Symposium: Modifying the Food Environment: Energy Density, Food Costs, and Portion Size

Portion Sizes and the Obesity Epidemic[1,2]

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ABSTRACT The rise in obesity rates over the past 30 y has been paralleled by increases in the portion size of many foods and the prevalence of eating away from home. Foods of particular concern are those that have a high energy density (kJ/g). Many well-controlled, laboratory-based studies have found that large portions of energy-dense foods can lead to excess energy intakes. This influence of large portions on energy intake has been supported by data collected in naturalistic settings. Further research is needed to explore strategies that can be used to moderate the effects of portion size on food consumption. One promising strategy is to reduce the energy density of foods, while maintaining food weight or volume, so that consumers can eat satisfying portions while reducing their energy intakes. There is a need for effective educational messages that not only emphasize limiting the consumption of foods high in energy density, but also encourage the consumption of those with a low energy density, such as fruits and vegetables. The delivery of consistent messages will require more cooperation among the food and restaurant industries, policy makers, and scientists. Effective strategies will also require consumers to understand and accept the importance of eating reasonable portions for better health. J. Nutr. 135: 905–909, 2005.

KEY WORDS: • *portion size* • *energy density* • *energy intakes* • *obesity* • *weight management*

The current obesity rates show no sign of declining and over 65% of Americans are now classified as overweight or obese (1). Not surprisingly, media attention has focused on physical inactivity and on excess energy intakes. Press reports (2) have singled out the large portion sizes of high-calorie foods served in restaurants as being responsible, at least in part, for the surge in obesity rates. The influence of food portion size and energy density, particularly of away-from-home foods, on energy intake is the topic of this review.

Rising obesity rates have been paralleled by an increase in the consumption of foods away from home (3). In 1996 the average American family spent ~40% of the food dollar on meals purchased away from home, an increase from 26% spent in 1970 (4). Americans are now 40% more likely to consume meals from restaurants 3 or more times a week as they were in the late 1980s (5).

With an increase of meals purchased away from home, it is likely that consumers are being exposed to larger portions. Studies of food portions offered at fast food outlets, chain restaurants, and convenience stores indicate that portion sizes of many items have increased (3). According to Nestle (3), this trend began in the U.S. as early as the 1970s, with portion sizes increasing sharply in the 1980s and continuing to rise. Data from Denmark show similar trends (6). The growth of portion sizes has been most evident in fast food restaurants where the "supersizing" of some menu items is relatively common (7). Items available at fast food restaurants are estimated to be 2 to 5 times larger than 2 decades ago (8). In general, food packaging and common portion sizes of popular dishes are 25% larger in the U.S. than in France where rates of obesity are lower (9). With the availability of many foods in larger sizes, it is not surprising that epidemiological studies indicate people are consuming larger portions of food (10).

Do larger portions lead to greater energy intakes?

Although the increase in the size of portions and the prevalence of overweight and obesity have occurred in parallel, a crucial step in assessing a causal relationship between portion size and obesity is to determine experimentally whether portion size affects energy intake. Multiple, well-controlled studies have shown that providing subjects with larger portions of food in a laboratory setting leads to significantly higher energy intakes (11–14). For example, when adults were served 4 different portions of macaroni and cheese on different days, subjects consumed 30% more energy (676

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kJ) when offered the largest portion (1000 g) compared to the smallest portion (500 g) (11). The effect was seen both when the portion on the plate was determined by the investigator and when the participants served themselves from bowls containing different size portions. Despite the difference in intake, participants reported similar ratings of hunger and fullness after eating. After the study was over, more than half (55%) of the subjects did not notice that there were differences in the portions served. It is surprising that in a controlled laboratory setting, where the main focus was food and eating, a majority of participants in the study appeared to be unaware of the changes in the amount of food offered and the subsequent effect on their intake, hunger, and satiety. It seems likely that when individuals are in situations where there are more distractions, such as when eating out, they would be even less aware of portion size.

The portion size of amorphous foods that have no defined shape, such as macaroni and cheese, has been shown to be particularly difficult to judge, especially when the portions are large (15). Further studies indicate that intake can also be influenced by the portion size of other types of foods, such as those with clearly defined shapes or units. One of the most common unit foods is the sandwich. In most fast food establishments there is a choice of sandwich sizes; often the larger sandwiches are purchased because the consumers perceive them as better value in that they get more food for their money (16). A key question is, if consumers choose a larger sandwich, are they likely to eat more? To answer this question, men and women were offered submarine sandwiches on different days that varied in size: 6, 8, 10, and 12 inches (13). There was a systematic and significant effect of portion size on intake. When served the 12-inch sandwich compared to the 6-inch sandwich, women consumed 31% more energy (665 kJ) and men consumed 56% more energy (1485 kJ). Ratings of hunger and fullness after lunch did not differ significantly when subjects were served the 8-, 10-, and 12-inch sandwiches, despite the increase in energy intake.

The amount of food in a package has also been shown to influence how much is eaten. To test how the size of the bag affects intake, on 5 occasions men and women were served an afternoon snack that consisted of 28, 42, 85, 128 or 170 g of potato chips in a plain, unlabeled foil bag (12). Portion size had a significant effect on snack intake. For example, when served the 170 g package, women ate 18% (200 kJ) more and men ate 37% (511 kJ) more than when served the 85 g package. As subjects increased their snack intake with increasing package size, they also reported feeling fuller; however, they did not adjust their intake at the subsequent dinner meal to compensate for the increased energy intake and fullness. On average, when served the largest snack compared to the smallest, subjects consumed an additional 596 kJ at snack and dinner combined. Thus, bigger portions of a prepackaged snack increased energy intake in the short term. It is not clear that all prepackaged foods will have a similar effect. It is possible that the effect will be greatest for highly palatable foods, such as chips, that people find difficult to stop eating.

Studies conducted in natural settings confirm that food portions influence energy intake. A study in a cafeteria-style restaurant tested whether increasing the portion size of a pasta entrée from 248 g (standard portion, 1766 kJ) to 377 g (large portion, 2647 kJ), while keeping the price the same, would affect intake (17). As seen in **Figure 1**, portion size had a significant impact on how much pasta was consumed. Increasing the portion of pasta by 50% was associated with a 43% increase in energy intake (719 kJ) for the pasta and a 25% increase (664 kJ) for the entire meal. A satisfaction survey

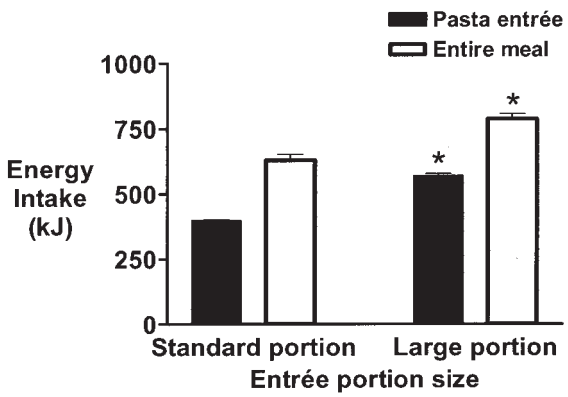

FIGURE 1 Energy intake in a restaurant when served a standard entrée portion (248 g, 1766 kJ) or a large entrée portion (377 g, 2647 kJ). Intakes of the pasta entrée and the entire meal were significantly greater ($P < 0.0001$) when customers were served the large portion, compared to the standard portion (17).

showed no difference in ratings of the appropriateness of the 2 portions. Another study (18), also conducted in a natural setting, found that patrons at a movie theater ate a significantly greater amount of popcorn when provided with a large-sized bucket, compared to a medium-sized bucket of popcorn.

These controlled studies show that both in the laboratory and in more naturalistic settings, the portion size and package size of a variety of foods can affect energy intake in adults in the short term. It is possible that after a bout of overeating stimulated by large portions, compensatory mechanisms will limit subsequent intake. This was tested by increasing the portion size of all foods served to men and women over a 2-d period (19). There was a significant effect of portion size on energy intake over the 2 days. When the portions of all foods were doubled, energy intake on both days increased for all subjects by a mean of 26% (2218 kJ/d for women and 3402 kJ/d for men). Although subjects reported feeling more full after they consumed the larger portions, they did not compensate for the excess energy eaten over the course of the 1st d by reducing their intake on the 2nd d. Thus, these results show that the effects of portion size can persist over several days, with no indication of meal-to-meal compensation. Studies of longer term effects of portion size on energy intake are in progress.

Portion size and energy density influence energy intakes

Portion size is one of a number of variables that could increase food intake. Having a wide variety of palatable foods, eating in a convivial atmosphere, and the consumption of alcohol may all lead to higher energy intakes. The energy density (kJ/g) of foods is another contributing factor. Energy density refers to the amount of energy (kJ) in a given weight of food (g). Of the components of food, water has the greatest impact on energy density since it adds substantial weight without adding energy. Because of its high energy content, fat (37.7 kJ/g) influences the energy density of a food more than carbohydrate or protein (16.7 kJ/g). A systematic series of studies has shown that individuals consistently consume more energy when presented with foods having a higher energy density than with similar foods having a lower energy density (20–22).

Prentice and Jebb (23) recently compiled the energy density values of foods from well-known fast food outlets in

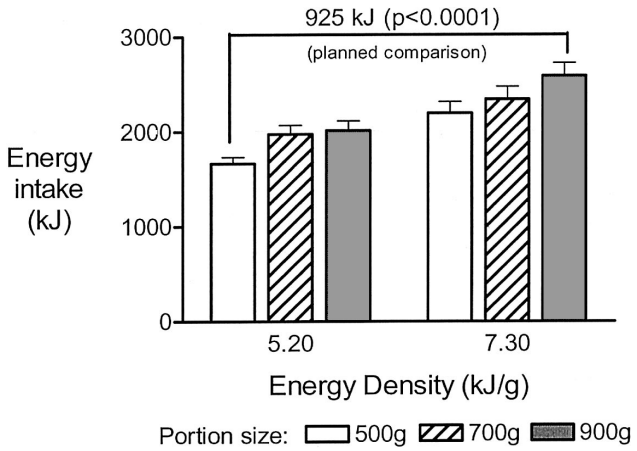

FIGURE 2 Energy intakes (mean ± SEM) for women (n = 39) by energy density and portion size. The effects of portion size and energy density add together to influence energy intake. Reproduced with permission by the *American Journal of Clinical Nutrition* (19).

Britain, finding that the mean energy density of *the entire menu* (beverages were not included) from these restaurants was 12.0 kJ/g. Further work is needed to determine the average energy density of fast food meals and to examine the influence of the new, popular salad options on meal energy density at these establishments. For comparative purposes, the energy density of the U.S. diet, based on all foods consumed over 2 days, was found to be 7.8 kJ/g (24). The relatively high energy density of fast food can facilitate the overconsumption of energy. For example, when served a fast food meal with extra large portions in a food court, adolescents consumed over 6908 kJ in one meal, which was about 62% of their estimated daily energy requirements (25). It seems likely that both the large portions and the high energy density of the foods in fast food outlets contributed to the excessive energy intakes.

The way that portion size and energy density of food combine to influence energy intake was determined in a controlled laboratory study. Kral et al. (19) served a lunch entrée at 2 energy density levels, 5.23 kJ/g and 7.32 kJ/g, in 3 different portion sizes (500 g, 700 g, 900 g) on different days. Subjects consumed 925 kJ more (56%) when served the largest portion of the high-energy-dense entrée, compared to when served the smallest portion of the low-energy-dense entrée (**Fig. 2**). Interestingly, there was no interaction between energy density and portion size, indicating that both factors act independently on energy intakes. When both were increased in a single meal, the effects of energy density and portion size added together to increase energy intake.

The consumption of large portions can, however, decrease overall energy intake if the food has a low energy density. Rolls et al. (26) investigated the effects of varying the portion size and energy density of a first course salad on overall ad libitum lunch intake. The salad varied in portion size (150 and 300 g) and energy density 1.38 kJ/g, 2.80 kJ/g, and 5.56 kJ/g. Overall meal intake was affected by both the portion size and energy density of the salad. Compared to having no first course, consuming the salad with lowest energy density *reduced* meal intake by 7% (268 kJ) for the small portion and 12% (448 kJ) for the large portion. These data indicate that eating a large portion of a low-energy-dense first course reduces meal intake and may be an effective strategy for weight management. The findings also exemplify the complexities involved in developing educational messages related to portion size and energy density. Simply advising people "to eat less" may not be as effective as encouraging the consumption of foods with a low energy density such as fruits and vegetables, while encouraging moderation when consuming foods high in energy density.

Long-term studies on the combined effects of energy density and portion size are crucial. In a recent study, the same menu items were served on 2 consecutive days in each of 4 weeks, but the foods were varied in energy density (standard or reduced by a mean of 30%) and portion size (standard or reduced by 25%) (27). Over both days the energy density and portion size of foods were found to have significant and additive effects on ad libitum energy intake. Reducing the energy density of foods by 30% led to a 23% decrease in daily energy intake (2276 kJ). Reducing the portion size of foods by 25% led to a 12% decrease in daily energy intake (1071 kJ). Thus, when smaller portions of lower energy-dense foods were served, daily energy intake was 3347 kJ less on both days than when larger portions of higher energy-dense foods were served. Despite the large variation in intake, there were no significant differences between conditions in mean ratings of hunger or fullness over the 2 days. This study shows that the effects of energy density and portion size on energy intake are additive and persist over at least 2 days, without differentially affecting ratings of satiety. Additional studies are needed to determine whether these effects persist for longer periods.

Do larger food portions equal larger people?

There are few studies on the relationship between food portion size and weight status, and even fewer studies that also address dietary energy density. Nationally representative data for children indicate that portion size alone accounted for 17 to 19% of the variance in energy intake (28); in other words, larger portions were associated with higher intakes. In addition, children with a higher BMI consumed portions of foods that were as much as 100% larger than those consumed by children with a lower BMI (29). These analyses, however, did not also examine the energy density of the foods consumed. This last point is important because large portions of low-energy-dense foods would likely be associated with a lower weight status. A small study in the Netherlands that examined both portion size and energy density indicated that obese women consume larger portions of high-energy-dense foods and smaller portions of low-energy-dense foods, as compared to nonobese women (30). While calculating dietary energy values in large groups of free-living individuals can be a complex task (24), there is a need for nationally representative epidemiological studies examining relationships between food portion size and weight status that take energy density into account.

Why are portion sizes increasing?

Eating out has become more common in part due to higher incomes, more 2-income households, and growth in the restaurant industry. Pricing influences consumers' food purchases (31,32), suggesting that the rise in portion size is partially attributable to consumer demand for economic value. As a result, many restaurants are providing large portions at a low cost per unit as a marketing strategy (16). This is possible because food cost is only a small percentage of the cost of a meal and because agricultural subsidies have helped to reduce the cost of some foods and commodities, such as vegetable oil and sugar, which have become very inexpensive (33,34).

What interventions should be put in place?

A number of recent reports have included statements regarding food portion sizes (35,36). The FDA Report entitled "Calories Count" (37) recommended that foods be labeled as a single-serving if they could be reasonably consumed at one sitting because part of the problem people have identifying appropriate food portions may arise from difficulties in interpreting the information on food labels (38). The report also encouraged food manufacturers to use appropriate comparative labeling statements and urged the restaurant industry to provide point of purchase information. The 2005 Dietary Guidelines Advisory Committee acknowledged the importance of energy density in making food choices (39), and suggested that limiting portion sizes, especially of energy-dense foods, could help to reduce calorie intake. On the other hand, consumption of low-energy-dense foods that are nutrient-dense "provides individuals a way to meet nutrient needs while avoiding the overconsumption of calories" (40). Research is needed to determine if adding information about energy density to food packages could be a useful tool for helping consumers to choose appropriate portions and to rapidly compare the energy content of similar foods.

One approach to limiting the intake of energy-dense foods is to impose penalties such as "sin taxes" on beverages and foods high in fat and energy (32). However, determining which items should be taxed is problematic and it is not clear whether foods with large portion sizes should also be taxed. In addition, there are no data on whether such taxes would significantly affect food choices. An alternative approach would be through incentives to provide healthful, low-energy-dense foods and to provide reasonable portions. The Food and Drug Administration considered pilot testing the use of their name and logo on menus and advertisements as an incentive for restaurants to provide patrons with voluntary point-of-purchase nutrition information (37). This would allow patrons to make informed decisions. It would also provide the food industry with motivation to provide a greater range of portion sizes and to make smaller portions more appealing. While it is not feasible for restaurants to serve portions based on an individual customer's energy needs, the restaurant industry can provide a variety of choices that would make it easier for customers to eat less. More attractive pricing strategies (31,32) could be used to promote the selection of smaller portion sizes.

However, smaller portions or "eating less" may not always be an effective solution because it is not just large portion sizes that increase energy intake, but rather large portions of energy-dense foods. Instead, foods could be modified to give consumers satisfying portions and good taste as well as less energy at a reasonable price. One strategy is to decrease the energy density of menu items. Reductions in energy density are unlikely to affect customer satisfaction if palatability is not compromised and cost is not increased. A combination of fat reduction along with the addition of water-rich vegetables could reduce the energy density of popular foods such as burgers, sandwiches, and pizza. It is likely that with unit foods such as these, patrons will order and consume their usual portion size, but will ingest less energy while feeling just as full and satisfied (13). In one study, a fish dish was substantially reduced in fat and energy, with no effect on how much people liked the dish, how well it matched their expectations, and how likely they would be to purchase it again (41). Even small reductions in energy density are likely to have a big impact at a population level. For example, using an alternative method for cooking French fries in fast food restaurants, which decreases fat absorption, could lead to a significant reduction in per capita energy consumption (42).

There is a need for extensive funding to deliver effective educational messages that not only emphasize limiting intake of foods with a high energy density, but also encourage consuming foods with a low energy density, such as fruits and vegetables. Organizations that have been successful at increasing consumption of foods low in energy density, such as the Produce for Better Health Foundation (43), should be rewarded with larger budgets. Policy makers need to organize a well-funded campaign using marketing and psychological techniques, as sophisticated as those being used by industry, to help consumers understand the long-term health effects of eating large portions of energy-dense foods (44). This can help consumers equip themselves with the knowledge and skills to adequately determine portions that are appropriate to their energy requirements. When faced with large portions of energy-dense, palatable foods in restaurants, people should adopt strategies to limit their intake, such as ordering reduced-sized portions, saving part of the entrée for another meal, or sharing with a friend. Consumers also need to encourage the food industry to provide high quality, low-energy-dense foods. It is important that consumers purchase these items when available so that the food industry has an economic incentive to provide tasty, healthful options that can be consumed in reasonable portions without promoting excessive energy intake.

Supersizing obesity prevention efforts

There is increasing evidence that excessive food portions, particularly of energy-dense foods, contribute to the overconsumption of energy. Telling people to simply "eat less" is not likely to be an effective solution, because it is not just large portion sizes that increase energy intake, but rather large portions of energy-dense foods. Large portions of foods low in energy density such as vegetables, fruits, and broth-based soups can aid weight management by providing satisfying portions with few calories (45,46). There is a need to deliver effective educational messages that combine the principles of portion size and energy density. The development and intensive marketing of appealing, low-energy-dense foods can help create an environment in which consumers are better able to maintain a healthy weight. Successful strategies will not only require cooperation among the food and restaurant industries, policy makers, and scientists, but will also require consumers to understand and accept the importance of eating reasonable food portions for better health.

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