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# Salad and satiety: the effect of timing of salad consumption on meal energy intake

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## Abstract

In a previous study, consuming a fixed amount of low-energy-dense salad as a first course reduced meal energy intake. We investigated whether this effect depended on serving salad before rather than with the main course, or on compulsory rather than ad libitum consumption. On five occasions, 46 women consumed ad libitum a main course of pasta, accompanied four times by low-energy-dense salad (300 g; 100 kcal [418 kJ]). At two meals the salad was served 20 min before the pasta (once compulsory; once ad libitum), and at two meals the salad was served with the pasta (once compulsory; once ad libitum). Results showed that adding a fixed amount of salad to the meal reduced energy intake by 11% (57±19 kcal [238±79 kJ]. Ad libitum salad consumption was less than compulsory consumption and did not significantly affect energy intake. Across all participants, the timing of serving the salad did not significantly influence energy intake, but the effect of timing depended on participant scores for flexible dietary restraint. Consuming low-energy-dense salad before rather than with the main course increased vegetable consumption by 23%. To moderate energy intake, maximizing the amount of salad eaten may be more important than the timing of consumption.

### Keywords

Energy density; Energy intake; Food intake; Preload; Satiety; Meal structure; Flexible restraint score; Human

## Introduction

To address the problem of obesity, it is important to identify effective strategies for decreasing energy intake. Research has shown that reducing the energy density of foods and meals is one promising approach for moderating energy intake in both the short and long term (Rolls, 2009; Ello-Martin, Roe, Ledikwe, Beach, & Rolls, 2007). In multiple controlled studies, consuming a preload of a low-energy-dense food such as soup, fruit, or vegetables reduced meal energy density and energy intake. It is unclear, however, whether the effect of consuming a low-energy-dense food depends upon eating it as a first course, or whether it would be as effective eaten as a side dish along with the main course. In addition, previous studies have required that participants consume a fixed amount of food (i.e., a preload),



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which may differ from the amount they would consume ad libitum; the consequences of this have received little attention. The objective of the present experiment was to investigate whether the effects of consuming a low-energy-dense salad depended on the timing of serving it within a meal (either before or with the main course), or on intake being fixed rather than ad libitum.

In a previous study of the influence of salad on satiety, we found that adding a preload of a large portion of a low-energy-dense salad to a meal reduced intake of the main course and decreased meal energy intake by an average of 12% (Rolls, Roe, & Meengs, 2004). In that study, the salad was served 20 min before the main course and the amount of salad was fixed. Other studies have shown similar effects on meal energy intake of adding a fixed preload of low-energy-dense soup (Rolls, Bell, & Thorwart 1999; Flood & Rolls 2007) or fruit (Flood-Obbagy & Rolls 2009). Because of the short interval after consuming the preload, it is likely that these results are due to engaging initial satiety mechanisms including cognitive and sensory factors (such as expectations of satiety value based on previous experience or visual and oral cues about volume), as well as early post-ingestive cues such as stomach distension (Blundell et al., 2010). There has been little investigation, however, of variations in the timing of consuming food items served within a meal. Additionally, few studies have compared the effects of meal manipulations using fixed versus ad libitum consumption. Although using fixed amounts of food reduces variability in intake, imposed consumption differs from typical eating conditions and may have consequences due to differences in demand characteristics or motivational factors (Rolls & McDermott, 1991; Finkelstein & Fishbach, 2010).

In the present experiment, the factors involved in the influence of low-energy-dense food on satiety were investigated by varying the timing of salad consumption within a meal, as well as comparing the effects of fixed and ad libitum consumption of the salad. It was hypothesized that meal energy intake would depend on when the salad was served, because satiety mechanisms would be engaged to a greater extent by consuming the salad as a first course rather than with the main course. Also of interest was whether ad libitum intake of the salad would differ when it was served alone as a first course rather than with competing foods, because this could influence energy intake. Additionally, we wanted to confirm the finding of the previous study, that although increasing the variety of food at a meal generally leads to increased energy intake (Raynor & Epstein 2001; Rolls et al., 1981), adding a low-energy-dense salad to a meal can lead to a reduction in meal intake. A final objective was to investigate whether individual characteristics such as dietary restraint affected the response to the experimental factors (Blundell et al., 2010). It was hypothesized that individuals with high dietary restraint, defined as the tendency to use conscious mechanisms to restrict food intake (Stunkard & Messick, 1985), would be less influenced by the timing of serving food within a meal. The findings of this experiment have implications for the understanding of factors affecting satiety as well as practical applications for structuring meals to modify food intake.

# Methods

## Experimental design

This experiment used a crossover design with repeated measures within subjects. On one day a week for five weeks, participants consumed a mid-day meal consisting of a main course of pasta accompanied by a large portion of low-energy-dense salad. Across the meals, the consumption of the salad was varied in two ways: whether it was served before the main course or together with the main course, and whether it was consumed in full (fixed intake) or consumed as desired (ad libitum intake). Specifically, at two meals the salad was served 20 min before the main course; one time subjects were instructed to consume the salad in full and once to consume it as desired. At two other meals the salad was served along with the main course; again, one was consumed in full and one was consumed as desired. At the remaining meal, no salad was served. The pasta was eaten ad libitum at all meals. The order of presenting the experimental conditions was counterbalanced across participants.

## Subject recruitment and characteristics

Participants for the study were recruited by advertisements in a local newspaper and by notices sent to electronic mailing lists of university staff and students. Individuals who responded to the notices were interviewed by telephone to determine whether they met the following inclusion criteria: were women between the ages of 20 and 45 years, had a reported body mass index between 18 and 40 kg/$m^2$, regularly ate three meals per day, and liked the foods to be served in the test meal. Potential participants were excluded from participation if they were dieting to gain or to lose weight, had food allergies or restrictions, were taking medications known to affect appetite, were smokers, were athletes in training, or were pregnant or breastfeeding.

Potential participants who met the initial criteria came to the laboratory for screening. At this time they completed several questionnaires, including the Zung Self-Rating Scale (Zung, 1986), which assesses symptoms of depression; the short form of the Eating Attitudes Test (Garner, Olsted, Bohr, & Garfinkel, 1982), which evaluates disordered attitudes toward food; and the Three-factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), which assesses dietary restraint, disinhibition, and tendency toward hunger. Potential participants also rated the taste of six food samples, including the two foods to be served at the test meal. The taste of each food was rated on a 100-mm visual analog scale with a left anchor of “Not at all pleasant” and a right anchor of “Extremely pleasant”. The height and weight of potential participants (without shoes and coats) was measured by trained personnel using an electronic scale and stadiometer (Seca Corp., Hanover, MD, USA). Individuals were only enrolled in the study if they scored ≤ 40 on the Zung Self-Rating Scale, scored ≤ 20 on the Eating Attitudes Test, had a measured body mass index between 18 and 40 kg/$m^2$, and rated the taste of both study foods ≥ 30 mm. Individuals gave signed informed consent to participate in the study. The consent form stated that the purpose of the research was to investigate perceptions of salad. The research was approved by the Office for Research Protections of The Pennsylvania State University, and individuals were financially compensated for their participation.

The sample size to be enrolled in the study was based on data from previous single-meal studies conducted among women. A power analysis was performed using an approximation technique based on the non-central F-distribution and an exemplary data set analyzed with a linear mixed model (Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006). The minimum clinically significant difference in meal energy intake for either experimental manipulation (timing of serving the salad or fixed versus ad libitum consumption) was assumed to be 40 kcal [167 kJ], which represents about 5 to 10% of typical lunch intakes for women in previous laboratory studies. It was estimated that a sample of 43 women would allow the detection of this difference in meal energy intake with > 80% power using a 2-sided test with a significance level of 0.05.

Fifty women were enrolled in the study. During the study, three women were excluded: two were unable to consume the fixed amount of salad within the allotted time, and one failed to return after the third meal. The data of one additional participant was identified as having undue influence on the outcomes according to the procedure of Littell et al. (Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006). After the first two meals this participant had extremely low lunch intakes (< 170 kcal [710 kJ]), and her data were excluded from analysis. Thus, 46 women were included in the study; 36 participants (78%) were normal weight, 8 (17%) were overweight, and 2 (4%) were obese. Other participant characteristics are shown in Table 1.

## Composition of test meals

The composition of the foods served at the test meal was not varied across experimental conditions. The salad was large (300 g) and low in energy (100 kcal [418 kJ]) and energy density (0.33 kcal/g [1.4 kJ/g]). The ingredients of the salad were iceberg and romaine lettuce, carrots, celery, cucumber, tomatoes, shredded light cheese (Saputo Cheese USA Inc., Lincolnshire, IL, USA), and fat-free Italian dressing (T. Marzetti Company, Columbus, OH, USA). The main course served at all test meals consisted of 700 g of cheese tortellini (Villa Frizzoni, Houston, TX, USA) with tomato sauce (Campbell Soup Company, Camden, NJ, USA); the energy density of the main course was 1.5 kcal/g [6.3 kJ/g].

## Daily procedures and data collection

Participants were tested on five occasions on the same day of the week, with at least one week between test days. They were instructed to keep their evening meal and their physical activity level consistent on the day before each test day, and to refrain from drinking alcoholic beverages on the evening before and during each test day. To encourage compliance with this protocol, participants kept a brief record of their food and beverage intake and physical activity. On test days, participants came to the laboratory at scheduled times to eat breakfast (which was not varied across test days) and the test lunch; the interval between breakfast and lunch was at least 3 h. Participants were instructed not to consume any foods or beverages, other than water, between breakfast and lunch, and not to drink any water during the hour before lunch. Prior to being served breakfast, participants completed a brief questionnaire that asked whether they had consumed any foods or beverages since awaking, had taken any medications, or had felt ill; a similar questionnaire was completed before lunch. If participants felt ill or did not comply with the study protocol, their test day was rescheduled. During all meals, participants were seated in private cubicles.



In the two test lunches which included a first course, the salad was served alone at the start of the meal; once, participants were instructed to eat as much of the salad as desired, and once, to consume the salad in full. After 20 min, participants were served the main course and were instructed to eat as much or as little as they liked. In the three test lunches without a first course, participants remained seated in the cubicle for 20 min before the main course was served, and were allowed to read magazines. In two of these conditions the salad was served along with the pasta, once with the instruction to eat as much as desired and once to be consumed in full. During these two meals, the eating cubicle was unobtrusively videotaped in order to characterize the participant's pattern of consuming the salad and pasta. In the control condition, no salad was served with the main course. The interval between serving the two courses was set at 20 min to allow sufficient time for the salad to be consumed and begin engaging satiety mechanisms, while allowing the first course and main course to be components of the same meal. At all meals, the main course was accompanied by one liter of water, which could be consumed as desired. All food items were weighed before and after meals in order to determine the amount consumed to within 0.1 g. Energy and macronutrient intakes were calculated using information from food manufacturers and a standard food composition database (U. S. Department of Agriculture, 2010).



Participants rated their hunger and fullness using visual analog scales immediately before the first course (when one was included) and immediately before and after the main course. For example, participants answered the question "How hungry are you right now?" by marking a 100-mm line that was anchored on the left with "Not at all hungry" and on the right with “Extremely hungry”. Participants also rated the characteristics of the test foods before each course of the meal; they were given a small sample of each food and used visual analog scales to rate the pleasantness of the taste and appearance (anchored by “Extremely pleasant” and “Not at all pleasant”). After the main course was completed, the taste and appearance of both foods were rated in a similar manner.

After lunch on the final test day, participants completed a discharge questionnaire in which they were asked their opinion of the purpose of the study and whether they noticed any differences between the sessions. They also reported their preference for the timing of eating a salad (before the main course, with the main course, or no preference) and their preference for the foods served at the test meal (salad, pasta, or no preference).

### Statistical analyses

Data were analyzed using a mixed linear model with repeated measures (SAS 9.1, SAS Institute, Inc., Cary, NC, USA). In order to investigate the effects of the experimental factors, the four salad conditions were compared; the fixed factors in this model were timing of serving the salad (before or with the main course), method of consuming the salad (fixed or ad libitum), and study week. The factors from the discharge questionnaire of participant food preference, timing preference, and knowledge of the study purpose were also tested in the model. The interaction of factors was investigated before examining their main effects, and a Tukey-Kramer adjustment was used for multiple comparisons where an interaction existed. To investigate the influence of serving salad at the meal compared to serving no salad, the four salad conditions were compared to the control condition. The fixed factors in this model were condition and study week; adjustments for multiple comparisons with the control condition were made using the Dunnett-Hsu method. The main outcomes analyzed for both models were energy intake for salad, for pasta, and for the entire meal, as well as overall energy density of the meal. Meal energy density was calculated on the basis of food intake only, excluding beverage intake (Ledikwe et al., 2005). The secondary outcomes analyzed were ratings of hunger and satiety and ratings of food characteristics; the ratings of hunger and satiety measured after the meal were adjusted by including the before-meal rating as a covariate in the model.

Analysis of covariance was used to examine the influence of continuous participant characteristics, such as body mass index and questionnaire scores, on the relationship between the experimental factors and the main outcomes in the salad conditions only. In addition to the factors of the TFEQ (dietary restraint, disinhibition, and tendency toward hunger), we investigated subscales from this questionnaire that have been defined by subsequent researchers (Bond, McDowell, & Wilkinson, 2001; Niemeier, Phelan, Fava, & Wing 2007; Ricciardelli & Williams, 1997). These included the dietary restraint subscales proposed for flexible control and rigid control of eating behavior (Westenhoefer, 1991). The seven items comprising the flexible restraint score focus on self-awareness of eating behavior, such as attentiveness to food intake, purposely limiting the amount eaten, and compensating for overeating by reducing subsequent intake. In contrast, the seven items contributing to the rigid restraint score emphasize dieting activities such as counting calories, controlling food purchases, and monitoring body weight.

Regression analysis was used to explore the influence of participant characteristics, regardless of the experimental conditions, on overall energy intake at lunch and on ad libitum salad intake. In the two conditions in which the salad was served along with the main course, McNemar’s test was used to compare the proportions of participants who ate the salad before starting the main course (rather than alternating between the two foods). The effect of the pattern of consuming the salads with the main course was tested by including it as a factor in a mixed model that compared only these two conditions. Daily energy requirements of participants were estimated from their sex, age, height, weight, and activity level (Institute of Medicine, 2002). Results were considered significant at $p < 0.05$ and are reported as mean ± SEM.

# Results

## Effects on energy intake

Varying the timing and method of consuming the salad had significant effects on energy intake of the salad, the pasta, and the entire meal (Figure 1). For salad intake, there was a significant interaction between the two experimental factors [F(1,45) = 7.29; $p = 0.010$]. In the ad libitum conditions, salad intake was 23% greater when it was served before the main course (71 ± 3 kcal [298 ± 13 kJ]) rather than with the main course (58 ± 4 kcal [241 ± 15 kJ]; $p = 0.0005$). Both ad libitum intakes of salad, however, were less than the compulsory salad intakes (100 kcal [418 kJ]). When the salad and pasta were served together, 48% of participants ate the ad libitum salad first (before starting the pasta) and 63% of participants ate the compulsory salad first. This difference did not reach statistical significance (McNemar's test statistic = 2.88; $p = 0.09$) and did not significantly affect energy intake at these two meals [F(1,16) = 1.25; $p = 0.28$).

For pasta intake (Figure 1), there was a main effect of the method of salad consumption [F(1,45) = 21.44; $p < 0.0001$]. Participants consumed less pasta in the conditions with ad libitum salad intake (378 ± 17 kcal [1582 ± 72 kJ]) than in conditions with compulsory salad intake (439 ± 17 kcal [1836 ± 69 kJ]). There was no significant effect of the timing of salad consumption on pasta intake; in particular, the difference in ad libitum salad intake did not significantly affect consumption of the main course in those conditions. When no salad was served, participants ate significantly more pasta (531 ± 24 kcal [2223 ± 100 kJ]) than when any salad was served [F(4,176) = 20.92; $p < 0.0001$].

Total energy intake at the meal was significantly affected by the method of consuming the salad, similar to the effects on pasta intake (Figure 1). Eating a fixed amount of salad either before or with the main course led to a decrease in meal energy intake of 28 ± 13 kcal [117 ± 54 kJ] compared to ad libitum consumption of salad [F(1,45) = 4.67; $p = 0.036$]. Compared to having no salad, consuming a fixed amount of salad significantly reduced meal energy intake by a mean of 57 ± 19 kcal [238 ± 79 kJ], equivalent to 11% [F(4, 176) = 3.08; p= 0.018]. Across all participants, total energy intake at the meal was not affected by the timing of consuming the salad; mean energy intake was 490 ± 17 kcal [2050 ± 71 kJ] when the salad was served before the main course and 488 ± 18 kcal [2042 ± 75 kJ] when the salad was served with the main course. The effect of timing of serving the salad on energy intake, however, was moderated by participant scores for flexible dietary restraint from the TFEQ (see section on participant characteristics).

## Effects on meal energy density and beverage intake

The energy density of the meal was significantly affected by both the timing and method of salad consumption [F(4, 176) = 285; p < 0.0001]; the pattern of effects was the inverse of that for salad intake. Meal energy density was highest at the meal with no salad (1.51 kcal/g [6.32 kJ/g]), decreased when the salad was consumed ad libitum *with* the main course (1.07 ± 0.02 kcal/g [4.46 ± 0.10 kJ/g]), decreased further when the salad was consumed ad libitum *before* the main course (1.00 ± 0.02 kcal/g [4.19 ± 0.08 kJ/g]), and was lowest when a fixed amount of salad was consumed either before or with the main course (0.85 ± 0.01 kcal/g [3.56 ± 0.06 kJ/g]).

Intake of water as a beverage with the main course was significantly affected by the timing of serving the salad [F(1,45) = 6.26; $p = 0.016$]. Participants drank 327 ± 17 ml water when the salad was served before the main course and 362 ± 20 ml when the salad and main course were served together. There was no significant difference in water intake between the ad libitum and fixed salad conditions [F(1,45) = 2.61; $p = 0.11$]. The amount of water consumed did not significantly affect the relationship between the experimental variables and food intake at the meal [F(5,189) = 0.74; $p = 0.59$].

## Influence of participant characteristics

Analysis of covariance showed that the effect of timing of serving the salad on meal energy intake was significantly influenced by the participant scores for flexible control of eating behavior (Westenhoefer, 1991), a subscale of the dietary restraint score from the TFEQ (Stunkard & Messick, 1985). The slopes for the relationship of meal energy intake across flexible restraint scores differed significantly between the meals in which salad was served before the main course (−19 ± 14 kcal/unit score [−79 ± 59 kJ/unit score]) and the meals in which salad was served along with the main course (−38 ± 14 kcal/unit score [159 ± 59 kJ/unit score]), as shown in Figure 2 [F(1,136) = 5.85; $p = 0.018$]. Participants with the lowest score for flexible restraint (0) consumed 56 ± 27 kcal [234 ± 113 kJ] less energy at the meal when the salad was served *before* the main course rather than along with it. Conversely, participants with the highest score for flexible restraint (6) consumed 67 ± 30 kcal [280 ± 126 kJ] less energy when the salad was served *along with* the main course. Participants who had medium scores for flexible restraint showed no significant effect of the timing of serving the salad on meal energy intake. This outcome was not significantly influenced by whether intake of the salad was fixed or ad libitum.

The relationship between the experimental variables and meal energy intake was not significantly influenced by any of the other participant characteristics, including age, body mass index, preference for timing of consuming salad, preference for salad or pasta, and other scores from the TFEQ (disinhibition, hunger, or total dietary restraint).

Regression analysis indicated that across all conditions, several individual characteristics had a significant effect on lunch energy intake. Regardless of the experimental manipulations, energy intake was negatively related to the flexible restraint score and the score on the Eating Attitudes Test, and positively related to the rigid restraint score (adjusted $R^2 = 0.19$; $p < 0.0001$). Ad libitum salad intake was positively related to participant age and height (adjusted $R^2 = 0.08$; $p = 0.011$).

## Ratings of hunger, satiety, and food characteristics

As expected, serving salad as a first course led to significant differences in hunger and fullness before the main course (Table 2). Compared to consuming no first course, ratings of hunger were lower and ratings of fullness were higher after eating a first-course salad [F(4,176) = 50.36; $p < 0.0001$]. After the main course, however, there was no significant effect of the timing of serving the salad; the only significant differences in hunger and fullness were between fixed and ad libitum consumption. When salad intake was fixed, ratings of hunger after the meal were significantly lower [F(4,175) = 9.43; $p < 0.0001$] and ratings of fullness were significantly higher [F(4,175) = 14.37; $p < 0.0001$] than when salad intake was ad libitum. Thus, ratings of hunger and fullness after the meal reflected the differences in food intake between the conditions with fixed and ad libitum consumption.

Before meals, participants gave high ratings for pleasantness of taste to samples of both the salad (mean 74 ± 2 mm) and the pasta (mean 69 ± 1 mm). After meals, the ratings of taste of the salad differed significantly by the two experimental factors. Participants rated the salad lower in taste (43 ± 3 mm versus 49 ± 3 mm) when it had been consumed before the main course rather than with the main course [F(1,45) = 6.86; $p = 0.012$]. Independent of that effect, fixed consumption of salad led to a lower rating in salad taste after the meal (43 ± 3 mm versus 49 ± 3 mm) than ad libitum consumption of salad [$F(1,45) = 5.86$; $p = 0.020$]. There were no significant differences in ratings of taste of the pasta across conditions after meals.

On the discharge questionnaire, 22 participants (48%) reported that they preferred eating a salad before the main course, 11 (24%) preferred eating a salad with the main course, and 13 (28%) reported no preference. When asked about preference for the two test foods, 20 participants (43%) preferred the salad, 11 (24%) preferred the pasta, and 15 (33%) reported no preference. Thirty participants (65%) reported that the purpose of the study was related to food intake; the remaining participants reported purposes related to taste, appetite, or more general effects. The effects of the experimental conditions were not significantly affected by whether or not the participants reported a study purpose that related to food intake, or by preference for the salad or the timing of consumption.

## Discussion

This experiment demonstrated that varying the timing of serving a salad, as well as whether its consumption was compulsory or ad libitum, affected both salad intake and meal energy intake. Ad libitum salad intake was increased 23% by serving the salad before rather than with the main course, and compulsory salad intake was even greater than ad libitum intake. Energy intake at the meal was reduced by 11% by adding a fixed amount of salad to the meal, similar to the findings of a previous study; ad libitum consumption of salad did not significantly affect meal energy intake. Across all participants, the timing of salad consumption did not affect meal energy intake; the effect of timing, however, depended on participant scores for flexible dietary restraint. Strategies that maximize consumption of low-energy-dense salad for a given individual are likely to be the most effective approach for reducing meal energy intake.

Most previous research on the influence of the timing of consumption on satiety has focused on variations in the interval between eating occasions. Studies that tested delays ranging between 15 and 180 min after consumption of preloads found that meal energy intake increased with the increasing interval (Rolls et al., 1991; de Graaf, de Jong, & Lambers, 1999). Gray et al. conducted two studies using the same soup preloads but with different intervals before the test meal (Gray, French, Robinson, & Yeomans, 2002; Gray, French, Robinson, & Yeomans, 2003). Although no statistical test was reported, the researchers noted that participants with an interval of 10 min consumed 27% less energy at the meal than those with an interval of 30 min. Across all participants in the present study, there was no difference in energy intake between consuming the salad 20 min before the main course and together with the main course.

The response of participants to the timing of serving the salad differed according to their degree of flexible control of dietary restraint. Research on dietary restraint has not always exhibited the expected relationships with either food intake (Stice, Sysko, Roberto, & Allison, 2010) or body weight (Cappelleri et al., 2009; Teixeira et al., 2010). In large studies, the subscale for flexible control of dietary restraint has been more consistently related to body mass or weight loss (Williamson et al., 1995; Westenhoefer, Stunkard, & Pudel, 1999; Provencher, Drapeau, Tremblay, Després, & Lemieux, 2003; Texeira et al., 2010), although not always (McGuire, Jeffery, French, & Hannan, 2001). In the present experiment, women with low scores for flexible control showed the hypothesized effect on meal intake. For these individuals, eating a low-energy-dense salad as a first course displaced intake of the more energy-dense main course, leading to a reduction in meal energy intake compared to eating the foods simultaneously. Women with high scores for flexible control, however, had the lowest energy intake when the salad and main course were served together. This finding could have several explanations. Controlled feeding studies have shown that among individuals with high dietary restraint, providing information about the energy content of foods can affect meal intake (Kral, Roe, & Rolls 2002; Miller, Castellanos, Shide, Peters, & Rolls, 1998). The present results suggest that flexible control of intake may be more effective when the cognitive and sensory cues from different foods at a meal are experienced simultaneously. Alternatively, it may be that in individuals with high flexible control, being presented with a larger amount and variety of food activates a greater degree of self-monitoring. Additional studies are required on the potential for characteristics such as flexible dietary restraint to moderate the response to satiety cues in the meal environment.

The comparison of fixed and ad libitum consumption of salad highlights several issues. Although the women in this experiment liked the salad and many preferred it to the main course, under ad libitum conditions they ate only about 60 to 70% of the amount they consumed in the compulsory conditions. The previous studies comparing fixed and ad libitum intake served a greater amount in the ad libitum conditions (Rolls & McDermott, 1991; de Graaf, de Jong, & Lambers, 1999). These studies showed that ad libitum intake can be made comparable to fixed intake if the serving is increased sufficiently; however, serving different portion sizes may confound the interpretation of other outcomes. Examples of cognitive factors that may influence the comparison between fixed and ad libitum intakes are perceptions of the food and the motivations for eating it (Finkelstein & Fishbach, 2010). In the present study, requiring the consumption of a fixed amount led to decreased hunger ratings and reduced meal energy intakes compared to ad libitum intake; these differences were consistent with the differences in the amount of salad consumed, but the contribution of motivational factors cannot be independently evaluated. To determine how perceptions of food affect intake, it would be of interest to test the effect of the fixed and ad libitum conditions on satiety ratings and intake when portion sizes were manipulated so that salad intakes were equal.

A main outcome of this study is that ad libitum intake of salad was increased 23% by consuming it before rather than with the main course, but this increase was insufficient to reduce energy intake of the main course and of the meal. This result is consistent with that of a previous study, which found that increasing the amount of cooked vegetables served at a meal increased ad libitum vegetable consumption, but did not significantly change intake of the other foods or energy intake at the meal (Rolls, Roe, & Meengs, 2010). Since in both studies the vegetables were low in energy density, adding them to the meal had the dual effects of increasing food portion size and reducing meal energy density; these two effects had opposite consequences on energy intake, resulting in no net difference. Although it is beneficial that including a low-energy-dense salad in the meal added a nutrient-rich food without increasing energy intake, for individuals managing their weight, it is preferable for meal energy intake to be decreased. In the present study, this result was seen only when salad intake was compulsory and thus a large amount was consumed. The salad served in this experiment was similar to one of the preloads in a previous study that found effects of salad on satiety (Rolls, Roe, & Meengs, 2004). The results of both studies showed that adding a fixed amount of low-energy-dense salad to a meal decreased energy intake in women by about 11%, despite an increase in the amount and variety of available food.

There are some aspects of the experiment that limit the generalizability of the findings. The sample included only women who reported that they were not actively dieting, thus the outcomes may not apply to men or to women who are dieting. There were no differences in energy intake between participants who chose to eat the with-meal salad before the pasta and those who ate the salad and pasta alternately; however, the statistical power for this between-subject comparison was low. It may be that consciously consuming low-energy-dense foods first can reduce meal intake without the need for separate courses, and this possibility should be investigated further. Finally, the effects on intake were only examined in the short term, and it is possible that over the longer term learning occurs and there is accommodation to the effects of timing of food consumption.

The results of this experiment confirm previous findings that adding a low-energy-dense food such as salad to a meal can reduce meal energy intake. This study extends these findings by providing information on the timing of consumption, which has implications for strategies to modify food intake at meals. If the goal is to increase vegetable intake, serving salad or soup as a first course in the absence of other foods is the most effective approach. For many people, eating a low-energy-dense first course also reduces meal energy intake (Rolls, Bell, & Thorwart 1999; Rolls, Roe, & Meengs, 2004; Flood & Rolls 2007; Flood-Obbagy & Rolls 2009). Restrained eaters who are attentive to their food intake, however, may adjust intake more readily when the low-energy-dense food is served together with other foods rather than in a separate course. Consuming a low-energy-dense salad can be used as a strategy to reduce meal energy intake, but the structure of the meal may be less important than an individualized approach that maximizes salad consumption.

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## Research Highlights

- Consuming a low-energy-dense salad at the start of a meal can reduce energy intake.
- In a crossover design, we compared serving a salad before or with the main course.
- Compulsory salad reduced meal energy intake by 11% regardless of when it was eaten.
- The effect of timing depended on participant scores for flexible dietary restraint.
- Maximizing salad intake was an effective strategy for reducing meal energy intake.

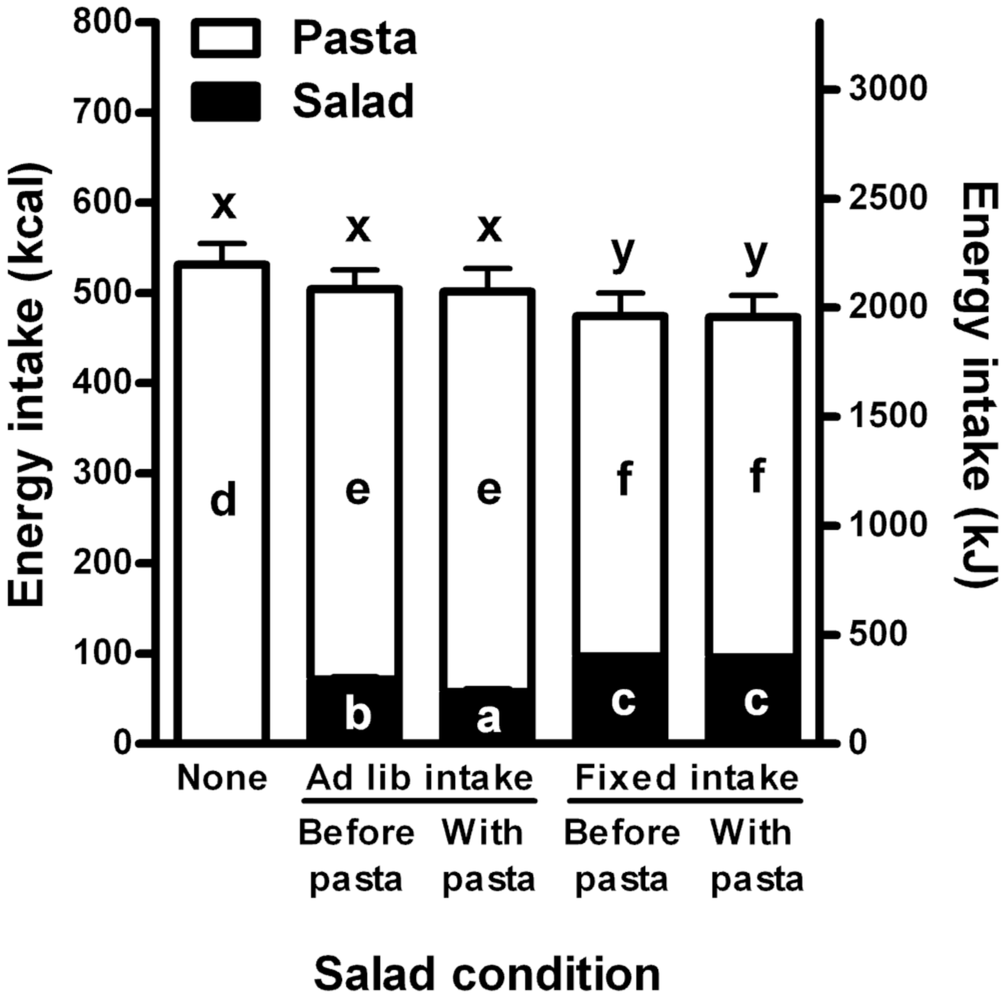


**Figure 1.**

Energy intake (mean ± SEM) of 46 women at meals in which the consumption of salad was either ad libitum or fixed, and the timing of consumption was either before or with the main course of pasta. At one meal, no salad was served. Among the four salad conditions, different letters for the same meal component indicate significant differences according to a mixed linear model with repeated measures ($p < 0.036$). For the no-salad condition, letters indicate significant differences from the four salad conditions according to a separate mixed model with a Dunnett-Hsu adjustment for multiple comparisons ($p < 0.012$).

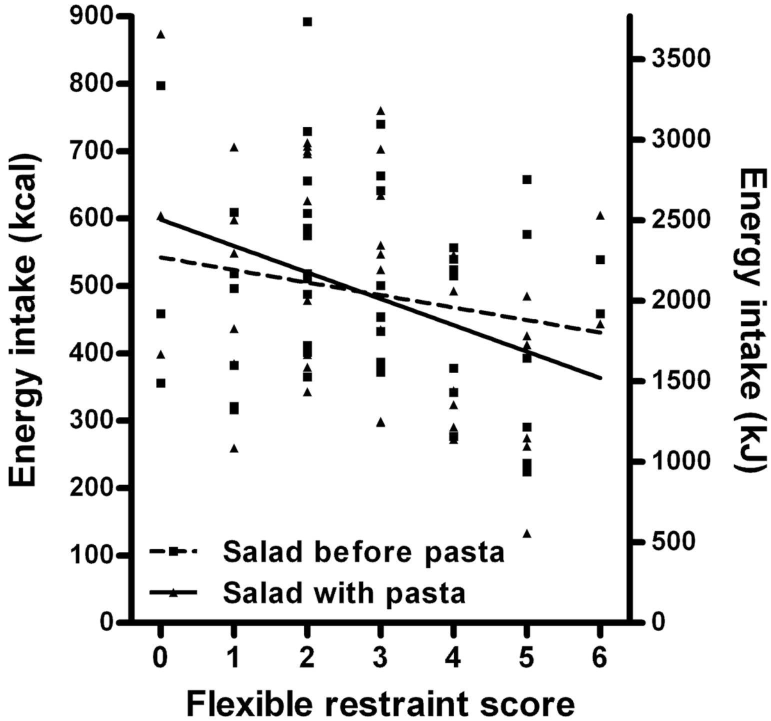


**Figure 2.**

Meal energy intakes of 46 women who consumed a salad either before or with the main course of pasta, in relation to participant scores for flexible control of restraint. The slopes of the regression lines were significantly different according to an analysis of covariance using a mixed linear model with repeated measures ($p$ = 0.018). Women with the lowest score (0) consumed 56 ± 27 kcal [234 ± 113 kJ] less energy when the salad was served before the main course and women with the highest score (6) consumed 67 ± 30 kcal [280 ± 126 kJ] less energy when the salad was served along with the main course. Energy intakes are combined for the conditions of fixed and ad libitum intake, which did not influence this outcome.




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## Table 1

Characteristics of participants (*n* = 46 women)

| | Mean | SEM | Range |
|---|---|---|---|
| Age (y) | 26.5 | 1.08 | 20 – 45 |
| Weight (kg) | 63.4 | 1.61 | 47.5 – 95.4 |
| Height (m) | 1.64 | 0.01 | 1.48 – 1.76 |
| Body mass index (kg/m$^2$) | 23.4 | 0.50 | 18.5 – 31.7 |
| Dietary restraint score[a] | 8.6 | 0.60 | 0 – 15 |
| Flexible control subscale[b] | 2.8 | 0.23 | 0 – 6 |
| Rigid control subscale[b] | 2.8 | 0.22 | 0 – 6 |
| Disinhibition score[a] | 5.3 | 0.50 | 0 – 13 |
| Hunger score[a] | 3.7 | 0.36 | 0 – 9 |

[a]Scale from Three-factor Eating Questionnaire (Stunkard & Messick, 1985).

[b]Subscale of dietary restraint score (Westenhoefer, 1991).

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**Table 2**

Ratings of hunger and fullness of participants at three time points during the meal ($n$ = 46 women)

| | Experimental condition | | | | | Significance[1] | |
|---|---|---|---|---|---|---|---|
| | No salad | Ad libitum salad intake | | Fixed salad intake | | | |
| **Rating and time point** | | **Salad before main course** | **Salad with main course** | **Salad before main course** | **Salad with main course** | **Effect of timing (before versus with main course)** | **Effect of method (ad libitum versus fixed intake)** |
| Hunger (mm)[2] | | | | | | | |
| Before first course | 62.3 ± 2.9 | 56.5 ± 2.8 | 61.2 ± 2.6 | 60.8 ± 2.8 | 60.5 ± 2.4 | NS | NS |
| Before main course | 62.8 ± 3.4 | 38.4 ± 2.6 | 63.1 ± 2.8 | 31.8 ± 2.6 | 64.8 ± 2.5 | $p < 0.0001$ | NS |
| After main course | 12.7 ± 1.7 | 7.3 ± 1.3 | 9.8 ± 1.6 | 5.6 ± 1.1 | 5.0 ± 0.8 | NS | $p < 0.001$ |
| Fullness (mm)[2] | | | | | | | |
| Before first course | 27.9 ± 3.0 | 29.3 ± 3.0 | 30.4 ± 3.0 | 29.0 ± 3.1 | 24.8 ± 3.0 | NS | NS |
| Before main course | 24.6 ± 2.9 | 53.2 ± 2.5 | 27.4 ± 3.2 | 57.5 ± 2.9 | 23.1 ± 3.1 | $p < 0.0001$ | NS |
| After main course | 77.2 ± 2.5 | 85.5 ± 1.4 | 82.3 ± 1.9 | 89.1 ± 1.7 | 88.6 ± 1.5 | NS | $p < 0.0001$ |

[1] Significance of the given effect according to a mixed linear model with repeated measures; NS indicates not significant.

[2] Ratings are from 100-mm visual analog scales