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Symposium—Eating Patterns and Energy Balance: A Look at Eating Frequency, Snacking, and Breakfast Omission

The Effect of Eating Frequency on Appetite Control and Food Intake: Brief Synopsis of Controlled Feeding Studies[1,2]

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Abstract

Increased eating frequency is postulated to increase metabolism, reduce hunger, improve glucose and insulin control, and reduce body weight, making it an enticing dietary strategy for weight loss and/or the maintenance of a healthy body weight. Because past research has primarily focused on the effects of eating frequency on changes in energy expenditure and body weight, limited data exist surrounding the impact of eating frequency on appetite control and energy intake. We provide a brief review of the controlled-feeding studies that primarily targeted the appetitive, hormonal, and food intake responses potentially altered with eating frequency. The 3 meal/d pattern served as the reference for defining increased or reduced eating frequency. In general, increased eating frequency led to lower peaks ($P < 0.05$) in perceived appetite, satiety, glucose, insulin, ghrelin, and PYY responses compared with reduced eating frequency. However, when examining these responses over the course of the day (i.e. using area under the curve assessments), no differences in any of these outcomes were observed. The rate of gastric emptying also appears to be unaltered with increased eating frequency. Subsequent food intake was examined in several studies with conflicting results. Regarding the effect of reduced eating frequency, several studies indicate significant increases in perceived appetite and reductions in perceived satiety when 1 or 2 meals were eliminated from the daily diet. Taken together, these findings suggest that increased eating frequency (>3 eating occasions/d) has minimal, if any, impact on appetite control and food intake, whereas reduced eating frequency (<3 eating occasions/d) negatively effects appetite control. J. Nutr. 141: 154S–157S, 2011.

Background

Eating frequency has become a fundamental component of most weight loss diets (1). Many of the current dietary plans have replaced the historical dietary recommendation to eat 3 large meals/d with a more frequent eating strategy that includes consuming smaller amounts of food every 2–3 h, 4–6 times/d. According to the NHANES III, 1999–2000, ~80% of all Americans eat at least 4 times/d, with an average eating frequency of 5 eating occasions/d (2,3). Although it is unclear as to why many Americans have adopted this approach, increased eating frequency has been postulated to increase metabolism, reduce hunger and food cravings, improve glucose and insulin control, and reduce body weight and body fat storage, making it an enticing dietary strategy for weight loss and/or the maintenance of a healthy body weight (1). Alternately, in the current obesogenic environment, eating more frequently might actually lead to an increased exposure to energy-dense, large-portion–size foods, resulting in the opposite effect (i.e. increased hunger, excess energy intake, and unhealthy body weight gain). Based on this rationale, several alternative dietary plans have advocated the reduction in the number of eating occasions, including the elimination of breakfast or dinner as potential weight loss strategies.

Numerous epidemiological studies have identified a strong inverse relationship between eating frequency, body weight (percent overweight), and obesity (4–7). However, randomized, controlled-feeding intervention trials do not support these findings. In a recent review article, Palmer et al. (8) examined 176 abstracts and/or articles containing nutritional weight maintenance and weight loss interventions from 1980 to the present (8). The studies reviewed contained varying eating

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[3] 1 kcal = 4.184 kJ.

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frequencies ranging from 1 to 9 eating occasions/d and included intervention periods of 2–8 wk in duration. Collectively, no differences in body weight and weight loss were observed when varying eating frequency within the weight maintenance and weight loss studies, respectively. Because many of these studies were of short duration (2–4 wk) with small sample sizes (7–19 participants), it is difficult to discern whether eating frequency did not affect body weight management or whether subtle changes in energy regulation occurred but were undetected due to the limitations of the previously mentioned studies.

Until recently, most of the research surrounding the topic of eating frequency and energy regulation had exclusively focused on the potential changes in energy expenditure. As indicated in the comprehensive review by Bellisle (6) as well as more recent studies of 24-h energy expenditure using chamber calorimetry (9,10), eating frequency appears to have no effect on total (daily) energy expenditure. As a result, researchers are currently focusing their attention on the other side of the energy balance equation by examining the impact of eating frequency on the factors involved with the regulation of energy intake.

Due to the substantial number of physiological (11,12), behavioral (13,14), and sociological (15) factors that play a critical role in ingestive behavior and the regulation of food intake, we recognize the difficulty in developing conclusions and recommendations for eating frequency. However, one strategy to control and/or eliminate the impact of many of these factors involves the use of controlled feeding studies, which provide individual foods, eating occasions, and/or total diets at specific times and quantities in a laboratory setting. Thus, this article, which is based on the presentation given at the 2009 Experimental Biology Symposium session entitled "Eating Patterns and Energy Balance: A Look at Eating Frequency, Snacking, and Breakfast Omission," will provide a brief synopsis of the current controlled-feeding studies that examine the effects of eating frequency on appetite control and food intake and will attempt to answer the following questions: *1*) Does increased eating frequency improve appetite control and subsequently reduce energy intake? and *2*) Does the reduction in eating frequency negatively influence these outcomes?

Terminology and consideration of study outcomes

Given the lack of a universal definition differentiating meals, mini-meals, and snacks, we decided to use the term 'eating occasion' to signify any instance in which food or caloric beverages were consumed. To compare findings across studies, we arbitrarily assigned the 3 eating occasions/d pattern as the reference for eating frequency. Any patterns containing >3 eating occasions/d were identified as increased eating frequency, whereas anything <3 eating occasions/d was considered reduced eating frequency.

Appetite is generally described as the desire to consume food and is experienced as perceived hunger, desire to eat, urge to eat, and/or prospective food intake. Alternately, satiety is the feeling of being satisfactorily full and unable to eat any more food. Therefore, appetite control is the summation of the perceived appetite and satiety sensations that ultimately lead to whether food is or is not consumed. Appetite control is typically quantified in several ways. The first involves the assessment of the previously mentioned perceived sensations through the use of visual analogue scale questionnaires of "how strong is your feeling of ...." (16) or indirectly by measuring subsequent energy intake. Another approach involves the examination of key appetite-suppressing and appetite-stimulating gastrointestinal hormones that are secreted in response to energy intake (17–19). Lastly, gastric emptying (specifically gastric motility) has been reported as another mechanism affecting appetite control (20). Throughout this article, each of these outcomes will be presented in relation to eating frequency.

Does increased eating frequency improve appetite control and subsequently reduce energy intake?

One approach in identifying the effect of increased eating frequency on appetite control and energy intake includes the comparison of perceived appetite and satiety sensations, hormonal responses, and subsequent energy intake following the consumption of food provided as either a single eating occasion compared with equally divided among multiple eating occasions. Speechly et al. (21) incorporated this type of experimental design. A morning breakfast containing ~33% (~1000 kcal)[3] of daily energy intake was provided as a single eating occasion or divided equally every hour throughout the morning (identified as frequent feeding). Perceived appetite sensations (consisting of hunger, prospective food consumption, and urge to eat) along with plasma glucose and insulin responses were measured throughout the morning hours followed by a lunch that was consumed ad libitum. The single eating occasion led to immediate (+15 min postprandial) reductions in perceived appetite, glucose, and insulin responses followed by a gradual rise toward baseline throughout the 5-h period, whereas the frequent feeding trial led to attenuated responses. Immediately prior to the ad libitum lunch, the single eating occasion led to a greater peak in perceived appetite with no differences in glucose or insulin responses compared with frequent feeding ($P < 0.05$) (21). When assessing the outcomes across the morning hours [using area under the curve (AUC) of the 5-h period], glucose AUC was higher ($P < 0.05$) following the single compared with frequent feeding patterns, whereas 5-h perceived appetite and insulin AUC responses did not differ following the single compared with frequent feeding patterns. During the lunch, which participants consumed ad libitum, energy intake was 27% greater after the single eating occasion (1220 ± 360 kcal) than after frequent feeding (900 ± 210 kcal).

In a similar study involving 16 healthy men, Jackson et al. (22) examined the effects of 2 large breakfast eating occasions (containing 43% of daily energy intake; ~1870 kcal) separated by 3 h compared with equally dividing the food among 6 eating occasions consumed every hour. Perceived appetite sensations (comprised of hunger, desire to eat, and prospective food consumption) and perceived satiety sensations (assessing feelings of fullness) were assessed throughout the morning and afternoon (22). Gastric emptying was also measured throughout the afternoon. It has been proposed that frequent feeding prolongs gastric emptying, which increases the exposure of food in the gut and thus increases satiety (22). Contrary to the previous findings, the infrequent eating pattern (2 eating occasions) led to greater reductions in perceived appetite throughout the morning (i.e. 3-h AUC) ($P < 0.05$) and greater increases in perceived satiety (3-h AUC) ($P < 0.05$) compared with the frequent eating pattern (6 eating occasions) (22). These differences were no longer apparent later in the afternoon (22). Similar to the perceived appetite and satiety sensations in the afternoon, the rate of gastric emptying was unaffected by eating frequency.

Unlike the previous studies that included only morning and afternoon assessments, Solomon et al. (23) extended the findings to include increased eating frequency throughout an entire day. Five healthy men followed either a 2-eating occasion/d pattern, separated by 4 h, or 12 eating occasions consumed every 40 min.

Plasma glucose, insulin, and ghrelin concentrations were assessed throughout an 8-h period (23). The 2 eating occasion/d pattern led to greater fluctuations in glucose, insulin, and ghrelin responses (i.e. greater peaks and lower troughs; $P < 0.05$) compared with the 12-eating occasion/d pattern (23). Overall AUC did not differ (23). Even though the previous studies examined the impact of frequent compared with infrequent eating, it is important to remember that eating frequencies at this quantity are beyond what could realistically be followed in daily living and thus provide limited information when developing appropriate dietary recommendations.

The overall message in the mainstream media proposes a more moderate eating frequency of eating 6 times/d. Taylor et al. (9) completed a study in which 8 overweight or obese women were provided with a reduced energy diet of 1000 kcal and asked to consume this in 2 eating occasions (every 8 h) or 6 eating occasions (every 2 h). In addition to the 1000-kcal diet, the participants were given free access to a wide range of food items to consume ad libitum (9). This approach allowed for the unique assessment of free-feeding energy intake within the confines of a strict controlled feeding setting. The 2-eating occasion/d strategy led to a total energy intake of 2565 kcal, which did not differ from the 6-eating occasion strategy (2646 kcal; $P = 0.58$, nonsignificant). Two limitations exist with this study design making the overall findings difficult to interpret: *1*) the prescribed reduced energy content provided during each dietary pattern potentially triggered the drive to consume additional food items irrespective of eating frequency; and *2*) in conjunction with the previous issue, the ad libitum access to foods altered the distinctiveness of the 2-eating occasion/d pattern by allowing the participants to eat in addition to the prescribed eating occasion time points.

We recently completed a study involving 13 overweight or obese men who habitually ate 3 times/d (24). On separate days, each individual randomly consumed a eucaloric diet of ~2100 kcal divided among 3 eating occasions (provided every 4 h) or 6 eating occasions (provided every 2 h). Perceived appetite (i.e. perceived hunger), perceived satiety (i.e. perceived fullness), plasma glucose, and hormonal responses were assessed throughout 10 h. Whereas both eating frequencies led to eating-related oscillations in perceived appetite, perceived satiety, and hormonal responses, the 6-eating occasion pattern led to attenuated responses. When assessing the overall 10-h AUC, perceived appetite and perceived satiety did not differ. The 10-h AUC glucose response was 30% lower (P-trend = 0.08) and the insulin response was 20% lower ($P < 0.05$) following the 6- compared with 3-eating occasion pattern. No differences in the 10-h AUC responses for the appetite-stimulating hormone ghrelin and the satiety hormone PYY were detected.

Within the context of obesity prevention and treatment, these data suggest only minimal, if any, improvements in appetite control through alterations in perceived appetite, perceived satiety, hormonal responses, and/or gastric emptying with increased eating frequency. One thing to consider is the attenuation in perceived appetite and hormonal peaks and troughs observed with frequent eating occasions. Because the peak in appetite has been documented to occur with voluntary meal request (25), it is plausible that the attenuated responses observed with increased eating frequency might delay or reduce the motivation to eat and subsequently reduce energy intake regardless of the overall (AUC) response.

Another point to consider when interpreting the study findings includes the energy level of the study diets and resulting meals. In the current studies, prescribed daily energy content varied from feeding below basal energy needs (i.e. energy restriction) to meeting (i.e. eucaloric) total estimated energy requirements. The size of the eating occasion also ranged from 170 to 2400 kcal, depending upon the eating frequency pattern. By default, as the number of eating occasions increase, the energy content of each occasion is reduced. Thus, the quantity of food provided during increased eating frequencies in eucaloric states was 350 kcal, whereas those in an energy-restrictive state were as low as 170 kcal. Several studies have shown that smaller eating occasions have little to no effect on perceived appetite, hormonal responses, or subsequent food intake (26,27), whereas larger meals of ≥400 kcal lead to significant changes in postprandial responses (28,29). The differential responses between smaller and larger eating occasions may simply be due to the inability of the body to detect the size of a smaller eating occasion as an adequate physiological load, reducing or eliminating the eating-related responses typically observed when larger eating occasions occur. However, further research is needed to establish the quantity of food consumption required to elicit the eating-related reductions in the appetitive and hormonal responses.

Does the reduction in eating frequency negatively influence appetite control and food intake?

Another critical aspect of eating frequency involves the other end of the eating frequency spectrum (i.e. reduced eating occasions of <3 eating occasions/d). In examining the lower range of eating frequency, 2 studies have been published that either remove 1 eating occasion (i.e. lunch) (10) or 2 eating occasions (i.e. breakfast and lunch) (30). According to Smeets et al. (10), 14 healthy females were provided with 2200 kcal as either 2 eating occasions (i.e. breakfast and dinner) or 3 eating occasions (breakfast, lunch, and dinner). While the previously described studies equally divide the daily intake among all eating occasions, this study provided 30% of the energy content at breakfast during both eating frequency trials. In the 2-eating occasion pattern, the remainder of the energy intake (70%) was provided at dinner, whereas the 3-eating occasion pattern included the additional 20% of energy intake at lunch with the remaining 50% given at dinner. Perceived satiety (comprised of feelings of fullness) was assessed before and after each eating occasion as well as the following morning. When comparing the 24-h AUC satiety responses, the 3-eating occasion pattern led to greater feelings of satiety (~15%) than the 2-eating occasion pattern ($P < 0.05$). Upon closer examination of the overall profile, no differences between these treatments were evident during the morning, evening, and subsequent morning responses. Thus, the difference occurred during the midday to afternoon time period when lunch was provided or skipped.

In another study by Stote et al. (30), 15 healthy adults completed 8 wk of eating all of their dietary energy (2400 kcal) as either a single eating occasion at dinner or equally divided amount breakfast, lunch, and dinner. Throughout each of the 8-wk periods, perceived appetite (consisting of hunger, desire to eat, and prospective food consumption) and satiety (consisting of feelings of fullness) were assessed prior to each dinner eating occasion. Predinner perceived appetite was significantly higher and predinner perceived fullness was lower following the 1- compared with 3-eating occasion/d pattern ($P < 0.05$). The differential response occurred ~10 d into the intervention and continued throughout the 8-wk period. Based on these studies, the reduction in eating frequency (<3 eating occasions/d) appears to negatively influence appetite control.

One thing to consider with this assessment is the idea that the changes in perceived appetite and/or food intake with reduced eating frequency may be influenced by which particular eating

occasion is omitted. For example, whereas 1 study omitted lunch (31), others have removed breakfast, lunch, or dinner (10,30,32). Because some data suggest that breakfast may elicit a more positive impact on appetite control (33), different responses may result depending on which eating occasion(s) is/are being targeted.

Summary

The controlled feeding studies presented throughout this article indicate minimal to no improvements in appetite control and the regulation of food intake with increased eating frequency beyond the typical 3-meal/d pattern. Alternately, reduced eating frequency (i.e. <3 meals/d) appears to negatively affect appetite control. Based on these studies, the claims in the mainstream media of reduced hunger and improved glucose and insulin control with increased eating frequency are unsubstantiated. However, the limited number of published studies surrounding this topic makes it difficult to develop an overall consensus regarding the influence of eating frequency on appetite control. Future studies involving longer-term interventions of 6 mo to 1 y, larger sample sizes to increase generalizability, and comprehensive outcomes involved with appetite control including, but not limited to, perceived appetite sensations, appetite-regulating gastrointestinal hormones, gastric emptying, and brain activation patterns are warranted to truly identify the role of eating frequency in the regulation of energy intake in adults.

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