

# The influence of food portion size and energy density on energy intake: implications for weight management<sup>1-4</sup>

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## ABSTRACT

The increase in the prevalence of obesity has coincided with an increase in portion sizes of foods both inside and outside the home, suggesting that larger portions may play a role in the obesity epidemic. Although it will be difficult to establish a causal relationship between increasing portion size and obesity, data indicate that portion size does influence energy intake. Several well-controlled, laboratory-based studies have shown that providing older children and adults with larger food portions can lead to significant increases in energy intake. This effect has been demonstrated for snacks and a variety of single meals and shown to persist over a 2-d period. Despite increases in intake, individuals presented with large portions generally do not report or respond to increased levels of fullness, suggesting that hunger and satiety signals are ignored or overridden. One strategy to address the effect of portion size is decreasing the energy density (kilojoules per gram; kilocalories per gram) of foods. Several studies have demonstrated that eating low-energy-dense foods (such as fruits, vegetables, and soups) maintains satiety while reducing energy intake. In a clinical trial, advising individuals to eat portions of low-energy-dense foods was a more successful weight loss strategy than fat reduction coupled with restriction of portion sizes. Eating satisfying portions of low-energy-dense foods can help to enhance satiety and control hunger while restricting energy intake for weight management. *Am J Clin Nutr* 2005;82(suppl):236S-41S.

**KEY WORDS** Portion size, energy density, energy intake, body weight, weight management, obesity

## INTRODUCTION

In the United States, portion sizes of many foods have been increasing since the 1970s; (1) this trend has been observed in a variety of settings including restaurants, supermarkets, and in the home (2-4). Increases in portion size have occurred in parallel with the rise in the prevalence of obesity, which suggests that large portion sizes could play a role in the increase in body weight (5). These observational studies should be interpreted with caution, because they cannot demonstrate causality. Investigators have not yet systematically examined the relationship between the portion size of foods and weight status; therefore, a crucial step in assessing this relationship is to determine experimentally whether portion size affects energy intake. Portion size, however, is only one of many factors that may encourage the overconsumption of food. Energy density (kilojoules per gram; kilocalories per gram) has been shown to significantly affect energy

intake; foods that are high in energy density increase energy intake while foods that are low in energy density decrease intake (6, 7). Thus, it is important to examine how energy density and portion size interact or combine to affect intake. This review will examine the experimental evidence related to the influence of portion size on energy intake and satiety. The impact that energy density and portion size have on energy intake will also be discussed, along with implications for weight management.

## THE EFFECT OF PORTION SIZE ON ENERGY INTAKE

### Children and portion size

In very young children, food intake appears to be relatively unaffected by portion size. Nationally representative data indicate that the average portions of foods consumed by 2-y-olds have remained stable over a 20-y period (8), although many commercially available products have increased in portion size during this time (3, 4). Data from a controlled study show that, when 3-y-old children were served different portions of macaroni and cheese on three separate occasions, they consumed similar amounts at each meal (9). This suggests that very young children, rather than responding to food cues such as portion size, are able to self-regulate their intake by responding to physiologic cues for hunger and satiety.

As children age, however, it appears that internal cues have less effect on food intake, whereas external factors exert more influence. In the study cited previously, when the different portions of macaroni and cheese were served to 5-y-old children, they consumed significantly more energy as the portion size was increased. This response to portion size occurred although their hunger did not differ at the start of the meals (9). Similarly, Fisher et al (10) found that 4-y-old children ate 25% more when they were served an entrée that was twice the size of an age-appropriate portion. The children who increased their intake the most when served large portions were those who had been identified as more likely to eat in the absence of hunger.

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It is not clear why children are more influenced by portion size as they age. Data suggest that early experiences lead to the development of behaviors that shape eating habits. In one experimental study, the 4-y-old children who were rewarded for cleaning their plates increased their energy intake (11). Conversely, the children who were taught to focus on satiety cues, indicated by the fullness in their stomachs, ate an appropriate amount of food. Thus, the response to portion size by children could be a learned behavior that leads to a shift of attention away from internal hunger and satiety cues toward food cues in the external environment. A lack of response to satiety signals may predispose children to overeat in an environment in which large portions of palatable foods are readily available (12, 13). The influence of large portions on intake, however, has been shown to be moderated simply by allowing children to serve themselves. One study demonstrated that children ate 25% less of a large entrée when they decided for themselves how much food to put on their plates compared with when they were served the large portion of the entrée by an adult (10).

Although there is a need for more data, these studies suggest strategies for parents and caretakers that may help children to eat appropriate portions. One approach is for adults to provide children with a variety of nutritious foods and allow children to determine how much they will eat by serving themselves (14). Adults should also encourage children to recognize hunger and fullness cues and to rely on these cues for the initiation and termination of eating; children should not be required to clean their plates nor be rewarded for doing so. As we understand more about eating behavior, it is likely that additional strategies will become available to help children preserve their ability to recognize and respond appropriately to internal signals and to resist environmental influences on intake such as portion size.

### Adults and portion size

Considering that children over the age of 3 y consume more food when presented with large portion sizes, it is not surprising that adults have been found to respond in a similar way. Some of the first work characterizing the influence of portion size was conducted using different package sizes in naturalistic settings. Wansink (15) examined the effect of package size on prospective food usage and found that individuals estimated they would consume more food when presented with larger packages than when presented with smaller packages. For example, when asked to dispense an appropriate amount for two people, women poured significantly more spaghetti and oil from larger food packages than from smaller packages. A similar effect was seen with small candy-coated chocolates (15). Thus, it was shown for a variety of foods that the bigger the package, the more food was served from it. It is critical, however, to show that package size and portion size affect not only how much food people serve but also how much they eat.

To systematically assess the effect of portion size on food intake, Rolls et al (16, 17, 19, 20) conducted a series of experiments, beginning with studies of a single meal (Table 1). In one study, when men and women were served different portions of macaroni and cheese on different occasions, they consumed 30% more energy (676 kJ; 162 kcal) when offered the largest portion (1000 g) than when offered the smallest portion (500 g) (16). In another study, when 6-, 8-, 10-, or 12-inch sandwiches were served on different days, both men and women significantly

increased their energy intake as the size of the sandwich increased. When served the 12-inch sandwich, women consumed 31% more energy (665 kJ; 159 kcal) and men consumed 56% more energy (1485 kJ; 355 kcal), than when served the 6-inch sandwich (17). In both of these studies, participants reported similar ratings of hunger and fullness at the end of the meals, despite large differences in intake. It is possible that the larger portions of food influenced subjects' expectations of the amount they could eat, which in turn affected their ratings of hunger and fullness. These results suggest that, in some circumstances, as portion size is varied, individuals adjust their perception of satiety cues while consuming more food.

The effect of portion size has also been observed in more naturalistic settings. A study in a cafeteria-style restaurant tested whether increasing the portion size of a pasta entrée from 248 g (standard portion, 1766 kJ; 422 kcal) to 377 g (large portion, 2647 kJ; 633 kcal), while keeping the price the same, would affect intake (18). Increasing the portion of pasta by 50% was associated with a 43% increase in energy intake (719 kJ; 172 kcal) for the pasta.

Without additional data, it could be argued that the effect of portion size on intake has little effect on body weight, because individuals may compensate for increased food intake by eating less at the following meal. One recent study examined how the portion size of a snack affects the energy intake of both the snack and the subsequent meal (19). On different days, subjects were served different package sizes of potato chips (28, 42, 85, 128, or 170 g) as an afternoon snack and were later served a standard dinner. Both men and women significantly increased their intake of potato chips as the package size increased. For example, when served the 170 g package, women ate 18% more and men ate 37% 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.

To investigate whether portion size has an impact on intake beyond a single eating occasion, Rolls et al (20) conducted a study in which they increased the portion size of all foods served at meals and snacks over 2 d. It was again found that increasing portion sizes led to significantly increased energy intake. When the portions of all foods were doubled, energy intake on both days increased by a mean of 26% for both women and men [2218 kJ/d (530 kcal/d) for women and 3402 kJ/d (813 kcal/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 first day by reducing their intake on the second day. These data demonstrate that the effects of portion size can persist over several days, resulting in substantial increases in food and energy intake. Future studies are needed to determine whether these effects continue over the long term and have an effect on body weight.

The experimental evidence demonstrates that portion size has a significant effect on food intake in adults in the short term. The effect of portion size was seen not only with a variety of foods in single meals (16, 17), entrées in a restaurant (18), and foods over several days (19) (Table 1), with a variety of characteristics. Increases in intake were observed in both men and women across a range of ages, body weights, and psychological factors, such as scores for dietary restraint and depression. It is not clear why individuals consistently increased their intake as portion size

**TABLE 1**

Laboratory studies on the effects of varying the portion size and energy density of foods on energy intake (EI) and satiety in adults

Investigators	Subjects	Duration of study	Manipulation of portion size (PS) and energy density (ED)	Effect on energy intake	Effect on ratings of hunger and fullness
Portion size studies: single meal					
Rolls et al (16)	51 men and women	Lunch 1 d/wk for 4 wk	Macaroni and cheese served in different PS (500, 625, 750, or 1000 g)	Macaroni and cheese intake increased with increasing PS (mean intakes: 2284, 2552, 2728, and 2962 kJ)	Hunger and fullness ratings after lunch did not differ
Rolls et al (17)	75 men and women	Lunch 1 d/wk for 4 wk	Submarine-type sandwich served in different PS (6-, 8-, 10-, or 12-in)	Sandwich intake increased with increasing PS (mean intakes: 2406, 2941, 3226, and 3489 kJ)	Hunger ratings did not differ after the 8-, 10-, or 12-in sandwiches
Portion size studies: meal-to-meal					
Rolls et al (19)	60 men and women	Snack and dinner 1 d/wk for 5 wk	Potato chips served in different PS (28, 42, 85, 128, or 170 g)	Snack intake increased with increasing PS (mean intakes: 577, 820, 1243, 1502, and 1577 kJ)	Fullness ratings after the snack increased with increasing PS
Rolls et al (20)	32 men and women	All meals/snacks 2 d/wk for 3 wk	Variety of foods served as meals and snacks in different PS (100%, 150%, or 200%)	2-d energy intake increased with increasing PS (mean intakes: 21,644, 25,191, and 27,363 kJ)	Fullness ratings after dinner were greater after larger PS
Portion size and energy density studies					
Rolls et al (27)	42 women	Salad and pasta lunch 1 d/wk for 7 wk	Required salad varied in PS (150 or 300 g) and ED (1.38, 2.8, 5.6 kJ/g) was followed by a standard pasta dish eaten ad libitum	Meal energy intake (pasta with salad) was minimized with large salad of lowest ED	Fullness ratings were increased by salad PS but not ED
Kral et al (30)	39 women	Lunch and dinner 1 d/wk for 6 wk	Pasta lunch served in different PS (500, 700, 900 g) and ED (5.23, 7.23 kJ/g). Standard dinner meal followed.	PS and ED independently increase energy intake. Intake significantly greater (925 kJ) when served large portion of high ED compared to small portion of low ED.	Hunger and fullness ratings after lunch did not differ

increased. In the single-meal studies (16, 17), it appeared that subjects were unaware of their extra intake, in that they did not report feeling fuller after eating significantly more food. In the studies that included multiple meals (16, 17), subjects reported that they felt fuller, yet they did not respond by eating less within the meal or at subsequent meals. This suggests that adults ignore or override hunger and satiety signals when presented with large portions of food. It is possible that individuals learn to eat in the absence of hunger as young children and continue with this eating behavior into adulthood (10, 21).

Further insight into adult eating behavior is provided by recent survey data from the American Institute of Cancer Research (22). In a survey of >1000 adults, 69% indicated that, when dining out, they finish their entrées all or most of the time. Of those adults, 30% reported that they would have been satisfied with a smaller portion. This suggests that, when eating out, many adults ignore satiety signals and eat beyond the point of noticeable fullness. Additionally, many survey respondents (42%) reported that they determine the amount of food to eat according to what they are used to eating. The portion sizes that individuals customarily eat may be related to frequent exposure to large portions over time. Clearly, future studies are needed to determine the reasons that individuals fail to rely on satiety cues and instead respond to external cues in the eating environment, such as portion size.

#### ADDRESSING THE PORTION SIZE EFFECT

Strategies for addressing the influence of portion size can be directed toward either the consumer or the eating environment. For consumers, one obvious approach is education about appropriate portion sizes. Previous efforts in training individuals to estimate portions of foods have not been notably successful, however, and much work remains to be done in both research and practice in this area (23). An approach that helps consumers resist the influence of large portions and lose weight is the use of commercially packaged meals that are controlled for portion size and energy content (24–26). Another possible strategy could be to train adults to recognize and respond to their physiologic cues related to satiety, as has been done with children (11).

Restaurants and other food providers could improve the food environment by offering a wider range of portion sizes or promoting and discounting the purchase of portion sizes that are reasonable rather than oversized. Reducing the portion sizes of foods, whether as a result of individual action, public education, or commercial initiative, may be an overly simplistic approach to moderating the effect of portion size on food intake. Experimental evidence shows that, in the short term, feelings of satiety and satisfaction are determined by the amount or volume of food consumed, as well as by the energy content (27, 28). At some

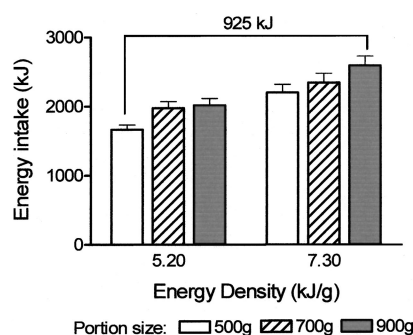
point, therefore, reductions in portion size will lead to hunger and dissatisfaction and may be perceived by consumers as negative and restrictive. More importantly, large portion sizes are not equally likely to cause overconsumption of energy for all types of foods. For these reasons, we need a directed response to the problem of portion size, which takes into account different food types and provides a positive and practical message to consumers. Recent research suggests that decreasing the energy density of foods may be an effective alternative to a general reduction in food portion sizes.

**THE ROLE OF ENERGY DENSITY**

Energy density refers to the amount of energy in a given weight of food (kilojoules per gram or kilocalories per gram). Of the components of food, water decreases energy density by adding weight but not energy, whereas fat increases the energy density of a food to a greater extent than either carbohydrate or protein. Studies that have systematically examined the effects of energy density of the diet have shown that it directly influences energy intake, an effect that is independent of the macronutrient composition of a food. In one experiment, in which energy density was manipulated but portion size was held constant, subjects were served all of their meals for 2 d on three separate occasions. The meals were mixed dishes that were either low (3.5 kJ/g; 0.8 kcal/g), medium (4.4 kJ/g; 1.1 kcal/g), or high (5.6 kJ/g; 1.3 kcal/g) in energy density. Subjects ate similar amounts of food (by weight) over the 2 d in all three conditions, regardless of the variation in energy density. As a result, when subjects were offered the lower-energy-dense foods, their energy intake over the 2 d was ≈30% less than when they were offered the higher-energy-dense foods. Despite the substantial reduction in energy intake, subjects rated themselves equally full and satisfied (29). Several other studies have confirmed that, when individuals consume meals lower in energy density, their daily energy intake is significantly lower than when they consume meals higher in energy density (29–32).

Until recently, studies have examined the effects of energy density and portion size separately from each other and determined their effects on satiation (the processes involved in the termination of a meal) and satiety (the effects of a food or a meal after eating has ended). However, under free-living conditions, individuals have access to foods that vary simultaneously in both portion size and energy density; therefore, it is important to examine how these two factors interact to affect energy intake both within a single meal and on subsequent intake.

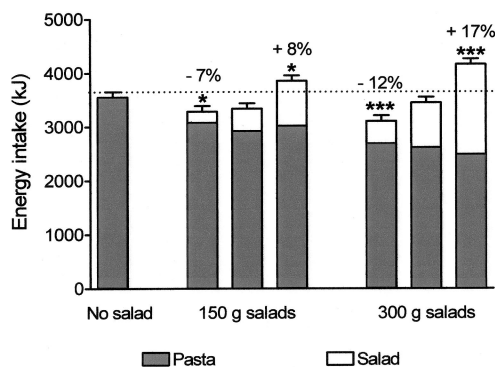
Because the energy density of food can have a significant effect on energy intake when portion sizes are similar, it is of interest to determine how the energy density of food influences intake when portion sizes are varied. The energy density of food may interact with or add to the effects of portion size on ad libitum intake. This was tested by serving women a casserole as an entrée in three different portion sizes (500, 700, and 900 g) and at two energy density levels [5.23 kJ/g (1.25 kcal/g) and 7.33 kJ/g (1.75 kcal/g)] (33). Both portion size and energy density had independent effects and therefore combined to effect energy intake. Thus, subjects consumed the most energy when served the largest portion of the higher-energy-dense entrée (2594 kJ; 620 kcal) compared with when served the smallest portion of the lower-energy-dense entrée (1665 kJ; 398 kcal). The ratings for hunger and fullness did not differ between these two conditions,



**FIGURE 1.** Mean ± SEM energy intakes by energy density and portion size (*n* = 39). The figure illustrates their combined effects on energy intake (in kilojoules). Planned comparisons between the smallest portion of the lowest-energy-dense condition and the largest portion of the highest-energy-dense condition showed significant differences in intake (*P* < 0.0001). Reprinted with permission from reference 33.

despite a 56% difference in energy intake (Figure 1). Another study in which the additive effects of energy density and portion size were examined over 2 d showed that the effects persist beyond a single meal and that the large portions of higher-energy-dense foods had the greatest impact on energy intake (34). Thus, both in the short-term and over 2 d, the effects of portion size and energy density add together to influence ad libitum intake, or satiation.

For foods that are low in energy density, satisfying portions can be encouraged, because they produce fullness while adding little energy. A recent controlled study showed that consuming a large portion of a food low in energy density can even displace energy intake at the rest of the meal (27). On different days, subjects were required to consume a first course salad, which was varied in portion size (150 and 300 g) and energy density (1.38, 2.80, and 5.56 kJ/g; 0.33, 0.67, and 1.33 kcal/g); the first course was followed by a main course of pasta that was consumed ad libitum. Energy intake for the entire meal was minimized when subjects ate the large portion of the low-energy-dense salad as a first course; furthermore, when the meal included this salad, energy intake was less than when the meal was eaten with no salad at all (Figure 2). Although subjects consumed significantly less energy at the meal with the large low-energy-dense salad, they felt just as full as when they consumed the meals with the other large salads. Consuming a low-energy-dense broth-based



**FIGURE 2.** Mean ± SEM meal energy intake after consumption of compulsory first course salads that differed in portion size (in grams) and energy density (in kilojoules per gram). Difference in meal intake compared with consuming no salad: \**P* < 0.05; \*\*\**P* < 0.0001. Reprinted with permission from reference 27.

soup as a first course has also been found to reduce overall meal intake (35). Thus, the experimental evidence shows that using the effects of both the portion size and energy density of foods is effective in maintaining satiety and reducing energy intake in the short term.

These studies indicate that energy density and portion size work together to influence energy intake and satiety (Table 1). The findings suggest several different strategies that can help to lower energy intake and increase satiety. When choosing entrées to be consumed ad libitum, reductions in both energy density and portion size can significantly decrease energy intake while maintaining fullness. Conversely, when choosing a first course, the greatest enhancement of satiety and reduction in overall meal intake was seen with large portions of foods low in energy density, such as salad or soup. Simple strategies to lower the energy density of meals involve reducing fat and adding water-rich foods, such as soups, vegetables, and fruits (36, 37).

### IS IT POSSIBLE TO EAT SATISFYING PORTIONS AND LOSE WEIGHT?


A crucial question is whether consuming low-energy-dense foods is an effective long-term strategy for controlling hunger while reducing energy intake and thus will result in weight loss. This strategy was tested in a recent clinical trial (38). One group of obese women was counseled to incorporate into their diet satisfying portions of low-energy-dense foods, such as fruits, vegetables, and broth-based soups, and to choose and prepare foods with less fat. A comparison group was counseled to limit the portions of all foods and to reduce their fat intake. After 6 mo, the women who were advised to eat more low-energy-dense foods consumed significantly more servings of low-energy-dense fruits and vegetables than the comparison group and thus decreased the energy density of their diets. These dietary changes were associated with a 40% greater weight loss in the reduced-energy-density group (9.0 kg; 20 lb) than in the comparison group (6.7 kg; 15 lb) after 6 mo. Contrary to standard advice to eat small portions to lose weight, advice to eat satisfying portions of low-energy-dense foods was a more successful strategy for weight loss. Thus, when giving dietary advice for weight management, the emphasis should be on the types of food that can be eaten in satisfying portions instead of on restrictive messages that advocate reducing the portions of all foods. If individuals choose foods that are low in energy density, they will be able to eat their usual amount of food, and this will help to eliminate the sense of deprivation that can accompany energy restriction.

### CONCLUSIONS

As obesity rates continue to rise, it is important to understand how properties of food such as portion size and energy density influence energy intake and weight status. The available data indicate that the effects of portion size and energy density combine so that large portions of energy-dense foods are particularly likely to stimulate overconsumption of energy. Although individuals respond to large portions of a variety of foods by increasing energy intake, they do not consistently report or respond appropriately to increased feelings of satiety. The abundance of large portions of inexpensive, energy-dense foods in the current eating environment appears to override satiety mechanisms so

that individuals consume more energy than is required for physiologic needs.

Multifaceted approaches are needed that will involve changes to the current food environment, educational initiatives, and participation by individuals (5). Food providers can help individuals moderate their intake by offering foods in a variety of portion sizes that are reduced in energy density and that are palatable and economical. Such food modifications may be particularly successful if they involve little change in consumer behavior. For example, people have come to accept current food products, such as yogurt, that have been reduced in fat and energy density. This is because yogurts have been formulated to remain palatable, the changes are subtle, and the price is acceptable. Other popular foods, such as burgers and sandwiches, could also be modified to decrease the energy density by combining a reduction in fat content with the addition of water-rich vegetables (7). This would allow consumers to eat their usual portions but with less energy and fat.

Well-funded initiatives are vital to provide individuals with the knowledge and skills to make necessary changes. Such initiatives should include tools to aid selection of appropriate portions and should provide information about how the energy density of foods affects decisions about portion size. Consuming low-energy-dense foods allows individuals to decrease energy intake while still consuming satisfying portions and maintaining satiety. Large portions of foods low in energy density, such as fruits and vegetables, are not only acceptable but should be encouraged. Public health messages promoting low-energy-dense foods can be an effective strategy to counteract the effect of large portions on intake and can help to enhance satiety and control hunger while restricting energy intake for weight management. 

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