Eating Frequency and Energy Regulation in Free-Living Adults Consuming Self-Selected Diets¹–³

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Abstract
The relative importance of eating frequency to weight control is poorly understood. This review examines the evidence to date on the role of eating frequency in weight control in free-living adults. The majority of cross-sectional studies in free-living adults show an inverse relationship between eating frequency and adiposity; however, this is likely an artifact produced by the underreporting of eating frequency concurrent with underreporting of energy intake. When implausible energy intake reporting (which is mostly underreporting) is taken into account, the association between eating frequency and adiposity becomes positive. In studies in which eating frequency is prescribed and food intake is mostly self-selected, there is either no effect or a minor positive effect of eating frequency on energy intake. Most of those studies have been short-term and lack the necessary dietary biomarkers to validate reported energy intakes and eating frequencies. In conclusion, there is some suggestion from cross-sectional studies in which energy intake underreporting is taken into account and from experimental studies to date that greater eating frequency may promote positive energy balance. However, experimental studies of longer-term duration that include objective dietary biomarkers are necessary before firm conclusions about the relative importance of eating frequency in weight control can be made. J. Nutr. 141: 148S–153S, 2011.

There has been much speculation in the scientific literature as to the optimal pattern and timing of eating throughout a day for health (1–4). Despite many years of research on this topic, there is no consensus as to the relative importance of eating frequency in weight control (5). Here, we define eating frequency as the number of times per day one eats, regardless of whether that eating occasion is designated as a meal or snack. As Leidy et al. (6) point out, the popular press is full of advice advocating several small meals throughout a day as the preferred eating pattern for weight control and sometimes the descriptor “small” is even omitted. However, as reviewed below, the scientific basis for such advice is questionable. Leidy et al. (6) have reviewed studies on eating frequency in controlled trials where food is provided. In this manuscript, we summarize the research on studies of eating frequency and energy regulation in free-living adults consuming self-selected diets to draw attention to recurring methodological shortcomings that need to be addressed in future studies.

Summary of cross-sectional studies on eating frequency and adiposity in adults
One of the earliest studies on the relationships of eating frequency with adiposity and other biomarkers of chronic disease risk in adults was that by Fabry et al. (7) in 1964. In 379 men aged 60–64 y, they observed an inverse relation between reported eating frequency and the prevalence of excess adiposity and increasing prevalence of individual risk factors for chronic disease such as poor glycemic control and high blood cholesterol (Fig. 1). The authors speculated that the ability to overeat at single eating occasions and build body energy reserves, rapidly absorb glucose, and efficiently undergo lipogenesis was useful in prehistory when food intake was more intermittent compared with modern times. However, in today’s world where food is most often widely available, having such a physiological adaptation is detrimental to health.

Since Fabry et al.’s (7) work, many other investigators have gone on to show similar results in cross-sectional studies. A brief summary of the results of the 19 cross-sectional studies (20
analyses in adults published to date (Table 1) shows that the majority of investigators have found an inverse relationship between reported eating frequency and adiposity. Sixteen of the 20 analyses conducted showed that individuals who reported eating more frequently were leaner than those who reported eating less frequently; in 10 of the 16 analyses the relationship was significant. On the other hand, 4 of the 20 relationships were positive (3 of the 4 were significant). In those studies, eating frequency was measured by a number of methods (questionnaire, dietary recording, 24-h recalls) as was adiposity, and about one-half of the studies had generous sample sizes (exceeding n = 2000). Thus, on the surface there would appear to be a solid relationship between eating more frequently and maintaining normal body weight status, and that, pending the support of experimental studies, the advice to eat more frequently for better weight control might be well-founded.

**The problem of underreporting of energy intake**

It is widely accepted that most dietary assessment methodology is subject to reporting bias and that this bias is mainly in the direction of underreporting rather than overreporting (8,9). Therefore, a crucial problem contributing to most of the studies reviewed in Table 1 is that many individuals underreported their energy intake relative to energy requirements. First shown by Bellisle et al. (2) in 1997, the greater the magnitude of underreporting of energy intake, the less frequently the participants also reported eating. Therefore, the apparent inverse relation between eating frequency and adiposity in most studies is likely an artifact and in large part can be attributed to the underreporting of eating frequency concomitant with the underreporting of energy intake. The impact of energy intake underreporting on observed relationships between eating frequency and BMI is illustrated further in some of our own work reported previously (10), as shown in Table 1 and Figure 2. In that analysis of ~6500 adult participants in the Continuing Survey of Food Intakes by Individuals (CSFII) 1994–96, we calculated reported eating frequency and energy intake from the average of 2 multiple-pass, 24-h dietary recalls. We identified implausible energy intake reporters using an objective methodological system in which energy intake is compared with energy requirements, allowing for error and normal biological variation in both measures, as detailed previously (10–12). When we analyzed the plausibly reporting subsample separate from the total sample, the relationship (regression coefficient) between reported eating frequency and BMI moved from nonsignificant and inverse to significant and positive (Table 1; Fig. 2). In addition, although the relationship between reported eating frequency and energy intake was significant and positive in the total sample, the magnitude of the coefficient was dramatically higher and reached a much higher level of significance in the plausibly reporting subsample.

To examine the impact of energy intake reporting plausibility on trends over time of total eating frequency in the United States (Fig. 3A,B), we extended our analysis of plausibly reporting

![FIGURE 1](image1.png)

**FIGURE 1** Meal frequency in relation to overweight, hypercholesterolemia, and glucose tolerance in 379 men aged 60–64 y. Within a variable, P-values indicate significant differences among eating frequency groups according to Student’s t test. Adapted with permission from (7).

**TABLE 1** Cross-sectional studies on eating frequency and adiposity in adults

<table>
<thead>
<tr>
<th>1st Author (year) (reference)</th>
<th>n</th>
<th>Association²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabry (1964) (7)</td>
<td>379</td>
<td>—</td>
</tr>
<tr>
<td>Metzner (1977) (26)</td>
<td>2028</td>
<td>—</td>
</tr>
<tr>
<td>Charzewska (1981) (27)</td>
<td>896</td>
<td>—</td>
</tr>
<tr>
<td>Dreon (1988) (28)</td>
<td>155</td>
<td>NS</td>
</tr>
<tr>
<td>Edelstein (1992) (29)</td>
<td>2034</td>
<td>NS</td>
</tr>
<tr>
<td>Kant (1995) (30)</td>
<td>7147</td>
<td>—</td>
</tr>
<tr>
<td>Summerbell (1996) (31)</td>
<td>187</td>
<td>NS</td>
</tr>
<tr>
<td>Drummond (1998) (32)</td>
<td>95</td>
<td>(men)³ + NS (women)</td>
</tr>
<tr>
<td>Ortega (1998) (33)</td>
<td>150</td>
<td>—</td>
</tr>
<tr>
<td>Whalqvist (1999) (34)</td>
<td>293</td>
<td>—</td>
</tr>
<tr>
<td>Amosa (2001) (35)</td>
<td>82</td>
<td>NS</td>
</tr>
<tr>
<td>Titan (2001) (36)</td>
<td>14,866</td>
<td>—</td>
</tr>
<tr>
<td>Berteus Forslund (2002) (37)</td>
<td>177</td>
<td>⁴</td>
</tr>
<tr>
<td>Ruidavets (2002) (38)</td>
<td>2002</td>
<td>—</td>
</tr>
<tr>
<td>Ma (2003) (39)</td>
<td>499</td>
<td>—</td>
</tr>
<tr>
<td>Forslund (2005) (40)</td>
<td>4259</td>
<td>⁴</td>
</tr>
<tr>
<td>Huang (2005) (10)</td>
<td>6499</td>
<td>NS (total sample)</td>
</tr>
<tr>
<td>Huang (2005) (10)</td>
<td>2685</td>
<td>⁴ (plausible subsample)¹</td>
</tr>
<tr>
<td>Berg (2009) (41)</td>
<td>3610</td>
<td>NS</td>
</tr>
</tbody>
</table>

¹ The plausible subsample is the group of individuals remaining after excluding implausible energy intake reporters (10, 12).
² NS, Nonsignificant association, P > 0.05.
³ Significant negative association, P ≤ 0.05.
⁴ Significant positive association, P ≤ 0.05.

![FIGURE 2](image2.png)

**FIGURE 2** β-Coefficients for regressions of BMI on reported energy intake and eating frequency in adults aged 20–90 y participating in the CSFII 1994–96. Shown are results from the total sample (n = 6499) and the plausible subsample (n = 2685 using 1.0 SD for the plausibility cutoff). β-Coefficients significantly differ from 0: * P < 0.05; ‡ P < 0.001. Adapted with permission from (10).
compared with total samples of adults participating in CSFII 1994–96 (13) and applied the same statistical methodology to 2 previously conducted surveys, the Nationwide Food Consumption Survey (NFCS) 1977–78 (14), and the CSFII 1989–91 (15).

In that analysis, we also tallied main meals and snacks separately, using methodology described previously (10,16). As illustrated, analyses in the total samples (Fig. 3A) and the plausible subsamples (Fig. 3B) both indicate a secular trend toward an increase in the number of times per day adults were eating in that ~20-yr span. According to the analyses in the total samples, eating frequency increased by 0.5 times/d on average, from 3.8 to 4.3 times/d from 1977–78 to 1994–96. Importantly, the dietary methodology differed somewhat across the surveys. The 1994–96 survey utilized the multiple-pass 24-h dietary recall method, which may yield significantly higher reported intakes than the dietary recording but was designed to increase reported energy intake compared with nonmultiple pass, 24-h dietary recall methodology due to increased probing of the subject (17,18). Therefore, some or all of the increase in eating frequency could be due to this difference in methods used among surveys. However, the analysis in the plausible subsample also indicates a change in eating frequency over time by the same amount, 0.5 times/d, but shows a higher eating frequency at each time point. Note that the higher eating frequencies were entirely due to snacking and that meal frequency remained relatively consistent at 2.6–2.7 times/d. Thus, the 2 analyses together provide data to suggest that eating frequency may have been underestimated in the total sample at each time point, by 0.3–0.4 times/d, and that the underestimation could be entirely attributed to an underreporting of snack frequency regardless of the dietary methodology employed.

It is important to note that the underreporting of eating frequency does not preclude underreporting of other aspects of the diet that impact total energy intake, including portion consumed and energy density. In fact, Huang et al. (10,11) showed that all 3 factors, eating frequency, portion consumed, and energy density, may mediate underreported energy intake.

We further analyzed in more detail data from the CSFII 1994–96 to explore the relative contribution of energy intake in the 3 main meals and aggregated snacks to weight status using multiple regression (16). In that paper, we reported results exclusively from the plausible subsample, but herein we provide the results from the same analysis in the total sample as well and show a side-by-side comparison (Fig. 4). In the total sample (Fig. 4A), reported energy intake from lunch and dinner is significantly higher in overweight compared with normal-weight participants, but not in obese compared with overweight participants. Furthermore, there is no significant increase in energy intake from breakfasts or snacks from normal-weight to overweight to obese participants. Examining the results from the total sample alone may lead to the conclusion that individuals with increasing weight status generally consume higher amounts of energy from lunch and dinner but not from breakfasts or snacks. However, one should reach a different conclusion after also examining Fig. 4B, which shows the plausible subsample. That analysis shows that energy intake from all eating occasions, breakfast, lunch, dinner, and snacks, generally increases with increasing weight status, although again, significantly so from normal weight to overweight but not from overweight to obese. The results in the total sample suggest that energy intake from breakfasts and snacks are not importantly associated with BMI, yet the results in the plausible sample suggest that breakfast and snacks are just as importantly associated with BMI as are lunch and dinner. Comparing the results obtained in the total compared with plausible samples thus provides an indication that both breakfast and snacks may be underreported. The underreporting of breakfasts and snacks is consistent with numerous previous studies also suggesting a selective underreporting of foods and beverages high in fat and/or added sugar, because those types of foods may commonly be consumed at both types of eating occasions [e.g. sweet rolls, donuts, muffins, pancakes at breakfast; cookies, chips, candy bars at snacks (19)]. Objective biomarkers that can identify intake from individual eating occasions need to be developed to verify a selective underreporting of certain eating occasions that contribute to the overall underreporting of eating frequency.

**Prospective studies**

We are not aware of any published prospective studies in adults in which high compared with low eating frequencies are prescribed ad libitum, free-living energy intake conditions, and changes in energy intake and body weight are followed over time.

**Experimental studies**

Another type of study design to examine that should yield clues as to whether eating frequency has lasting effects on body weight is randomized intervention trials in which high and low eating frequencies are prescribed in self-selected diets for a period of

![FIGURE 3](https://example.com/figure3.png)

**FIGURE 3** U.S. trends in meal and snack frequencies in total samples (A) and ± 1.0 SD plausible subsamples (B) from the NFCS 1977–78 (14), the CSFII 1989–91 (15), and CSFII 1994–96 (13). Number of observations for total samples: NFCS 1997–78 (n = 13,750); CSFII 1989–91 (n = 2474); CSFII 1994–96 (n = 6412). Number of observations for plausible subsamples: NFCS 1997–78 (n = 6,29 using 1.65 SD for plausible cutoff); CSFII 1989–91 (n = 1164 using 1.3 SD for plausible cutoff); and CSFII 1994–96 (n = 3704 using 1.4 SD for plausibility cutoff).

![FIGURE 4](https://example.com/figure4.png)

**FIGURE 4** Energy intake from breakfast, lunch, dinner, and snacks (aggregate) in relation to weight status in 20–59 yr olds from the total sample (n = 6499) (A) and the plausible subsample (n = 2689) (B) from CSFII 1994–96 (13). Within each eating occasion, labeled means without a common letter differ, P ≤ 0.05.
Summary and future directions

In summary, the effects of eating frequency on energy regulation and body weight in free-living people consuming self-selected diets are still largely uncertain. Cross-sectional studies (7,10,26–41) suggest that eating frequency is positively associated with energy intake and body weight, after accounting for energy intake reporting plausibility; however, very few studies have examined the relationship between eating frequency and BMI with plausible dietary intake reporting. A prospective cohort study (21) showed a nonsignificant increase of 14.6 kJ/d (61 kcal/d) when participants were asked to eat 8 times a day compared with 3 times a day, and there was no significant change in body weight (20), with the participants losing slightly more weight when eating 6 times a day compared with eating 3 times a day. The difference was only 0.3 kg over a long period of time, so it could add up to a clinically important difference, e.g., 3.9 kg or 8.5 pounds in 1 year. However, in that study, the participants had self-selected the number of meals and snacks, whereas the other studies examined a prescribed eating frequency prescribed along with the eating frequency and goal. Therefore, additional randomized controlled trials that are longer term, in which intake is measured objectively, are needed to determine whether the minor influence of the higher eating frequency and body weight and studies of longer duration are necessary to determine the long-term effects of eating frequency on increased energy intake seen thus far. Stronger study designs testing both the higher and lower eating frequency conditions would determine whether the increased energy intake and body weight are significant. Cross-sectional studies (7,10,26–41) suggest that eating frequency is positively associated with energy intake and body weight, after accounting for energy intake reporting plausibility; however, very few studies have examined the relationship between eating frequency and BMI with plausible dietary intake reporting.

### Table 2: Eating frequency effects in prescribed, self-selected diets with a target isocaloric energy intake on body weight

<table>
<thead>
<tr>
<th>1st Author (year) (reference)</th>
<th>Design</th>
<th>Participants</th>
<th>Physiologic state</th>
<th>Low EF Goal</th>
<th>High EF Goal</th>
<th>Reported Low EF,1 times/d</th>
<th>Reported High EF,1 times/d</th>
<th>Weight on Low EF, kg</th>
<th>Weight on High EF, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnold (1993) (22)</td>
<td>2-wk randomized crossover</td>
<td>n = 19 adults</td>
<td>Healthy</td>
<td>32 ± 0.2</td>
<td>9</td>
<td>8.3 ± 0.6</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Arnold (1994) (20)</td>
<td>4-wk randomized crossover</td>
<td>n = 16 adults</td>
<td>Hypercholesterolemic</td>
<td>32 ± 0.3</td>
<td>9</td>
<td>8.2 ± 0.5</td>
<td>−0.1 (P &lt; 0.05)</td>
<td>−0.4 (P &lt; 0.05)</td>
<td></td>
</tr>
<tr>
<td>McGrath (1994) (23)</td>
<td>3-wk switch from normal</td>
<td>Men: snackers n = 12; nonsnackers n = 11</td>
<td>Healthy</td>
<td>33 ± 0.3</td>
<td>6</td>
<td>5.9 ± 0.9</td>
<td>Stable; NR</td>
<td>Stable; NR</td>
<td></td>
</tr>
<tr>
<td>Arnold (1997) (21)</td>
<td>4-wk randomized crossover</td>
<td>n = 13 adults</td>
<td>Type 2 diabetes or IGT</td>
<td>31 ± 0.3</td>
<td>9</td>
<td>7.8 ± 0.8</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Thomsen (1997) (24)</td>
<td>2-wk randomized crossover</td>
<td>n = 10 adults</td>
<td>Type 2 diabetes</td>
<td>31 ± 0.3</td>
<td>8</td>
<td>NR</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

1 Values are mean ± SD; abbreviations: EF, eating frequency; IGT, impaired glucose tolerance; NR, value or statistic not reported; NS, not significant (P > 0.05).
2 In the low EF condition, 1 × 30 kJ or 2 × 18 kJ snacks were allowed if desired.
3 Reported EI was 14.6 kJ/d higher in high EF compared with low EF but this difference was NS (P > 0.05).
4 Reported energy intake was 37 kJ/d higher in the high EF condition (P = 0.04).
5 Five of 8 meals were provided.

Table 2 presents the results of 5 studies that measured an increase in energy intake with higher eating frequency. The studies were conducted over a short period of time, from 2 to 4 weeks (20–24). One study was not a crossover study and involved a change from a normal eating frequency to a regular eating frequency. The lack of a significant change in body weight in the Arnold (1994) study (20) and one of the others (24) food intake was not significantly different, e.g., 3.9 kg or 8.5 pounds in 1 year. However, in that study, the participants lost slightly more weight when eating 6 times a day compared with eating 3 times a day. The difference was only 0.3 kg over a long period of time, so it could add up to a clinically important difference, e.g., 3.9 kg or 8.5 pounds in 1 year. However, in that study, the participants had self-selected the number of meals and snacks, whereas the other studies examined a prescribed eating frequency prescribed along with the eating frequency and goal. Therefore, additional randomized controlled trials that are longer term, in which intake is measured objectively, are needed to determine whether the minor influence of the higher eating frequency and body weight are significant. Cross-sectional studies (7,10,26–41) suggest that eating frequency is positively associated with energy intake and body weight, after accounting for energy intake reporting plausibility; however, very few studies have examined the relationship between eating frequency and BMI with plausible dietary intake reporting. A prospective cohort study (21) showed a nonsignificant increase of 14.6 kJ/d (61 kcal/d) when participants were asked to eat 8 times a day compared with 3 times a day, and there was no significant change in body weight (20), with the participants losing slightly more weight when eating 6 times a day compared with eating 3 times a day. The difference was only 0.3 kg over a long period of time, so it could add up to a clinically important difference, e.g., 3.9 kg or 8.5 pounds in 1 year. However, in that study, the participants had self-selected the number of meals and snacks, whereas the other studies examined a prescribed eating frequency prescribed along with the eating frequency and goal. Therefore, additional randomized controlled trials that are longer term, in which intake is measured objectively, are needed to determine whether the minor influence of the higher eating frequency and body weight are significant.
effectiveness and efficacy of different eating frequencies on weight loss and the prevention of body weight gain are needed. Inclusion of objective biomarkers to assess intake in these studies is essential. Dietary reporting bias, particularly that of under-reporting of energy intake, has become a detriment to nearly all studies that rely upon self-reported dietary intake. As illustrated in this review, underreporting can influence interpretations and conclusions that are made about relationships between eating frequency and adiposity such that they may be inappropriate and even opposite from the truth. Until there is an objective biomarker of eating frequency, there will be uncertainty about adherence to the dietary goals of studies in which different eating frequencies are behaviorally prescribed.

Acknowledgments
M.A.M. wrote the manuscript and was responsible for its final content, designed the tables and most figures, and conceived of the study design and analyses associated with Figures 2 through 4. N.C.H. performed statistical analyses and data management associated with Figure 4, designed the same figure, and commented on the manuscript draft. S.B.R. contributed to conception of the study design and analyses associated with Figures 2 through 4. T.T.K.H. performed statistical analyses and data management associated with Figures 3 and 4 and commented on the manuscript draft. All authors read and approved the final version of the paper.

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