RESEARCH ISSUES: THE FOOD ENVIRONMENT AND OBESITY

Evidence for Efficacy and Effectiveness of Changes in Eating Frequency for Body Weight Management[1–3]

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ABSTRACT

In self-reported diets of free living individuals, frequent eating is associated with higher energy intake, yet beliefs about the possible beneficial effect of higher eating frequency for managing body weight persist. Prospective cohort studies and controlled trials of manipulation of eating frequency published by 31 December 2012 were reviewed to assess whether variation in eating frequency may be an adjunct to weight management. Four prospective cohort studies were identified; 2 of these included adults followed for 10 y and 2 followed pre-adolescent/adolescent girls for 6 or10 y. Within each age category, the findings of the 2 studies were contradictory. Six controlled trials with adult subjects serving as their own controls found no significant changes in body weight due to manipulation of eating frequency interventions lasting 6–8 wk. In 6 additional intervention trials of 8–52 wk duration, free-living adults were counseled to change the eating frequency of self-selected food intake with no significant differences in weight loss attributable to eating frequency. Overall, the consistency of the null findings from controlled trials of manipulation of eating frequency for promoting weight loss suggests that beliefs about the role of higher eating frequency in adult weight management are not supported by evidence. Interpretation of the evidence from published observational studies is complicated by differences in definition of eating frequency and limited knowledge of systematic and random errors in measurement of eating frequency. *Adv Nutr 2014;5:822–828.*

Introduction

Studies of manipulation of eating frequency in relation to components of energy metabolism and adiposity in laboratory animals are nearly 50 y old (1). One of the earliest trials of eating frequency and body weight outcome in children was conducted in 1966 (2). The available literature on the topic in humans can be roughly divided into cross-sectional associations of eating frequency with self-reported or measured body weight; short-term studies of manipulation of eating frequency in relation to components of energy expenditure and metabolic biomarkers; prospective cohort studies of baseline eating frequency and change in body weight over follow-up; short- and long-term trials of eating frequency manipulation and change in body weight; and more recently, short-term trials of manipulation of eating frequency in relation to self-perceived appetite and satiety and concentrations of appetite and satiety hormones. Several thoughtful reviews on various facets of the topic have been published previously (3–8). The scope of the present review is more narrowly defined as assessment of efficacy and effectiveness of eating frequency manipulation for body weight management in healthy children, adolescents, and adults.

Eating Frequency in the U.S. Population

In the NHANES 2005–2008, American adults reported 4.9 ± 0.03 (mean ± SE) and 2–19-y olds reported 5.1 ± 0.04 eating occasions in a 24-h recall; over 80% of all Americans reported ≥ 4 eating episodes on the recall day. Data from the NHANES 2005–2008 confirm earlier reports of positive association of eating frequency with energy intake in the U.S. population (9,10). After adjustment for age, ethnicity, gender, family income, day of recall, and BMI, each additional

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eating episode predicted 200 kcal of energy in Americans 2–19 y of age and 180 kcal in ≥20 y olds. Most reports of secular trends in eating frequency among 2–19-y-old Americans suggest an increase over the past 3 decades (11–13); however, the extent of this change varies based on the definition of eating frequency, the survey used as the baseline, and the analytic methodology. With NHANES 1971–74 as the baseline, the increase in eating frequency over 30 y was <0.5 episode in 2–19-y olds (12), and still smaller in adults (14). These studies defined eating frequency as sum of all unique eating episodes when a food or beverage (but not water) was reported, and are adjusted for differences in characteristics of populations surveyed over time (12,14). Popkin and Duffey (13) used a different definition of eating frequency, baseline survey, and analytic methodology to compare eating frequency in Nationwide Food Consumption Survey 1977–78 (baseline) with that in 2003–2006, and reported increase of 1 or more eating episodes over this period.

Cross-sectional studies have generally reported an inverse association between eating frequency and body weight in adults (8). Bellisle and coworkers (3,4) have argued that these inverse associations are spurious and may reflect differential under-reporting of food intake by overweight/obese individuals and reverse causation. Subsequently, several studies have examined the eating frequency and body weight association after exclusion of possible energy under-reporters, with mixed results (6,15–18). Howarth et al. (15) excluded 59% of the eligible sample in the Continuing Survey of Food Intakes by Individuals 1994–96 as implausible energy intake reporters and found that higher eating frequency predicted higher BMI. Exclusion of nearly two-thirds of the sample from a national survey raises questions about generalizability of these findings. Other recent cross-sectional studies that accounted for implausible energy reporting have not consistently replicated these findings (16–20). In the Malmo Diet and Cancer cohort, higher eating frequency predicted lower body weight in men but was unrelated in women (16). In other studies (17–19), although energy intake increased with increasing eating frequency, eating frequency was not an independent correlate of BMI. The extent to which classification of subjects as under-reporters based on a comparison of reported energy intakes with estimated energy needs can successfully classify under-reporters of eating episodes is not known. In an analysis of the nature of dietary reporting in the NHANES III, the differences in eating frequency among tertiles of the ratio of reported energy intake to estimated energy needs were smaller than those observed for energy intake or amounts of foods (21). Similarly, in obese men, energy under-reporting (determined by a comparison of recorded energy intakes with energy expenditure measured using doubly labeled water) was not associated with omission of eating episodes (22).

The lack of directionality in cross-sectional studies precludes their ability to provide a clear signal linking eating frequency and BMI. We conducted PubMed searches ending 31 December 2012 to identify prospective cohort studies and controlled trials of eating frequency and body weight. The key words used included combinations of meal frequency, eating frequency, body weight, weight loss, and weight maintenance. Prospective cohort studies reporting baseline servings of snacks without overall frequency (23), number of meals without overall frequency (24), or comparing snackers with non-snackers without an overall frequency (25) were excluded, leaving 4 suitable for inclusion in this review (**Table 1**). Controlled trials in subjects with acute or chronic medical/metabolic conditions (26–28), or <5 subjects in each arm (29), and trials dealing exclusively with breakfast (30) or snacking without information on overall frequency (31) were excluded, leaving 12 suitable for inclusion in this review (**Table 2**).

Prospective Cohort Studies

The 2 studies in adults used different methods to determine eating frequency, differed in adjustment for confounders, and produced different results (9,32). In a nationally representative sample of U.S. adults, with multivariate-adjustment that included total energy intake and physical activity, there was no independent association of eating frequency (defined as the sum of all energy-contributing eating episodes in a 24-h recall) at baseline and prospective weight change over 10 y (9). Similarly, there was no relationship between eating frequency at follow-up determined from a questionnaire and weight change over preceding 10 y of follow-up (9). However, for men in the Health Professionals Study, eating frequency, determined from questions about 8 possible eating episodes in a day, predicted an increased risk of weight gain of ≥5 kg over 10 y (32). The multivariate analyses were adjusted for physical activity but not total energy intake. Both the published prospective studies of association of eating frequency with weight change in children examined prepubertal/pubertal girls but used a different definition of eating frequency and reported contradictory findings (33,34). Eating frequency of 4–5.9 occasions/d (but not 0–3.9) relative to ≥6, estimated from 7-d diet records, was associated with a smaller increase in BMI Z scores over a median of 6 y of follow-up (33). Conversely, in the National Heart, Lung, and Blood Institute's Growth and Health Study cohort of >2000 girls, baseline frequencies of 1–3, 3.1–4, and 4.1–6 eating episodes relative to >6 /d were associated with a larger increase in BMI at 10 y of followup (34).

Controlled Trials of Manipulation of Eating Frequency and Change in Body Weight

Metabolic unit studies involving controlled feeding of diets of known composition. We identified 6 controlled trials of 6-d to 8-wk duration in which adult subjects consumed diets of known nutrient and energy composition with varying frequency of eating (35–40). Four of the trials used randomized assignment (37–40), but all were crossover, in which subjects served as their own controls. In 3 of these trials, subjects were overweight or obese and the diets

TABLE 1 Prospective cohort studies of eating frequency and change in body weight

Authors, year (reference)	Population studied; baseline characteristics	Length of followup	Baseline diet assessment method	Measure of eating frequency	Outcome measure	Results: Multivariate adjusted
Kant et al., 1995 (9)	7147 men and women; 27–74 y mean BMI ~25.6	~10 y	Baseline:24-h recall at baseline Followup: 1 question each on number of meals and snacks/d	All unique eating episodes based on clock time	Weight change	No association in either gender Adjusted for race/ethnicity, length of followup, education, baseline BMI, energy intake, physical activity at baseline and followup, special diet status, morbidity, alcohol intake, smoking status, parity (women)
Van der Heijdan et al., 2007 (32)	20,064 men health professional; 40–75 y mean BMI ~25.8	10 y	8 categories of eating occasions	3, 4, or ≥5 eating occasions From predefined meal/snack categories in the questionnaire	Weight gain of ≥5 kg	Higher risk of weight gain with higher eating frequency ($P < 0.001$) Adjusted for age, working status, baseline BMI, smoking status, physical activity, alcohol intake
Thompson et al., 2006 (33)	101 girls; 8–12 y BMI for age percentile < 85	6 y (median)	7-d diet records	Number of eating episodes (grouped as 0–3.9, 4–5.9, ≥6) Eating episodes reported at least 15 min apart	Change in BMI Z-score	Smaller increase in BMI Z-score with 4–5.9 episodes relative to ≥6; frequency of 0–3.9 occasions did not differ from ≥6 Adjusted for baseline BMI. Eliminated parental income and education, race, parental BMI, physical activity, length of followup, age as NS through stepwise regression.
Ritchie, 2012 (34)	2372 girls; 9–10 y mean BMI ~18.6	10 y	3-d diet records for 2 y	Number of eating episodes (grouped as 1–3, 3.1–4, 4.1–6, ≥6/d) All unique eating episodes based on clock time.	Change in BMI	Inverse association of eating frequency at baseline with BMI change at followup ($P < 0.013$). Smallest increase in BMI in the >6 eating episode group relative to other frequencies of eating. Adjusted for baseline BMI, race, parental education, physical activity, TV viewing, total energy intake, and dieting for weight loss

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TABLE 2 Controlled trials of manipulation of eating frequency and weight change[1]

Authors, year (reference), design	Subject details N, age, weight	Intervention eating frequencies	Hypoenergetic or euenergetic	Length of intervention	Weight change difference between treatments	Comment
Controlled feeding studies with manipulated eating frequency						
Bortz, et al., 1966 (35) Crossover (nonrandomized)	$n = 6$; women 19–56 y obese	3, 1, or 9 occasions	Hypoenergetic (600 kcal/d) Liquid diet	17–24 d each treatment	NS	Energy divided equally into different occasions
Swindells et al., 1968 (36) Crossover (nonrandomized)	$n = 6$; women 19–38 y mean BMI = 23.1	3, 2, or 9 occasions	Euenergetic-based on calculated need Meat loaf, ice cream, tea, coffee, OJ	6 d each treatment	NS	Energy divided equally into different occasions
Young et al., 1971 (37) Crossover (randomized)	$n = 11$; men 20–23 y mean weight "68% over the metropolitan standard for height"	6, 3, 1 occasions	Hypoenergetic 1800 kcal/d 2-d rotating menu	35 d each treatment	NS	Energy divided equally into different occasions
Garrow et al., 1981 (38) Crossover (randomized)	$n = 14$; women mean age = 41 y mean BMI = 37.7	5 or 1 occasion	Hypoenergetic ~800 kcal/d	1 wk each treatment	NS	5 occasions with 13–25% of daily energy each
Johnstone et al., 1998 (39) Crossover (randomized)	$n = 8$; men mean age = 27.3 y mean BMI = 24.1	3 meals vs. meals +3 mandatory snacks	Euenergetic 3-d rotating menu of 10 items	1 wk each treatment	NS	Energy intake did not differ between the no snack and mandatory snack frequencies; 30% as mandatory snacks in the snack treatment
Stote et al., 2007 (40) Crossover (randomized)	$n = 15$ (5 men, 10 women) mean age = 45 y mean BMI = 23.4	1 meal vs. 3 meals	Euenergetic food provided by metabolic kitchen with on-site consumption of 1 meal/d 7-d rotating menu	8 wk each treatment	Weight in 1 meal/d 1.4 kg lower than 3 meal ($P < 0.01$)	Hunger, desire to eat higher and feeling of fullness lower on the 1 meal/d treatment Energy intake 65 kcal lower/d on 1 meal/d ($P < 0.01$)
Controlled trials using counseling for modification of eating frequency of self-selected diets						
Arnold et al., 1993 (41) Crossover randomized	$n = 19$ (10 men, 9 women) mean age 32.1 y mean BMI = 23.1	3 meals + 1/2 snacks or 9 meals	Euenergetic	2 wk	NS	NS difference in energy intake between treatments
Verboeket et al., 1993 (42) Randomized	$n = 14$ women 7/treatment 20–58 y; mean BMI = 30.2	2 (lunch + dinner) or 3–5 (mean 4.2)	Hypoenergetic ~1000 kcal/d	4 wk	NS	NS difference in energy intake, sleeping metabolic rate, or 24-h energy expenditure between treatments.
Poston et al., 2005 (43) Block randomization by baseline snacking status	$n = 100$ (24 men, 76 women) (50/treatment) 35–55 y; mean BMI~32	Meal replacement with Slim Fast (no snacks) or meal replacement with Slim Fast + snacks	Hypoenergetic 1200 kcal for women 1500 kcal for men	24 wk	NS	Attrition rate = 50% Differences in energy intake between treatments not reported

(Continued)

TABLE 2 *(Continued)*

Authors, year (reference), design	Subject details N, age, weight	Intervention eating frequencies	Hypoenergetic or euenergetic	Length of intervention	Weight change difference between treatments	Comment
Bertéus-Forslund et al., 2008 (44) Randomized	*n* = 140 (36 men 104 women) 70/treatment 18–60 y; mean BMI = 39	3 meals or 3 meals + 3 snacks	Hypoenergetic (individualized)	52 wk	NS	Attrition rate = 30% in 3 meals and 37% in 3 meals + 3 snacks NS difference in energy intake between treatments
Cameron et al., 2010 (45) Block randomization based on gender	*n* = 18 (9 men and 9 women) 18–55 y; mean BMI = 37	3 meals or 3 meals + 3 snacks	Hypoenergetic (individualized)	8 wk	NS	Attrition rate = 11%; NS effect of meal frequency effect on appetite and gut peptides Differences in energy intake between treatments not reported
Bachman and Raynor. 2012 (46) Randomized	*n* = 51 (57.8% female) 25 in 3 meals and 26 in grazing treatment mean age = 51.0 y; mean BMI = 35.5	3 meals or grazing (counseled to eat minimum of 100 kcal every 2–3 h)	Hypoenergetic 1200 kcal for those <200 lb 1500 kcal for those with >200 lb	6 mo	NS	Attrition rate = 12–16%; NS differences in energy intake between treatments Self-reported hunger was lower in the grazing group

[1] NS, not significant ($P > 0.05$); OJ, orange juice.

were hypoenergetic (35,37,38); in the other 3 trials, subjects with weight within the acceptable range consumed euenergetic diets (36,39,40). The eating frequencies manipulated included 1, 3, 5, 6, and 9 occasions. The body weight changes were not significantly different among eating frequency interventions in all trials employing frequencies of ≥3 (35–39). In the trial by Stote et al. (40), there was significantly greater weight loss after 8 wk of 1 meal/d treatment (loss of 0.6 kg) relative to 8 wk of 3 meals/d regimen (gain of 0.8 kg).

Controlled trials using counseling for modification of eating frequency of self-selected diets. Six trials that used counseling to modify eating frequency of self-selected diets were identified (41–46). In 5 of these trials, obese subjects (mean BMI > 30) were prescribed hypoenergetic diets and randomly assigned to eating frequency treatments lasting for 8–52 wk (42–46). One studied only women (42) but the other 5 trials included both genders (41,43–46). The eating frequencies examined included 2 vs. 3–5; meal replacements with and without snacks; 3 meals vs. 3 meals + 3 snacks; 3 meals vs. >100 kcal every 2–3 h; and 3 meals + 1or 2 snacks vs. 9 meals. Attrition rates were 11–12% for trials that lasted 8–24 wk; 50% with the meal replacement ± snacks trial over 24 wk; and 30–37% for the 1-y trial. Weight loss occurred in all treatments in 5 trials (42–46); however, eating frequency treatment effects were not significant in any of the trials. Moreover, 4 of these trials found no significant difference in reported energy intake between frequency treatments (41,43,45,46) [the other 2 trials did not report energy intakes (42,44)].

The theoretic basis for the putative role of eating frequency in weight management is 2-fold. The first argument is older and postulated that frequent eating may increase energy expenditure due to the thermogenic effect of frequent ingestion of nutrients. As discussed by Bellisle and colleagues (3,4), the experimental evidence for a metabolic advantage due to diet-induced thermogenesis, higher resting metabolic rate, and higher energy expenditure due to frequent eating is not supportive of this hypothesis. The second argument posits that frequent eating may relate to the energy intake side of the energy balance equation by decreasing hunger and increasing satiety, with subsequent lower downstream energy intake. Leidy and Campbell (7), in a recent review of the limited evidence from controlled trials that examined hunger and satiety response to changes in eating frequency over the course of a day, concluded that there were few differences in these parameters. Moreover, 2 recent studies have reported that changes in the concentrations (area under the curve) of the peptides ghrelin and PYY in response to manipulation of eating frequency were not significantly different (47,48). However, 2 randomized crossover controlled feeding studies have found self-described hunger to be greater when eating frequency was reduced from 3 occasions to 1 or 2 (41,49). Another recent study also reported lower self-reported hunger rating, but not lower energy intake, in the group counseled to eat ≥100 kcal every 2–3 h relative to the 3 meals/d treatment (46).

Conclusions

The published randomized controlled trials with manipulation of eating frequency ranging from 1 wk to 1 y for promoting weight loss have consistently yielded null findings. Moreover, in trials that reported energy intakes, higher eating frequency was not accompanied by lower energy intakes. The quality of the studies and the consistency of the null findings suggest that higher eating frequency is not independently effective in adult weight management. It is noteworthy that in the controlled trials reviewed above, subjects varied their eating frequency within the constraints of the energy intake prescription. Given the current food environment of abundant and affordable foods of high-energy density and the consistently observed positive association of eating frequency with energy intake, it is unlikely that free living individuals increase their eating frequency without increasing energy intake. While it is unlikely that any 1 recommendation on eating frequency will be universally applicable, the most useful dietary advice regarding weight management for adults may be to focus on energy intake rather than eating frequency.

Future Directions

There is considerable variation in the definition of eating frequency in the published literature. We know little about the consequences of these definitional differences for estimated frequency or its metabolic correlates. The evidence base for the impact of systematic errors (due to biased dietary reporting) on estimation of eating frequency is limited (6,21,22). Random error due to day-to-day variability in eating frequency has been examined in just 1 report (50) and is also likely to differ by the method of dietary assessment and the definition of eating frequency. Greater understanding of these errors can help in a more nuanced interpretation of results of observational studies. The evidence base for evaluation of efficacy and effectiveness of eating frequency for weight management in children and adolescents is nonexistent. Both prospective cohort studies and controlled trials on the subject are indicated. There is evidence of tracking of childhood dietary behaviors to adult years (51), whether this applies to frequency of eating is not known.

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