty, as well as lifestyle factors such as physical activity level and smoking status, were used as covariates. Classifications of these variables were the same as the approach used in a previous study⁽²⁷⁾. In brief, race/ethnicity was classified as Hispanic, non-Hispanic white, non-Hispanic black or other; ratio of family income:poverty was coded to a categorical variable as ≤ 1.85 , 1.86–3.50, > 3.50 ; physical activity level was classified as vigorously active, moderately active or sedentary, which was estimated from answers to questions 'does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate for at least 10 min continuously' and 'do you do any moderate-intensity sports, fitness or recreational activities that cause a small increase in breathing or heart rate for at least 10 min continuously'; and smoking status was coded as non-smoker, former smoker or current smoker. Moreover, total energy intake was also adjusted for in the analysis where appropriate.

Statistical analysis

SAS version 9.3 (SAS Institute) was used for statistical analysis; 4-year sample weight and specific SAS survey procedures were used to account for the complex multistage design of the NHANES. As a previous study reported sex-specific associations between eating frequency and cardiometabolic risk factors⁽¹¹⁾, data for men and women were analysed separately in the main analyses to examine potential sex-specific differences. Characteristics of participants were compared between sexes by survey χ^2 tests for categorical variables and by survey linear regression for continuous variables. Survey multivariate linear regression was used to estimate covariate-adjusted associations between eating frequency and each outcome of interests. Data were presented as weighted percentages, least squares means or regression coefficients with their standard errors, where appropriate. The statistical significance was considered as $P < 0.05$.

Two sensitivity analyses were conducted to determine associations between eating frequency and total energy intake, energy density, the HEI-2010 total score, BMI and waist circumference. First, a pooled analysis combining data from men and women was conducted, with sex as an additional covariate in the statistical model. Second, the associations were analysed using the second 24-h dietary recall data from participants whose complete data were available.

Results

Characteristics of the participants

The average eating frequency was 4.48 (SE 0.03, range 1–10) in men and 4.38 (SE 0.03, range 1–12) in women. Characteristics of the participants (men and women) are presented in Table 1. Significant sex differences were found in race/ethnicity, ratio of family income:poverty, physical activity, smoking status and age ($P < 0.05$ for all). The difference in BMI was not significant between men and women ($P = 0.430$); however, men had a significantly greater waist circumference than women ($P < 0.001$). Men also had significantly higher total energy intake and higher energy density (except when water was not

included in the calculation of energy density), as well as a significantly lower HEI-2015 total score, compared with women ($P < 0.05$ for all). Examination of individual component scores of the HEI-2015 revealed that men were less compliant to the dietary guidelines compared with women for most types of foods (Table 1).

Energy intake and energy density

There was a significant positive association between eating frequency and total energy intake in both men and women (both $P < 0.001$, Table 2). A significant inverse association between eating frequency and energy density was found in

Table 1. Characteristics of the participants (Weighted percentages, least squares means with their standard errors)

Categorical variables	Men (n 4017)			Women (n 3774)			P*
	n	Weighted %	SE	n	Weighted %	SE	
Race/ethnicity							0.002
Hispanic	941	14.0	2.0	896	12.7	1.8	
Non-Hispanic white	1839	69.9	2.5	1682	68.4	2.6	
Non-Hispanic black	828	9.6	1.1	814	11.7	1.3	
Other	409	6.5	0.8	382	7.1	0.8	
Ratio of family income:poverty							<0.001
≤1.85	1835	31.8	1.6	1892	36.2	1.4	
1.86–3.50	910	23.9	1.1	856	25.6	1.3	
>3.50	1272	44.3	1.6	1026	38.3	2.0	
Physical activity							<0.001
Vigorously active	1786	51.0	1.4	910	28.3	1.4	
Moderately active	1149	27.7	1.1	1397	38.2	1.1	
Sedentary	1082	21.3	1.0	1467	33.5	1.2	
Smoking status							<0.001
Non-smoker	1839	49.1	1.5	2377	60.2	1.1	
Former smoker	1136	27.4	1.2	669	20.2	1.2	
Current smoker	1042	23.5	1.1	728	19.6	1.0	
Continuous variables							
		Least squares mean	SE		Least squares mean	SE	
Age (years)		46.1	0.5		47.4	0.5	<0.001
BMI (kg/m ²)		28.4	0.2		28.2	0.2	0.430
Waist circumference (cm)		100.4	0.5		94.6	0.5	<0.001
Eating occasions		4.48	0.03		4.38	0.03	0.005
Energy intake (kJ)		10 873	96		7706	52	<0.001
Energy density (kJ/g)†		8.38	0.06		7.92	0.07	<0.001
Energy density (kJ/g)‡		4.16	0.04		4.09	0.04	0.107
Energy density (kJ/g)§		2.39	0.03		2.29	0.02	0.006
HEI-2010 total score		48.24	0.39		49.88	0.47	<0.001
HEI-2010 total vegetables score		2.68	0.03		2.96	0.04	<0.001
HEI-2010 greens and beans score		1.06	0.05		1.30	0.06	0.001
HEI-2010 total fruit score		2.00	0.04		2.35	0.06	<0.001
HEI-2010 whole fruit score		1.93	0.05		2.28	0.06	<0.001
HEI-2010 whole grains score		1.97	0.09		2.37	0.08	<0.001
HEI-2010 dairy products score		4.20	0.08		4.69	0.08	<0.001
HEI-2010 total protein foods score		4.04	0.04		3.76	0.04	<0.001
HEI-2010 seafood and plant proteins score		1.94	0.05		2.03	0.05	0.249
HEI-2010 fatty acids score		5.09	0.08		5.09	0.09	0.987
HEI-2010 Na score		4.30	0.06		4.36	0.08	0.541
HEI-2010 refined grains score		6.56	0.09		6.23	0.07	0.001
HEI-2010 solid fat, alcohol and added sugar energy content score		12.47	0.18		12.47	0.17	0.976

HEI-2010, Healthy Eating Index 2010.

* P value for comparisons between men and women.

† Energy density calculated as energy from all food items divided by weight of all food items.

‡ Energy density calculated as energy from all food items and beverages excluding water divided by weight of all food items and beverages excluding water.

§ Energy density calculated as energy from all food items and beverages including water divided by weight of all food items and beverages including water.

Table 2. Associations between eating frequency and energy intake and energy density (Regression coefficients with their standard errors)

	Men (n 4017)			Women (n 3774)		
	β	SE	P	β	SE	P
Energy intake (kJ)*	264.7	18.9	<0.001	204.4	9.6	<0.001
Energy density (kJ/g)†‡	-0.152	0.037	<0.001	-0.218	0.034	<0.001
Energy density (kJ/g)†§	-0.105	0.022	<0.001	-0.086	0.022	<0.001
Energy density (kJ/g)†	-0.057	0.017	0.002	-0.092	0.019	<0.001

* Adjusted for age, race/ethnicity, ratio of family income:poverty, physical activity level and smoking status; β is the change in the outcome variable for each unit increase of eating frequency when adjusting for covariates.

† Adjusted for age, race/ethnicity, ratio of family income:poverty, physical activity level, smoking status and energy intake.

‡ Energy density calculated as energy from all food items divided by weight of all food items.

§ Energy density calculated as energy from all food items and beverages excluding water divided by weight of all food items and beverages excluding water.

|| Energy density calculated as energy from all food items and beverages including water divided by weight of all food items and beverages including water.

Table 3. Associations between eating frequency and the Health Eating Index 2010 (HEI-2010)* (Regression coefficients with their standard errors)

	Men (n 4017)			Women (n 3774)		
	β	SE	P	β	SE	P
HEI-2010 total score	1.698	0.243	<0.001	1.630	0.245	<0.001
Adequacy component						
Total vegetables	-0.014	0.029	0.638	0.013	0.035	0.717
Greens and beans	-0.005	0.037	0.901	0.050	0.032	0.132
Total fruit	0.332	0.030	<0.001	0.328	0.031	<0.001
Whole fruit	0.341	0.032	<0.001	0.366	0.031	<0.001
Whole grains	0.259	0.054	<0.001	0.275	0.056	<0.001
Dairy products	0.243	0.060	<0.001	0.252	0.052	<0.001
Total protein foods	0.025	0.030	0.398	-0.044	0.034	0.199
Seafood and plant proteins	0.180	0.040	<0.001	0.110	0.038	0.006
Fatty acids	-0.091	0.063	0.159	-0.119	0.056	0.040
Moderation component						
Na	0.217	0.065	0.002	0.275	0.054	<0.001
Refined grains	0.177	0.067	0.012	0.129	0.076	0.099
Solid fat, alcohol, and added sugar energy content	0.033	0.107	0.759	-0.005	0.112	0.963

* Adjusted for age, race/ethnicity, ratio of family income:poverty, physical activity level, smoking status and energy intake; β is the change in the outcome variable for each unit increase of eating frequency when adjusting for covariates.

both men and women; this was observed regardless of inclusion of water and beverages in the calculation of energy density ($P < 0.01$ for all, Table 2).

Diet quality

Associations between eating frequency and the HEI-2010 total score and each component score are shown in Table 3. A significant positive association between eating frequency and diet quality was observed in both men and women (both $P < 0.001$). Significant positive associations were also observed for most adequacy component scores, including total fruit, whole fruit, whole grains, dairy products and seafood and plant proteins, in both men and women ($P < 0.01$ for all). In contrast, a significant negative association was observed between eating frequency and the fatty acids component score in women ($P = 0.040$) but not in men ($P = 0.159$). For moderation components, the Na component score was significantly and positively associated with eating frequency in both men ($P = 0.002$) and women ($P < 0.001$), whereas the component score for refined grains

was significantly and positively associated with eating frequency in men ($P = 0.012$) but not in women ($P = 0.099$).

BMI and waist circumference

As shown in Table 4, eating frequency was significantly and inversely associated with BMI in women ($P = 0.003$); however, the association was not statistically significant in men ($P = 0.130$). In contrast, eating frequency was significantly and inversely associated with waist circumference in both men ($P = 0.032$) and women ($P = 0.010$).

Sensitivity analysis

The pooled analysis combining data from both men and women revealed that eating frequency was significantly and positively associated with energy intake, as well as significantly and inversely associated with energy density, diet quality, BMI and waist circumference ($P < 0.05$ for all, data not shown). Among participants included in the present study, 3470 men and 3420 women also provided a complete second 24-h

Table 4. Associations between eating frequency and BMI and waist circumference* (Regression coefficients with their standard errors)

	Men (n 4017)			Women (n 3774)		
	β	SE	P	β	SE	P
BMI (kg/m ²)	-0.166	0.107	0.130	-0.400	0.123	0.003
Waist circumference (cm)	-0.568	0.254	0.032	-0.798	0.292	0.010

* Adjusted for age, race/ethnicity, ratio of family income:poverty, physical activity level, smoking status and energy intake; β is the change in the outcome variable for each unit increase of eating frequency when adjusting for covariates.

dietary recall. The mean difference in eating frequency between the day of the first dietary recall and the day of the second dietary recall was 0.18 (SE 0.03) in men and 0.11 (SE 0.03) in women, respectively. Both differences were statistically significant ($P < 0.001$). Only 25.5% of men and 30.4% of women had the same eating frequency on both days; however, the difference in eating frequency between the two dietary recalls was no more than one eating occasion for the majority of participants (67.9% of men and 72.1% of women). Analysis of the second 24-h dietary recall data also revealed similar results regarding associations between eating frequency and energy intake, energy density, diet quality and waist circumference ($P < 0.05$ for all, data not shown), whereas the inverse associations between eating frequency and BMI in both men and women were statistically significant ($P = 0.040$ and $P = 0.003$, data not shown).

Discussion

There has been an increase in eating frequency over the past 30 years in all age groups⁽¹⁾. The present study using nationally representative data from the USA found that men ate, on average, 4.48 times each day, whereas it was 4.38 times for women. A better understanding of how eating frequency influences body weight may lead to improved strategies to aid weight loss. Data from the present study suggest that increased eating frequency is associated with increased energy intake, a diet with lower energy density and better diet quality; moreover, it was inversely associated with BMI and waist circumference, although the association with BMI was not significant in men when the first 24-h dietary recall data were analysed.

Results from this study are consistent with previous results, which report a positive association between eating frequency and energy intake⁽³⁾, and several cross-sectional studies, which have found an inverse significant relationship between eating frequency and body weight or BMI^(2,10), but not others^(3,12,13). There are several possible explanations for these discrepant and paradoxical results. First, eating frequency and anthropometric measures are related to several socio-economic and lifestyle variables, which may confound the results. If these are not adequately controlled for, then spurious associations may be reported. The list of covariates adjusted for was not consistent among studies. Second, the true relationship between eating frequency and body weight may be masked by under-reporting of energy intake, which is an issue in common observational

studies that rely on self-reported diet recalls⁽²⁸⁾. Although randomised-controlled trials are better placed to show a causal relationship between eating frequency and anthropometric measures of interest, a few studies have been conducted thus far^(16,17). These studies have altered eating frequency as part of an energy-restricted diet and generally show no effect of eating frequency on weight loss^(16,17). However, the results from these weight loss studies cannot be extrapolated to the general population who are not on a weight loss diet and wish to maintain a healthy body weight or prevent weight gain. Moreover, there are some weaknesses to randomised-controlled trials that could also mask a true relationship (e.g. poor participant compliance to the treatment protocol). Mechanistic data that may support a role for eating frequency also provide inconsistent results. One hypothesis is that increasing eating frequency may aid weight management through an effect on appetite control⁽²⁹⁾. However, no compelling evidence for this effect currently exists. Another plausible hypothesis is that increasing eating frequency increases dietary-induced thermogenesis. Currently available data also fail to support this hypothesis⁽⁵⁻⁷⁾. Owing to the inconsistent results and relative paucity of data, further research is required to clarify the role of eating frequency on weight management.

Several studies have found that a diet with higher energy density is associated with poor appetite control⁽³⁰⁾ and a higher body weight^(31,32). However, the present study is not able to demonstrate a causal relationship between eating frequency and energy density. It is possible that individuals who eat more frequently are also more health conscious and choose low-energy density foods. It is also possible that low-energy density foods influence eating frequency by a more rapid return of hunger, which stimulates an eating occasion⁽³³⁾. Further research is warranted to understand how food characteristics influence eating patterns and how this influences health.

The present study provides evidence that increased eating frequency is associated with improved diet quality. As eating frequency increased, there was an increase in the HEI-2010 total score and higher component scores such as total fruits, whole fruits, whole grains, dairy products and seafood and plant proteins. One potential explanation for associations between eating frequency and diet quality is that people who are more health conscious eat healthier meals or snacks more frequently. A causal effect, however, remains to be investigated.

There are some limitations to the present study. First, the results do not indicate any causal relationship because the data were from a cross-sectional study. Second, the NHANES dietary data analysed may not reflect a dietary pattern over a longer

period as there could be inter-day variations in dietary intake. As shown by a sensitivity analysis in the present study, although most results were similar as the main analysis, the associations between eating frequency and BMI in men were different depending on the day of the dietary recall. Moreover, the physical activity level included in the statistical model was derived from a self-reported questionnaire; this might not have completely ruled out the possibility of confounding. Finally, the present study did not aim to investigate the impact of snacking; therefore, eating frequency did not differentiate eating occasion of main meals from snacks. Nonetheless, to our knowledge, it was the first study that examined associations between eating frequency and diet quality using a nationally representative data. Longitudinal studies are encouraged to examine the chronic impact of a dietary pattern characterised by increased eating frequency on change in body weight.

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