Research review

Effects of snacks on energy intake: An evolutionary perspective

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Abstract

The question addressed in this paper is whether the consumption of snacks contributes to higher energy intake and body weight in humans. Currently available snacks have a higher energy density than most of the foods that were available in Paleolithic diets. Humans have a weak defense against overeating, which is a functional trait from an evolutionary perspective. Various studies found that people do not compensate their energy intake after the consumption of snacks. This is particularly true for energy-containing drinks, which provide calories in liquid form. It is concluded that snack consumption may contribute to a positive energy balance.

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Keywords: Evolution; Meals; Snacks; Energy intake

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Introduction

In the popular press it is often noted that the number of snacks that are eaten during the day has increased in the last decades and will further increase in the near future. The alleged increase in snack consumption is often assumed to be one of the changes in the dietary pattern that has contributed to the increase in the prevalence of obesity (Jahns, Siega-Riz & Popkin, 2001; Zizza, Siega-Riz & Popkin, 2001). The objective of the present paper is to evaluate the effects of snack consumption on energy intake and long-term energy balance (i.e., body weight and obesity) from an evolutionary perspective.

Meals and snacks from an evolutionary perspective

People eat in episodes, and not continuously. The number, size, and composition of eating moments or eating episodes per day vary in time, history, and culture (Meiselman, 2002). In the modern industrialized societies, we distinguish between meals and snacks. The term ‘meal’ usually refers to the three main eating moments of the day, including breakfast (in the morning), lunch (at the beginning of the afternoon), and dinner (at the beginning of the evening). The term ‘snack’ refers to other eating episodes, and includes all foods and drinks consumed outside the context of the three main meals.

Meals are very often consumed at a regular basis on fixed times of the day within particular social and environmental contexts (e.g., home, restaurant, canteen).
Most meals are not composed of one type of food, but contain different foods and/or courses (Meiselman, 2002). Meals are also often consumed in the company of other people implying that people share their foods with others. Sharing foods with others is not new from an evolutionary perspective; primates and social predators are also known to share foods. Primates as well as grazing animals spent a large time of their days searching, and subsequently eating foods immediately. This pattern of eating has more resemblance to snacking than to the eating of meals.

Meals in modern industrialized societies are consumed on a more regular basis than snacks. Data from Hulshof (1994) (see De Graaf, 2002) referring to 141 young Dutch adults in the early 1990s demonstrated that the average within-subject coefficient of variation (standard deviation/mean) of energy intake was about 30–40% for breakfast, lunch and dinner, compared to 90–125% for morning, afternoon and evening snacks. This implies that for most people snacks are not consumed at a regular basis (Table 1).

Most snacks in the industrialized world have a high-energy density. Sweet snacks such as cookies, cakes, pies, ice cream, and chocolate candy bars contain high amounts of sugar and fat. On average their energy content is about 1500–2000 kJ/100 g (400–500 kcal/100 g) (NEVO, 2004; Whybrow, 2005). Savory snacks such as potato chips are also high-energy density products with about 2200 kJ (550 kcal)/100 g, even in its 'low fat' (so-called 'diet' or 'light') form (2000 kJ or 500 kcal)/100 g). Sugar/fat-containing soft drinks or yoghurt-like beverages, which are also regularly consumed outside the context of the three main meals, do not have a high-energy density by themselves (170 kJ/100 g), but as they are consumed in large portion sizes they still result in a considerable energy intake (400 kJ) per portion of 250 ml. The high-energy density of current snacks stands in strong contrast to the low-energy density of most foods in Paleolithic diets, which predominantly consist of minimally processed plant-based foods and foods from animal origin (Cordain et al., 2005).

For example, most fruits and vegetable contain less than 100 kJ/100 g (NEVO, 2004).

From a large number of recent studies we know that humans easily overeat on high-energy dense foods (e.g., Blundell, Lawton, Cotton, & MacDiarmid, 1996; Rolls & Bell, 1999). In addition, it has been demonstrated that already in infancy individuals learn to like tastes and flavors that are associated with a high-energy density (e.g., Birch, McPhee, Steinberg & Sullivan, 1990). We like energy-dense foods and we easily consume considerable amounts from them. This tendency for passive (unconscious) overconsumption of energy/fat makes sense from an evolutionary point of view: being able to ingest more energy than you expend is beneficial because it allows for energy (fat) storage that may be required in times of food scarcity.

### Eating frequency and body weight

As noted in the introduction, it is often assumed that the number of snacks that are eaten during the day has increased in the last decades and will continue to increase in the near future. Actual longitudinal data on the contribution of meals and snacks to the daily energy intake do not confirm this assumption, however. For instance, data from Dutch food consumption surveys show that the average contribution of snacks to the daily energy intake was relatively constant (about 30–35%) in the past 15 years (data were collected in 1988, 1992/1993, 1997/1998, and 2003; RIVM/TNO, 2004; Voedingscentrum, 1998). Data from the US Bogalusa heart study in 10-year-old children show that the average total number of eating episodes even decreased from 6.6 in 1973 to 5.2 in 1994 (Nicklas et al., 2004).

The presumed increase in snack consumption is often regarded to be one of the changes in the dietary pattern that contributes to the increase in the prevalence of obesity (Jahns et al., 2001; Zizza et al., 2001). However, the relationship between eating frequency and body weight is not consistent across studies. Some studies find a positive relationship between number of eating episodes and BMI, whereas other studies find an opposite effect (Bellisle, McDevitt & Prentice, 1997). A recent large-scale \( (n > 5000) \) Swedish study found that on average obese people consumed snacks more frequently than lean subjects do (Bertéus Forslund, Torgerson, Sjostrom, & Lindroos, 2005). In line with this observation, reported energy intake increased with increasing snacking frequency (Bertéus Forslund et al., 2005). In contrast with these findings, however, a recent 7-year follow-up longitudinal study among 196 non-obese girls did not find any relationship between the consumption of energy-dense snacks and weight status (Phillips et al., 2004).

If eating frequency exerts an influence on body weight status, it works through its effect on ad libitum energy intake, and not through effects on expenditure. Given a certain energy intake, energy expenditure through diet-induced thermogenesis (i.e. the increase in energy expenditure after ingestion of food) has been shown to be

<table>
<thead>
<tr>
<th>Energy/nutrient Eating occasion</th>
<th>Brkfst</th>
<th>Morning</th>
<th>Lunch</th>
<th>Afternoon</th>
<th>Diner</th>
<th>Evening</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (MJ)</td>
<td>34</td>
<td>125</td>
<td>41</td>
<td>95</td>
<td>40</td>
<td>90</td>
<td>20</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>35</td>
<td>121</td>
<td>41</td>
<td>89</td>
<td>43</td>
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<td>21</td>
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<tr>
<td>Protein</td>
<td>42</td>
<td>148</td>
<td>47</td>
<td>125</td>
<td>40</td>
<td>128</td>
<td>22</td>
</tr>
<tr>
<td>Fat</td>
<td>52</td>
<td>160</td>
<td>54</td>
<td>139</td>
<td>59</td>
<td>135</td>
<td>33</td>
</tr>
<tr>
<td>Alcohol</td>
<td>244</td>
<td>265</td>
<td>245</td>
<td>219</td>
<td>229</td>
<td>169</td>
<td>159</td>
</tr>
</tbody>
</table>

Subjects recorded their intake during 6–9 separate days. (Data from Hulshof, 1994).
constant regardless of the number of eating moments through which the intake was achieved (Verboeket-Van de Venne & Westerterp, 1991, 1993). This implies that energy expenditure does not depend on eating frequency. It may thus be hypothesized that the effects of snack consumption on energy balance works through the intake side of the equation.

One of the basic questions regarding the effect of snacks on body weight status is whether or not the consumption of snacks leads to an increase in ad libitum energy intake. Do people compensate their intake after the consumption of snacks or do they not? The answer to this question is related to the notion that appetite and energy intake compensation are learned responses to various types of cues. People respond to external cues like the time of day and the eating environment.

Appetite as a learned response

As we noted earlier in this paper, people eat in episodes—especially insofar meals are concerned. Before a meal people are hungry, and after a meal they are satiated. After the consumption of a meal hunger gradually builds up again, until the next eating moment (Blundell et al., 1996). This pattern seems different for snack consumption, however. Many snacks are consumed when people are not hungry (Castonguay, Applegate, Upton, & Stern, 1983). The rhythm of appetite responses across the day has been observed in many studies, and coincides with the meal pattern that is maintained. In a study by De Graaf and colleagues (De Graaf, Jas, Van der Kooy, & Leenen, 1993) Dutch subjects in the beginning of the 1990s showed three peaks in appetite for a meal: just before breakfast, just before lunch, and just before dinner. The pattern of peaks in appetite for snacks was slightly different: appetite for something savory was high before lunch, before dinner, and later in the evening (around 10 pm). This rhythm stayed in effect when people were on a weight loss diet in which the daily meal pattern remained intact (De Graaf et al., 1993).

If hunger/appetite is a direct signal of energy deficit, hunger should increase continuously when people stop eating for a longer period of time. This does not happen, however. When people are on a weight loss diet, initially their hunger increases but even after a few days feelings of hunger tend to stabilize (De Graaf et al., 1993). This is also true when people do not eat at all. In an early fasting study it was shown that during a 3-week fasting period in the absence of food stimuli, rated hunger levels gradually declined (Silverstone, Stark, & Buckle, 1966). Voluntary abstinence of food may result in the complete loss of feelings of thirst and hunger (Peel, 1997).

In a more recent study Finch and colleagues (Finch, Day, Razak, Welch, & Rogers, 1998) investigated hourly appetite responses during Ramadan as a function of how many days individuals had been fasting. Ramadan is the holy month for Muslims and during the 29–30 days the Ramadan period continues, Muslims are not allowed to eat and drink between sunrise and sunset. The results showed that for the women, afternoon appetite ratings later in the Ramadan were lower than early in Ramadan. Apparently these women got used to not eating during the day.

In a similar way as people can get used to fasting, they may become habituated to eating during particular moments. In a study by Haverkort and Prakken (1992), people who were not used to eating a mid-morning snack were offered a high fat/high sugar snack for five subsequent days. During these days they also monitored their appetite for something sweet. As Fig. 1 shows, subjects expressed a high appetite for something sweet just before the consumption of the snack after a few days. Apparently, people got very easily used to the consumption of the mid-morning snack.

In an early experimental study by Birch and colleagues (Birch, McPhee, Sullivan, & Johnson, 1989) it was shown that meal initiations in the absence of hunger can be conditioned under the influence of external cues. In this study children in the experimental group were presented with a combination of light and music after which they participated in playing some games. The food was presented together with the games. In the control group children were also exposed to light/music during playing, but there was no food present. In the test trials after the conditioning trials, children in the experimental group ate more and waited less time before eating when the conditioning light/music stimuli were present. So, the music/light stimuli that had been paired with eating in the experimental group were shown to induce an eating response.

Summarizing these data, it appears that there is only a weak connection between energy balance and short-term hunger and satiety responses. In many circumstances people eat when they are not hungry while at the same

![Fig. 1. Response to “appetite for something sweet” as a function of time in the morning during a reference phase of 5 days, in which subjects did not get any food during the morning, and during a conditioning phase of 5 days in which subjects got a high-sugar/high-fat snack at 10.15 am.](image-url)
they do not eat when they are hungry. External signals such as the availability of foods and sensory cues play a larger role in eating than hunger.

**Do people compensate for energy intake from snacks?**

There are many published studies on energy intake compensation after the covert or overt manipulation of the energy content of foods. Most of the studies worked with meals/preloads, but a few studies have also dealt specifically with the effects of snacks on energy intake. The majority of these studies showed that most subjects are not sensitive to covert energy manipulations in foods (Herman, Polivy, & Leone, 2005; Whybrow, 2005). People eat not much less after high-energy preloads compared to low-energy preloads.

One of the few studies examining the effect of snacks on energy intake is a study by Hulshof (1994) who investigated the effects of croissants with covert different fat (30, 53, and 72 g fat/preload) levels on energy intake compensation. The croissants were served, either as breakfast (8 am), as lunch (0.30 pm) or as an afternoon snack (3 pm). After eating the croissants, subjects were not allowed to eat for 3 h. The results showed that subjects did not notice the difference in the energy levels of the snacks (1.7, 2.5 and 3.4 MJ) as appetite ratings were similar after consumption of the different types of croissants. Energy intake at dinner was independent of the energy level of the croissants, and it was also independent of the time of the croissant consumption. Even when the croissants were consumed at 3 pm, this did not have a suppressive effect on energy intake during dinner compared to the situation in which the croissants were given at noon (0.30 pm). Fig. 2 shows that appetite ratings after the 3 pm preloads quickly returned to levels comparable to the ratings in the other conditions.

Another study specifically aimed at the effect of snack consumption on energy intake is an elegant study by Marmonier and colleagues (Marmonier, Chapelot, Fantino, & Louis-Sylvestre, 2002) with 11 time-blinded young men. In this study subjects were served an ad libitum lunch, a 1 MJ snack during the afternoon, and an ad libitum dinner. The snack was served at three different times, dependent on the physiological response of the subject, i.e. 5 min before the peak of the glucose level, 40 min after peak glucose or 2 h before dinner request during a baseline no snack condition. So, the snacks were served at a time where the subjects were still satiated. The results showed that the intake during dinner was not lower in the snack conditions compared to the no snack conditions (Fig. 3).

A more recent study on the effect of (liquid) mid-morning snacks on appetite responses and energy intake at lunch is a study from Zandstra and colleagues (Zandstra, Stubenitsky, De Graaf & Mela, 2003). In this study high (1.14 MJ/272 kcal) and low (0.28 MJ/66 kcal) energy yoghurt drinks were used with novel flavors. These drinks were consumed by 69 men and women during 8 weeks for 5 days per week. Subjects consumed the low-energy drinks on 20 days, and on the other 20 days the high-energy drinks. There was no difference in effect between the low- and high-energy yoghurt on energy intake at lunch, even after 20 exposures (Zandstra et al., 2002).

The three studies discussed above all show that subjects show no energy intake compensation after snacks. An early study by Westerterp-Plantenga and colleagues (Westerterp-Plantenga, Wijckmans-Duysens, & Ten Hoor, 1994) suggested that energy intake compensation after a reduced-fat lunch depended on the habitual meal frequency of subjects. They found that nibblers, who have a high eating frequency, compensated better than gorgers who normally have a low eating frequency. This might be due to the notion, that nibblers have more opportunities to compensate than gorgers. Nibblers have a higher eating frequency.
frequency, and at each eating episode they have the opportunity to compensate from earlier moments of overeating. Another aspect in this respect is that in nibblers the time lag between different eating moments is shorter. Research of Rolls and colleagues (Rolls et al., 1991) shows that a shorter time span between preload and test-meal leads to higher compensatory responses. One counter-argument against nibbling is that increased eating frequency also increases the number of opportunities to overeat. More data are needed to settle this issue.

Discussion

The findings discussed in this paper suggest that in general people do not compensate for the energy intake from snacks, especially not for snacks that are consumed on an irregular basis. As noted in the introduction, in general snacks are consumed at a more irregular basis than meals. This implies that the consumption of snacks may contribute to a higher energy intake on the short term. It is not clear yet, whether or not in the long run a higher snack intake results in a higher body weight. The recent data from a large scale Swedish study (Bertéus Forslund et al., 2005) suggest that this may indeed be the case. However, we need more data to confirm this finding.

There might be a difference in the effect of snacks which are consumed on a regular basis compared to snacks which are consumed on an irregular basis. As noted before, appetite is a learned response. If snacks are consumed on a very regular basis people might show better intake compensation than when they are not consumed at a regular basis.

Another element in the discussion of the contribution of snacks to energy intake is the nature of the snack. It has been repeatedly shown that liquid foods are less satiating than solid foods (Haber, Heaton, Murphy & Burroughs, 1977; Hulshof, De Graaf & Weststrate, 1996; Mattes, 1996). Therefore, snacks in the form of sugar-containing soft drinks may add relatively more to the energy intake than solid snacks, and thus contribute to a higher body weight (Raben, Vasilars, Moller, & Astrup, 2002; Tordoff & Alleva, 1990). This observation is in line with the conclusion of Booth and colleagues (Booth, 1999; Booth, Blair, Lewis & Baek, 2004) that “the first line of defense against weight gain is avoiding all sources of energy during drink breaks”. This idea has also been confirmed by epidemiological data (Ludwig, Peterson & Gortmaker, 2001).

The absence of our sensitivity to liquid calories may be related to the observation that liquid calories are no part of any regular diet of any mammal, except for milk during infancy, which is a period of rapid increase in weight. Another (not competing) explanation for this lack of sensitivity is that the sensory signals during consumption of liquids may be very short; people ingest liquid foods at a much faster rate than solid foods. This leads to the hypothesis that the sensory signals during consumption of liquids are not sufficiently clear to bring up a link with a clear metabolic satiety response. People are not physiologically equipped to sense the energy content from liquids, even not after repeated exposure.

The position in this paper that the irregular consumption of snacks may contribute to a positive energy balance does not necessarily imply that this is the major factor in the development of overweight. Considering the lack of consistent data to relate eating frequency to BMI, it seems probable that average meal size may also be an important contributor to a positive energy balance. The analysis of eating patterns that contribute to a lower energy intake may be a fruitful area for future research on the modern epidemic of overweight.

References


