Portion size of food affects energy intake in normal-weight and overweight men and women[1–3]

Barbara J Rolls, Erin L Morris, and Liane S Roe

ABSTRACT

Background: Large portions of food may contribute to excess energy intake and greater obesity. However, data on the effects of portion size on food intake in adults are limited.

Objectives: We examined the effect of portion size on intake during a single meal. We also investigated whether the response to portion size depended on which person, the subject or the experimenter, determined the amount of food on the plate.

Design: Fifty-one men and women were served lunch 1 d/wk for 4 wk. Lunch included an entrée of macaroni and cheese consumed ad libitum. At each meal, subjects were presented with 1 of 4 portions of the entrée: 500, 625, 750, or 1000 g. One group of subjects received the portion on a plate, and a second group received it in a serving dish and took the amount they desired on their plates.

Results: Portion size significantly influenced energy intake at lunch ($P < 0.0001$). Subjects consumed 30% more energy (676 kJ) when offered the largest portion than when offered the smallest portion. The response to the variations in portion size was not influenced by who determined the amount of food on the plate or by subject characteristics such as sex, body mass index, or scores for dietary restraint or disinhibition.

Conclusions: Larger portions led to greater energy intake regardless of serving method and subject characteristics. Portion size is a modifiable determinant of energy intake that should be addressed in connection with the prevention and treatment of obesity. *Am J Clin Nutr* 2002;76:1207–13.

KEY WORDS Portion size, serving size, serving method, energy intake, food intake, obesity, adults

INTRODUCTION

The current eating environment is characterized by convenient, relatively inexpensive, highly palatable foods served in large portions. The portion sizes of foods that are sold for immediate consumption have increased in recent years (1, 2), and this trend parallels the rising prevalence of obesity in the United States (3). Frequent opportunities for the consumption of large quantities of food, especially food that is high in energy density, may be contributing to excess energy intake and thus the development of obesity (4).

To link large portion sizes of food to excess energy intake and the increased prevalence of obesity, the effect of portion size on food intake must be established. Only a limited number of studies have examined this relation (5–9). Two studies conducted in young men have provided conflicting results. In one study, when investigators manipulated the portion size of lasagna, results indicated that the men consumed a significantly greater amount of food only when there was at least a doubling in portion size (5). In contrast, a preliminary study indicated that men consumed a significantly greater amount of macaroni and cheese when they were served portions that were as little as 27% larger (6).

In the studies that found an effect of portion size, subjects were presented with predetermined portions, and they ate the food directly from the plate on which it was served. In other studies of food intake regulation, in which the subjects themselves determined the amount of food to place on their plates, they ate a relatively consistent weight of food (10–13). These differing results suggest that the serving method may be an important determinant of whether portion size has an effect on intake. We hypothesized that when the subjects themselves determined the portion of food on the plate, the amount presented in a serving dish would not affect intake, but when the experimenter determined the portion on the plate, portion size would influence intake.

It is possible that some individuals, such as those who are overweight or obese, are particularly susceptible to the influence of portion size. Results are inconsistent, however, in studies that tested whether obese individuals are more likely than normal-weight individuals to be responsive to variations in portion size (7, 9), to clean their plates (14, 15), or to have impaired ability to estimate portion size (16). Independent of body weight, a tendency toward either dietary restraint or disinhibition could influence how people respond to increases in portion size (17, 18). We predicted that subjects with high dietary restraint, who have a tendency to deliberately restrict their food intake, would resist this environmental influence and would be minimally affected by portion size. On the other hand, subjects with high disinhibition, who are more prone to eat in response to environmental cues, would be directly influenced by portion size. We also investigated whether women and men had different responses to variations in portion

[1] From the Department of Nutritional Sciences, The Pennsylvania State University, University Park, PA.

[2] Supported by grants DK39177 and DK59853 from the National Institutes of Health.

[3] Reprints not available. Address correspondence to BJ Rolls, Department of Nutritional Sciences, 226 Henderson Building, The Pennsylvania State University, University Park, PA 16802-6501. E-mail: bjr4@psu.edu.

Received November 21, 2001.

Accepted for publication February 22, 2002.

size; in an earlier study, men were found to be less likely than women to stop eating for external reasons, such as having cleaned their plates (19).

SUBJECTS AND METHODS

Subjects

We recruited 51 male and female participants through advertisements in local and university newspapers and posters. Potential subjects were interviewed by telephone to determine that they were aged 21–40 y, were in good health, were not currently following a weight-loss diet or trying to gain weight, were not using medication known to affect food intake or appetite, were not athletes in training, were not pregnant or lactating, had no food allergies or food restrictions that would affect food intake, and regularly ate 3 meals/d. Potential subjects completed the following questionnaires in our laboratory: the Eating Inventory (20), which measures dietary restraint (possible score: 0–21), perceived hunger (possible score: 0–14), and disinhibition (possible score: 0–16); the original-scale Eating Attitudes Test (EAT–40; 21), which detects symptoms of an eating disorder (possible score: 0–120); the Zung Self-Rating Depression Scale and Depression Status Inventory (Zung Questionnaire; 22), which is an indicator of depression (possible score: 0–63); and a detailed demographic questionnaire. Measurements of weight and height were also taken at this time. Candidates were included in the study only if their body mass index (BMI; in kg/m^2) was 20–28. Potential subjects were excluded if they scored ≥30 on the EAT–40 or ≥40 on the Zung Questionnaire or if they reported that they disliked any of the foods to be served at the test meal. The subjects were not informed of the actual purpose of the study but were told that the purpose was to examine the effects of lunch on taste. The subjects were compensated for their participation. The Institutional Review Board of The Pennsylvania State University approved all aspects of the study.

Design

The experiment used a between-subjects design with repeated measures within each group. On 4 separate days, subjects came to the laboratory to eat lunch, which included an entrée of macaroni and cheese. In each experimental condition, subjects were presented with 1 of 4 portion sizes of the lunch entrée: 500, 625, 750, or 1000 g. The smallest portion (500 g) of the macaroni and cheese was selected to be larger than typical intakes under laboratory conditions. The order of presentation of the portion sizes was balanced across subjects, and the test days were separated by ≥1 wk. The method of serving the lunch entrée was the between-subjects factor: one group of subjects received the entrée on a plate, and the other group of subjects received it in a serving dish and took the amount they desired onto their plates. Subjects were assigned to the 2 groups so that the groups were matched for age, sex, BMI, and scores for dietary restraint and disinhibition.

Procedures

Subjects were asked to keep their evening meal and their activity level as similar as possible on the day before each test day and to refrain from eating or drinking (except water) after 2200. Subjects were also asked to refrain from drinking alcohol on the day before and throughout each test day and to eat a similar breakfast on the morning of each test day. During each test day, subjects were instructed not to consume any food or energy-containing beverages for 3 h before the test meal and not to drink water for 1 h before the test meal. On completion of each test meal, subjects were instructed not to consume any food or energy-containing beverages for the next 3 h and to eat a similar dinner on the evening of each test day. Subjects kept a brief record of their food intake and activity patterns on the day before and the day of each test meal; the purpose of the record was to encourage compliance with the study protocol.

On each test day, subjects reported to the laboratory at their designated lunchtime. At that time, the food and activity records were collected and subjects completed a brief questionnaire to determine whether they felt well, had consumed alcohol in the previous 24 h, had taken any medications known to affect appetite or food intake, or had consumed any food or energy-containing beverages in the 3 h preceding the test meal or water in the 1 h preceding the test meal. The experimenters reviewed the records and questionnaires to monitor compliance with the study protocol. Subjects who failed to comply with the protocol were scheduled for another test day.

At the start of each test meal, subjects were seated in individual cubicles and were not allowed to read or do work during the meal. Lunch consisted of commercial macaroni and cheese in various portion sizes (Kraft Foods, Inc, Glenview, IL), carrot sticks (30 g), a snack-size milk chocolate bar (17 g), and water (1 L). Subjects were instructed to eat as much or as little of the macaroni and cheese as desired and to drink as much or as little of the water as desired. Subjects were required to consume the carrots and chocolate in full. All food items were weighed before and after the meal to determine the amount consumed to the nearest 0.1 g, and the duration of the meal was recorded to the nearest 0.5 min. For persons in the serving-dish group, the amount of macaroni and cheese that was removed from the dish but left uneaten on the plate was also measured. Energy and macronutrient intakes of each food were calculated with the use of nutrition information from the food manufacturers. The energy density of the macaroni and cheese was 6.8 kJ/g.

Subject groups

Subjects were assigned to 1 of 2 groups (plate group or serving-dish group), which differed in the method in which they were served the lunch entrée. Subjects in the plate group received the macaroni and cheese on individual 30-cm plates and ate the food directly from their plates. Subjects in the serving-dish group received the entrée in a large serving dish and were instructed to serve the food from the dish onto a 30-cm plate before eating; they were allowed to serve themselves as many times as desired. The test meals of subjects in the serving-dish group were videotaped in an unobtrusive manner. The experimenters viewed the videotapes and counted the number of serving spoonfuls of the entrée that were taken from the serving dish during each meal.

Visual analogue scale ratings

Subjects completed ratings of hunger and satiety immediately before and after lunch. Subjects rated their hunger, thirst, prospective consumption (how much food they thought they could eat), nausea, and fullness on visual analogue scales (VASs). For example, subjects answered the question "How hungry are you right now?" by rating hunger on a 100-mm line anchored by "not hungry at all" on the left end and "extremely hungry" on the right end. Other anchors consisted of the phrases "not at all" and "extremely"

TABLE 1
Subject characteristics[1]

	Plate group (n = 14 M, 13 F)	Serving-dish group (n = 12 M, 12 F)
Age (y)	22.0 ± 0.4	22.5 ± 0.6
Height (cm)	171 ± 2	170 ± 2
Weight (kg)	69.3 ± 2.0	69.5 ± 2.4
BMI (kg/m^2)	23.5 ± 0.4	23.9 ± 0.4
Dietary restraint score[2]	4.9 ± 0.8	6.7 ± 0.9
Disinhibition score[2]	3.6 ± 0.4	3.4 ± 0.4
Hunger score[2]	4.9 ± 0.5	4.5 ± 0.6
Depression score[3]	29.5 ± 1.0	29.5 ± 1.0
Eating attitudes score[4]	7.0 ± 0.6	8.0 ± 0.7

[1] $\bar{x}$ ± SEM. There were no significant differences in means between subject groups.
[2] Eating Inventory (20).
[3] Zung Questionnaire (22).
[4] Eating Attitudes Test (21).

combined with the adjectives "thirsty," "nauseated," and "full." The anchors for the rating of prospective consumption were "nothing at all" and "a large amount." Immediately before and after lunch, subjects were also presented with 10-g samples of macaroni and cheese, which were rated for palatability (pleasantness of appearance, odor, taste, and texture) with the use of VASs. Subjects were excluded from the experiment if their rating for the taste of the entrée was < 40 mm on the first test day.

Discharge

Subjects completed a discharge questionnaire at the end of the study, which asked what they thought was the purpose of the study, whether there were any factors that affected their responses, and whether they noticed any differences between the test days. The questionnaire also asked whether the subjects had eaten any foods between meals that were unreported and whether the amount of macaroni and cheese offered was appropriate. Subjects also completed the Eating–Then and Now questionnaire (23), which was used to assess past and current eating habits, including frequency of cleaning the plate.

Statistical analyses

Data were analyzed with the use of the SAS System for WINDOWS, version 8.1 (SAS Institute Inc, Cary, NC). Food intake (g), energy intake (kJ), mean duration (min), and VAS ratings (mm) were analyzed with the use of a mixed linear model (PROC MIXED, SAS Institute, Inc) with repeated measures. The fixed factor effects in the model were portion size (500, 625, 750, and 1000 g) and serving method (plate or serving dish); subjects were treated as a random effect. The interaction between portion size and serving method was tested for significance before examination of the main effects of these factors. The residuals from the model for food intake at lunch were examined for normality and equal variance. Regression analysis was used to calculate the within-subject slope for food intake (amount eaten/amount presented). We used t tests to compare data on subject characteristics between groups. Results were considered significant at $P < 0.05$. For subjects in the serving-dish group only, the average amount of macaroni and cheese per serving spoonful was calculated by dividing the weight of food removed from the dish by the number of serving spoonfuls taken (assessed from the videotapes).

We did not define criteria for identifying outlying values of food intake for individual subjects, because we were testing whether intake increased with portion size. Instead, we identified subjects who consumed the entire portion of macaroni and cheese presented at any test meal. Subjects who left < 30 g macaroni and cheese uneaten were considered to have consumed the entire portion and were defined as plate cleaners. Mean intakes and ratings were analyzed both with and without subjects who cleaned their plates in any condition.

To examine the influence of subject characteristics on the relation between portion size and intake, the factor of subject sex was added to the model. The interactions of serving method, portion size, and sex were tested to determine the factors to use in the model. Continuous subject characteristics were then tested as covariates in this model. Results are reported as means ± SEMs.

RESULTS

Subjects

Fifty-nine subjects were selected for participation, but 8 subjects did not complete the study: 5 were excluded for reporting a low rating for the taste of the macaroni and cheese, 2 had scheduling conflicts that prevented completion of the study, and 1 withdrew from the study because of illness. The final sample consisted of 51 normal-weight and overweight men and women aged 21–30 y. There were 27 subjects in the plate group and 24 in the serving-dish group; the 2 groups did not differ significantly in any of the subject characteristics that we measured (**Table 1**). Male and female subjects did not differ in age (men, 22.6 ± 0.5; women, 21.9 ± 0.4 y), scores for disinhibition (men, 3.3 ± 0.3; women, 3.7 ± 0.5) or hunger (men, 5.2 ± 0.6; women, 4.2 ± 0.5), or scores on the EAT–40 (men, 8.0 ± 0.5; women, 6.9 ± 0.7). Men, however, had a significantly greater BMI than women had (men, 24.3 ± 0.4; women, 23.0 ± 0.4; $P = 0.04$), whereas women had significantly higher scores for dietary restraint (men, 4.2 ± 0.8; women, 7.4 ± 0.9; $P = 0.007$) and depression (men, 27.8 ± 0.9; women, 31.3 ± 0.9; $P = 0.008$).

Food and energy intake

Subjects in both groups consumed significantly greater amounts of the lunch entrée as portion size increased ($P < 0.0001$; **Figure 1**); there was no interaction between serving method and

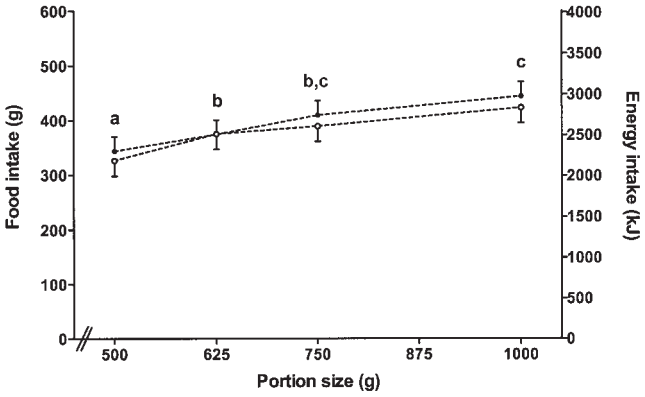

FIGURE 1. Mean (±SEM) food and energy intake of the lunch entrée by condition of portion size in each subject group (●, plate group, n = 27; ○, serving-dish group, n = 24). Means with different letters were significantly different with both groups combined, $P < 0.05$.

TABLE 2
Ratings of hunger and satiety after lunch by subject group and portion size[1]

	Plate group (n = 27)				Serving-dish group (n = 24)			
	Portion size				Portion size			
	500 g	625 g	750 g	1000 g	500 g	625 g	750 g	1000 g
"How hungry do you feel right now?"	14 ± 3.0	10 ± 2.1	8 ± 2.0	11 ± 2.7	9 ± 1.8	9 ± 2.0	8 ± 2.4	7 ± 1.6
"How thirsty do you feel right now?"	17 ± 2.7	17 ± 2.6	17 ± 2.7	16 ± 2.8	15 ± 2.9	15 ± 2.8	10 ± 2.3	12 ± 3.3
"How much food do you think you could eat right now?"	13 ± 2.0	9 ± 1.8	9 ± 1.2	10 ± 1.7	11 ± 1.8	9 ± 1.9	8 ± 1.7	8 ± 1.5
"How nauseated do you feel right now?"	10 ± 2.5	8 ± 1.9	8 ± 2.0	12 ± 2.4	2 ± 0.4	4 ± 1.0	7 ± 3.0	5 ± 2.0
"How full do you feel right now?"	79 ± 2.9	82 ± 2.3	80 ± 2.6	81 ± 3.1	83 ± 2.8	85 ± 2.6	87 ± 2.6	82 ± 4.2

[1] $\bar{x}$ ± SEM. There were no significant differences in means between conditions in either group.

portion size. When both subject groups were combined, the participants consumed 335 ± 15 g of the 500-g portion, 374 ± 19 g of the 625-g portion, 400 ± 22 g of the 750-g portion, and 434 ± 26 g of the 1000-g portion. Energy intakes in the 4 conditions of portion size were 2286 ± 103, 2553 ± 126, 2728 ± 149, and 2962 ± 181 kJ, respectively. Thus, subjects consumed 30% more food (99 g) and energy (676 kJ) when presented with the largest portion than when presented with the smallest portion. Intakes in all conditions were significantly different from each other ($P < 0.05$), except for those between the 625-g and 750-g conditions ($P = 0.097$). The proportion of the lunch entrée that was eaten decreased significantly as the portion size increased ($P < 0.05$); subjects in both groups consumed 67% of the smallest portion but only 43% of the largest portion. Intake of water at lunch did not differ by condition of portion size (data not shown).

Plate cleaners

Five persons in each group were identified as plate cleaners, because at ≥ 1 test meal they consumed all but 30 g of the entrée that was presented to them. All 10 of these persons consumed the entire 500-g portion, 5 consumed the entire 625-g portion, 3 consumed the entire 750-g portion, and 1 consumed the entire 1000-g portion. Eight of the plate cleaners were men and 2 were women.

When plate cleaners were excluded from the analysis, the effect of portion size on intake remained; subjects in both groups consumed a significantly greater amount of food as portion size increased ($P < 0.0001$). Thus, plate cleaners were not responsible for the effect of portion size on intake. With plate cleaners excluded, subjects in both groups consumed 27% more food (79 g) and energy (536 kJ) when they were presented with the largest portion than when they were presented with the smallest portion.

Visual analogue scale ratings

Ratings of hunger and satiety

Across all conditions of portion size, no significant differences were found before lunch in ratings of hunger, prospective consumption, fullness, thirst, or nausea in either group (data not shown). After lunch, there were also no significant differences between conditions in these ratings (**Table 2**). In particular, although food intake increased as portion size increased, ratings of hunger and fullness after lunch did not differ.

Ratings of palatability of the entrée

Across all conditions of portion size, no significant differences were found before lunch in ratings of appearance, odor, taste, or texture of the sample of macaroni and cheese in either group (data not shown). Taste ratings of the sample presented before lunch indicated that overall the entrée was well liked (70 ± 3.0 mm). After lunch, there were also no significant differences across conditions in ratings of palatability in either group. The taste ratings after lunch for both subject groups combined were 38 ± 0.0, 37 ± 0.1, 34 ± 0.2, and 34 ± 0.9 mm in the 500-, 625-, 750-, and 1000-g conditions, respectively.

Changes in ratings (from before lunch to after lunch)

There was no effect of serving method or portion size on the magnitude of the changes from before lunch to after lunch in the ratings of either hunger and satiety or palatability (data not shown). Subjects in both groups and across all conditions of portion size had similar changes in all of the ratings.

Influence of subject characteristics

Results of the analysis of the subject characteristics indicated that both men and women responded to portion size, such that increasing the portion size resulted in a significant increase in food and energy intake ($P < 0.001$; **Figure 2**). Female subjects, however, ate a mean of 30% less food than did male subjects. Regression analysis showed that, for every 100-g increase in portion size, the men had an increase in intake of 25 ± 7 g, whereas the women had an increase of 13 ± 3 g; these slopes were not significantly different ($P = 0.11$). None of the other subject characteristics—age; height; weight; BMI; scores for dietary restraint, disinhibi-

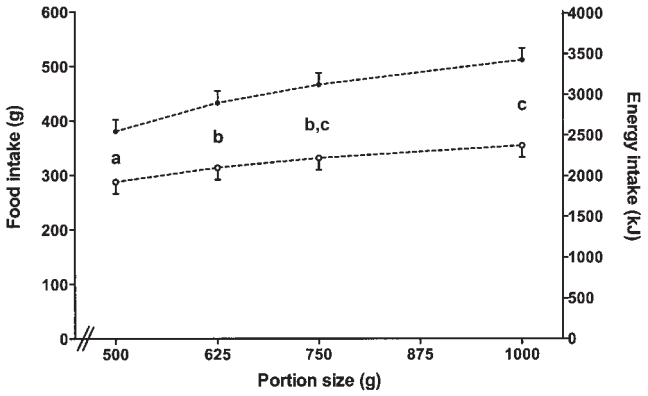

FIGURE 2. Mean (± SEM) food and energy intake of the lunch entrée by condition of portion size in males (●; n = 26) and females (○; n = 25). Data from both of the serving method groups were combined. Means with different letters were significantly different with both sexes combined, $P < 0.05$.

tion, or hunger; or scores on the EAT–40, Zung, or Eating–Then and Now questionnaires—covaried with the effect of portion size on the intake of macaroni and cheese. Thus, men and women, normal-weight and overweight individuals, and restrained and unrestrained eaters all showed a response to portion size.

Meal duration and serving frequency

The analysis of meal duration showed that portion size significantly affected the amount of time that the men spent eating ($P < 0.003$) but had no significant effect on the amount of time that the women spent eating ($P > 0.05$). The men spent an average of 12 ± 0.8 min eating when offered the smallest portion of macaroni and cheese and an average of 15 ± 0.8 min eating when offered the largest portion. The women ate for a mean of 11.5 min regardless of the portion size offered.

The videotape data for the serving dish group showed that the total number of spoonfuls taken from the serving dish did not differ significantly across conditions of portion size. Subjects served themselves a mean of 7 times regardless of the amount of food in the serving dish. Thus, as the portion presented in the dish increased, subjects took a significantly greater amount per serving spoonful ($P < 0.05$). By calculation, the mean amount per spoonful was 49 ± 3, 52 ± 3, 64 ± 7, and 55 ± 3 g in the 500-, 625-, 750-, and 1000-g conditions, respectively. Subjects in the serving-dish group left some plate waste in only 15% of their meals; the amount ranged from 2 to 34 g. Thus, after these subjects served the food onto their plates, they left very little of it uneaten.

Discharge

Most subjects (94%) did not correctly report the purpose of the study. Three subjects (2 from the plate group and 1 from the serving-dish group), however, correctly reported that the purpose of the study was to investigate whether the amount of food that was offered affected the amount that they ate. Less than one-half (45%) of the subjects reported that they noticed differences in the portion sizes of the macaroni and cheese that were presented to them. Whereas 26 subjects reported that the amount of macaroni and cheese offered was appropriate for them, 23 subjects indicated that the portion sizes were too large, 1 subject indicated that some portion sizes were appropriate and some were not, and 1 subject indicated that the portion sizes were too small.

DISCUSSION

The results of this study show clearly that increasing the portion size of macaroni and cheese affects food intake in adults during a single meal. There was a significant relation between the amount of food offered and energy intake. In contrast with the few previous studies, we showed that persons responded to both small and large increases in portion size and that there was little attenuation of the response over the range of portions tested. Presumably, however, regardless of the amount of food available, people will reach a maximum amount of any one food that they can consume. Further intake may be curtailed by sensory-specific satiety for that food or by general satiety factors such as gastric distension (24).

The finding that the ratings of hunger and fullness after the meal did not vary, although intake increased with the amount of food that was presented, suggests that portion size influences the development of hunger and satiety. Thus, when offered bigger portions, subjects ate a larger amount before they reached satiation. In addition, portion size did not affect the change in the hedonic response to the entrée after it was consumed. Typically, as a food is eaten, the pleasantness of its sensory properties decreases, and this is one factor limiting further intake of that food (25). In the present study, the rating of pleasantness of the taste of the macaroni and cheese did decrease after lunch; the decrease in the rating was similar for all conditions of portion size, however, despite substantial differences in the amount of food consumed. Therefore, the magnitude of the decrease in sensory ratings was not influenced by the weight of food that was consumed or by the food's energy content. In contrast with these findings, previous studies showed that the weight or volume of food consumed affects both the ratings of hunger and satiety and the change in the pleasantness of food (26–28). It is possible that the larger portions of food offered in the present study altered the subjects' expectations about the amount that they could eat, which in turn affected their ratings of hunger, fullness, and the pleasantness of the food. Previous work shows that sensory ratings can be strongly influenced by cognitive factors (29).

We hypothesized that the response to portion size would be influenced by whether it was the subject or the experimenter who determined the amount of food on the plate. Several experimental studies have shown that, when adults serve themselves, they eat a consistent weight or volume of the available foods, regardless of changes in the energy density of the foods (10–13). In those studies, the amount of food presented in the serving dish remained constant. In the present study, the amount of food in the serving dish was varied, and subjects did not eat a consistent amount of food. Portion size affected food intake similarly, whether the adults served themselves or whether someone else determined the portion on the plate. In contrast, a recent study showed that young children consumed a mean of 25% more macaroni and cheese when it was served on their plates than they did when presented with the portion in a serving bowl from which they could help themselves (30). It is not clear why the adults and children differed in their responses to portion size when they served themselves. Previous studies have indicated that children aged 3–5 y are shifting from eating primarily in response to physiologic signals to eating that depends more on environmental influences such as portion size (8, 31). They may have eaten more when a bigger portion was served to them because they have learned that cleaning the plate is what is expected and that they will be rewarded for doing so (31). When serving themselves, children may pay more attention to hunger cues. The adult subjects, on the other hand, may have become so accustomed to eating in response to the amount served that they were influenced by portion size even when they chose how much to put on their plates. This robust effect of portion size did not simply relate to a tendency to clean the plate or to avoid wasting food: few participants ate all of even the smallest portion, and the self-reported tendency to clean the plate did not relate significantly to the effect of portion size.

It is possible that people have the expectation that the amount of food served to them by others is appropriate. A survey initiated by the American Institute for Cancer Research found that >25% of the Americans polled said that they decided how much food to eat at a single sitting on the basis of how much food they were served (32). In a subsequent survey, 67% of those polled said that, when dining out, they finish their entrées most or all of the time (33). This is problematic because the number of Americans who consume a significant portion of their food intake outside the home, where others determine portion size, has risen sharply since the 1970s (34). The portion sizes used in the present study were

large, but they were consistent with those being offered in restaurants (35). Results from several studies have indicated that the frequency of consuming food in restaurants is positively associated with intakes of energy and fat and with body weight and body fatness (36–38). Because greater numbers of Americans are eating out than ever before, it is likely that the large portions typically served in restaurants are contributing to excess energy intake in the United States. It will be of interest in future studies to assess the effects of portion size in natural settings such as restaurants, cafeterias, and family meals. Recent studies suggest that it is likely that, in such settings, intake will be affected by portion size. For example, research showed that the portion of popcorn offered at movie theaters affected intake (39), and that the bigger the package size of foods such as pasta or candy, the greater the amount that subjects removed for consumption (40).

We hypothesized that some people would be more susceptible to the influence of portion size than would others. Our results show, however, that there was a substantial increase in food intake in response to larger portion size in both men and women with a range of values for BMI and scores for dietary restraint, disinhibition, hunger, eating attitudes, and depression. Thus, the ready availability of foods in large portions is likely to be facilitating the overconsumption of energy in many persons. From our results, we were unable to identify particular characteristics of persons that make them either more or less susceptible to the effect of portion size on intake. Although we found no relation with age, the subjects in the present study were aged 21–30 y. Future studies should assess adults at a wider range of ages, to determine whether the effect of portion size varies with age.

Most people are unaware of what constitutes an appropriate portion (16, 41) and, as in the present study, do not notice variations in portion size (32). Because portion size is a modifiable environmental factor, it should be addressed with regard to the treatment and prevention of obesity. One approach would be to educate people about appropriate portions and about interpreting nutrition labels. In addition, strategies that limit the amount of food available, such as eating at restaurants that offer smaller portion sizes, setting aside part of the serving at the beginning of the meal, or serving smaller amounts of food when eating at home, can help consumers avoid excess energy intake. Research indicates that the addition of portion-controlled meals to an energy-restricted, weight-loss diet increased the amount of weight that was lost (42).

The results of this study show that the amount of food that is presented during a single meal directly affects energy intake. Additional research is needed to further understand the contribution of portion size to the regulation of food intake and the development of overweight. Future studies should determine whether the effects of portion size on intake are seen with different types of foods. Macaroni and cheese is an amorphous food; ie, it has no distinct shape and is affected by the shape of its container. People find it particularly difficult to judge the portion size of amorphous foods (43). It will be of interest to assess whether intake is affected by increasing the portions of foods that come in discrete units or packages, such as sandwiches or snack foods, because research shows that there is a strong tendency for people to consume entire units of foods (44). The present study examined the effect of portion size in a single meal. It is important to determine whether the effect is sustained over a longer period and whether people compensate for excess energy intake that is due to the consumption of large portion sizes.

We thank Tanja VE Kral and Angela Sabol for their assistance in conducting the experiment and Elizabeth A Bell for her advice on study design and administration.

REFERENCES

1. Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. Am J Public Health 2002;92:246–9.
2. Harnack LJ, Jeffery RW, Boutelle KN. Temporal trends in energy intake in the United States: an ecological perspective. Am J Clin Nutr 2000;71:1478–84.
3. World Health Organization. Obesity: preventing and managing the global epidemic. Geneva: World Health Organization, 1998.
4. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. Science 1998;280:1371–4.
5. Edelman B, Engell D, Bronstein P, Hirsch E. Environmental effects on the intake of overweight and normal-weight men. Appetite 1986; 7:71–83.
6. Engell D, Kramer M, Zaring D, Birch L, Rolls BJ. Effects of serving size on food intake in children and adults. Obes Res 1995;3:381S (abstr).
7. Nisbett RE. Determinants of food intake in human obesity. Science 1968;159:1254–5.
8. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year-old but not 3-year old children's food intakes. J Am Diet Assoc 2000;100: 232–4.
9. Stunkard A, Coll M, Lundquist S, Meyers A. Obesity and eating style. Arch Gen Psychiatry 1980;37:1127–9.
10. Bell EA, Castellanos VH, Pelkman CL, Thorwart ML, Rolls BJ. Energy density of foods affects energy intake in normal-weight women. Am J Clin Nutr 1998;67:412–20.
11. Bell EA, Rolls BJ. Energy density of foods affects energy intake across multiple levels of fat content in lean and obese women. Am J Clin Nutr 2001;73:1010–8.
12. Saltzman E, Dallal GE, Roberts SB. Effect of high-fat and low-fat diets on voluntary energy intake and substrate oxidation: studies in identical twins consuming diets matched for energy density, fiber and palatability. Am J Clin Nutr 1997;66:1332–9.
13. Stubbs RJ, Johnstone AM, O'Reilly LM, Barton K, Reid C. The effect of covertly manipulating the energy density of mixed diets on ad libitum food intake in 'pseudo free-living' humans. Int J Obes Relat Metab Disord 1998;22:980–7.
14. Krassner HA, Brownell KD, Stunkard AJ. Cleaning the plate: food left over by overweight and normal weight persons. Behav Res Ther 1979;17:155–6.
15. LeBow MD, Chipperfield J, Magnusson J. Leftovers, body weight and sex of eater. Behav Res Ther 1985;23:217.
16. Young LR, Nestle M. Portion sizes in dietary assessment: issues and policy implications. Nutr Rev 1995;53:149–58.
17. Gorman BS, Allison DB. Measures of restrained eating. In: Allison DB, ed. Handbook of assessment methods for eating behaviors and weight-related problems. Thousand Oaks, CA: Sage Publications, Inc, 1995:149–84.
18. Westenhoefer J, Pudel V. Failed and successful dieting: risks of restrained eating and chances of cognitive control. In: Angel A, Anderson H, Bouchard C, Lau D, Leiter L, Mendelson R, eds. Progress in obesity research: 7th International Congress on Obesity. London: John Libbey & Company Ltd, 1996:481–7.
19. Tuomisto T, Tuomisto MT, Hetherington M, Lappalainen R. Reasons for initiation and cessation of eating in obese men and women and the affective consequences of eating in everyday situations. Appetite 1998;30:211–22.
20. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. J Psychosom Res 1985;29:71–83.
21. Garner DM, Olsted MP, Bohr Y, Garfinkel PE. The eating attitudes

test: psychometric features and clinical correlates. Psychol Med 1982; 12:871–8.
22. Zung WWK. Zung Self-Rating Depression Scale and Depression Status Inventory. In: Sartorius N, Ban TA, eds. Assessment of depression. Berlin: Springer-Verlag, 1986:221–31.
23. Branen L, Fletcher J. Comparison of college students' current eating habits and recollections of their childhood food practices. J Nutr Educ 1999;31:304–10.
24. Bell EA, Rolls B. Regulation of energy intake: factors contributing to obesity. In: Bowman B, Russell R, eds. Present knowledge in nutrition. 8th ed. Washington, DC: ILSI Press, 2001:31–40.
25. Rolls BJ. Sensory-specific satiety and variety in the meal. In: Meiselman HL, ed. Dimensions of the meal: the science, culture, business and art of eating. Gaithersburg, MD: Aspen Publishers, Inc, 2000: 107–16.
26. Bell EA, Thorwart ML, Rolls BJ. Effects of energy content and volume on sensory-specific satiety. FASEB J 1998;12:A347 (abstr).
27. Miller DL, Bell EA, Pelkman CL, Peters JC, Rolls BJ. Effects of dietary fat, nutrition labels, and repeated consumption on sensory-specific satiety. Physiol Behav 2000;71:153–8.
28. Rolls BJ, Hetherington M, Burley VJ. Sensory stimulation and energy density in the development of satiety. Physiol Behav 1988;44:727–33.
29. Rolls BJ, Andersen AE, Moran TH, McNelis AL, Baier HC, Fedoroff IC. Food intake, hunger and satiety after preloads in women with eating disorders. Am J Clin Nutr 1992;55:1093–103.
30. Fisher JO, Rolls BJ, Birch LL. Effects of repeated exposure to a large portion-sized entrée on children's eating. Obes Res 2001;9:76S (abstr).
31. Birch LL, McPhee L, Shoba BC, Steinberg L, Krehbiel R. Clean up your plate: effects of child feeding practices on the conditioning of meal size. Learn Motiv 1987;18:301–17.
32. American Institute for Cancer Research. New survey shows Americans ignore importance of portion size in managing weight. March 24, 2000. American Institute for Cancer Research home page: www.aicr.org. Internet: http://www.aicr.org/r032400.htm (accessed 8 November 2001).
33. American Institute for Cancer Research. As restaurant portions grow, vast majority of Americans still belong to "clean plate club", new survey finds. January 15, 2001. American Institute of Cancer Research home page: www.aicr.org. Internet: http://www.aicr.org/r011501.htm (accessed 8 November 2001).
34. Binkley JK, Eales J, Jekanowski M. The relation between dietary change and rising US obesity. Int J Obes Relat Metab Disord 2000; 24:1032–9.
35. Lindner L. Portion distortion. Tufts University Health & Nutrition Letter 2001;18(Feb):4–5.
36. Clemens LHE, Slawson DL, Klesges RC. The effect of eating out on quality of diet in premenopausal women. J Am Diet Assoc 1999; 99:442–4.
37. French SA, Harnack L, Jeffery RW. Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates. Int J Obes Relat Metab Disord 2000;24: 1353–9.
38. McCrory MA, Fuss PJ, Hay NP, et al. Overeating in America: association between restaurant food consumption and body fatness in healthy adult men and women ages 19 to 80. Obes Res 1999;7: 564–71.
39. Wansink B, Park SB. Accounting for taste: prototypes that predict preference. J Database Marketing 2000;7:308–20.
40. Wansink B. Can package size accelerate usage volume? J Marketing 1996;60:1–4.
41. Young LR, Nestle M. Variation in perceptions of a "medium" food portion: implications for dietary guidance. J Am Diet Assoc 1998; 98:458–9.
42. Ditschuneit HH, Flechtner-Mors M, Johnson TD, Adler G. Metabolic and weight-loss effects of a long-term dietary intervention in obese patients. Am J Clin Nutr 1999;69:198–204.
43. Slawson DL, Eck LH. Intense practice enhances accuracy of portion size estimation of amorphous food. J Am Diet Assoc 1997;97:295–7.
44. Siegel PS. The completion compulsion in human eating. Psychol Rep 1957;3:15–6.