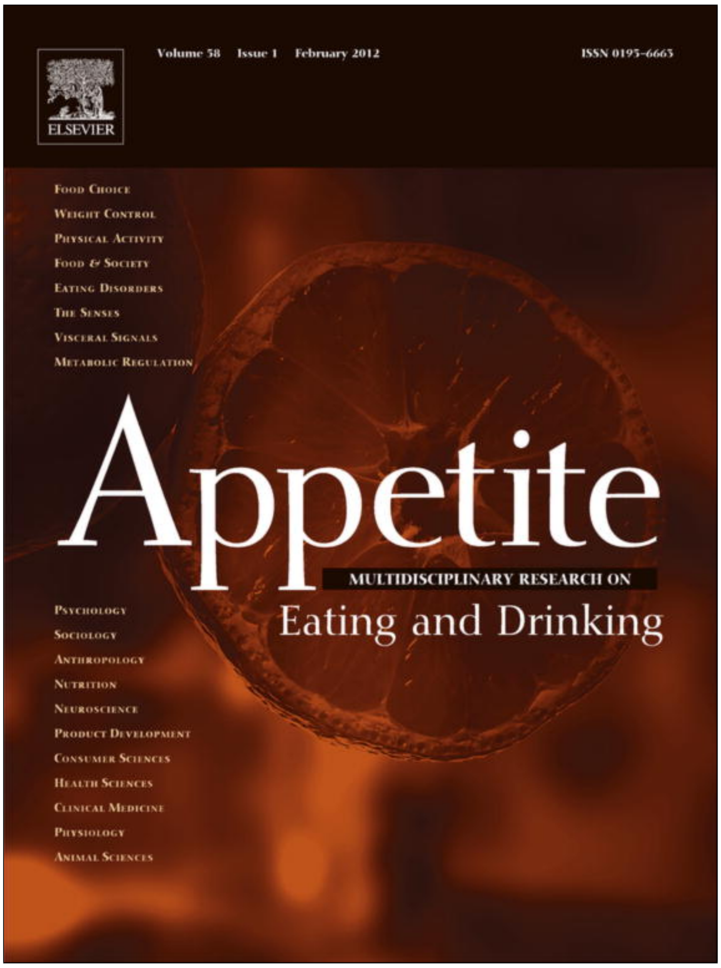
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Research report

Using a smaller dining plate does not suppress food intake from a buffet lunch meal in overweight, unrestrained women ☆

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ABSTRACT

The aim of the study was to determine whether plate size affects *ad libitum* energy intake (EI) at a buffet-style lunch in overweight, yet unrestrained women. Twenty overweight/obese (BMI = 25–40 kg/m^2) women attended two study visits, and were randomly assigned to small (19.5 cm) or large (26.5 cm) diameter plate size at a free choice lunch meal. At 9 am participants were given a small (0.5 MJ) breakfast, followed at 12 noon by the lunch meal from which they ate *ad lib* until comfortably full. Mean (SEM) EI at lunch was 3975 (239) kJ and 3901 (249) kJ respectively for small and large plate size. There was no detectable difference in EI between the two plate sizes ($P > 0.05$). When in a raised state of hunger and offered a palatable buffet meal, altering the diameter of the dining plate onto which food was self-served did not significantly alter *ad lib* EI. We conclude there was no evidence that a smaller plate suppressed EI in a group of unrestrained, overweight women encouraged to eat to appetite from a wide choice of items. Whether plate size is a useful cue for portion size, and hence control of EI, in individuals actively restricting intake however remains possible, and requires investigation.

Introduction

In our current environment where the quantities of food prepared and consumed outside the home is growing rapidly, many factors which may have had little previous relevance are becoming increasingly important. For example the portion size of foods served in restaurants, cafes, fast food or similar outlets has increased over the years (Nielsen & Popkin, 2003; Smiciklas-Wright, Mitchell, Mickle, Goldman, & Cook, 2003), and is associated with an increased food intake (Duffey & Popkin, 2011; Rolls, Roe, & Meengs, 2006; Wansink, van Ittersum, & Painter, 2006) which under many conditions may lead to overconsumption. Restricting portion sizes is a useful strategy by which to suppress energy intake (EI) and may be a useful adjunct to weight loss (Berg et al., 2008; Ello-Martin, Ledikwe, & Rolls, 2005; Pedersen, Kang, & Kline, 2007). Interestingly the manner in which foods are served, for example the container or bowl size of snack foods, has also been shown to be associated with a change in EI. For example, in early studies of snacking it was shown that presenting snacks in larger serving bowls lead to a greater intake (Wansink, 2005; Wansink et al., 2006), as did a more recent study where the presentation of chocolate snacks within larger containers again increased food intake, an effect which was independent of whether or not portion size itself increased (Marchiori, Corneille, & Keline, 2012).

In parallel with the increase in food portion size over recent years, there is also data to show that at least in the US, the average size of dinner plate onto which food is served and from which it is eaten has also increased (Klara, 2004). Whether this has an additive effect with increasing portion size on intake is less well understood. It seems perhaps not unreasonable that the use of a larger plate may lead to the serving of a larger food portion (Condrasky, Ledikwe, Flood, & Rolls, 2007), and historically recommendations have suggested that using a smaller plate at meals may be a strategy by which portion size, and hence food intake can be suppressed (National Institutes of Health, 1999; US Department of Agriculture, 2002).

There have been several studies which have investigated whether dining plate size affects food intake, however the outcomes to date have been mixed (Koh & Pliner, 2009; Rolls, Roe, Halverson, & Meengs, 2007a; Shah, Schroeder, Winn, & Adams-Huett, 2011; Wansink et al., 2006). Wansink et al. first showed that the size of the vessel from which food is eaten does affect energy intake, in a study where ice-cream self-served into a smaller

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dessert bowl decreased the amount eaten. In a further study of acquaintance, food sharing and plate size, Koh and Pliner also found some effects of plate size on eating behaviour (Koh & Pliner, 2009). However there are also a number of studies including a series of three interventions by Rolls and colleagues which have not corroborated these findings, failing to show that using a smaller diameter dinner plate decreased intake (Rolls et al., 2007a; Shah et al., 2011). In the Rolls' studies food was served onto dining plates of varying sizes in a number of ways including *ad lib* from a single main dish, *ad lib* from a buffet-style meal, and in a fixed amount. Under none of these conditions did a smaller dining plate decrease energy intake (Rolls et al., 2007a). Notably most of these studies were conducted predominantly in lean individuals. Only in one recent study have the effects of plate size been investigated in overweight individuals, and this was a small pilot investigation of women where again there was no detectable effect of altering dining plate size on EI when the women served themselves from a single meal item (Shah et al., 2011).

In light of the few studies conducted and the variable outcomes to date, in our current study we wanted to investigate whether a smaller plate size decreased food intake in a group of overweight, but unrestrained women presented with a palatable, buffet-style lunch meal. A fixed, but low-energy (0.5 MJ) breakfast was given early in the morning and no further food allowed until the buffet lunch to ensure that the women had a high level of hunger and increased desire to eat. Based on the lack of effect found by Rolls et al. (2007a) where hunger prior to the test lunch was not controlled, we hypothesised that a high state of hunger may be required before alterations in dining plate size drive any significant change in energy intake. The response to a dietary challenge or a change in eating environment, such as that imposed by changing the size of the dining plate, may be different between individuals in various states of hunger. In this study we were interested in testing the effect when hungry since the strategy of using a smaller plate to restrict intake arguably may be of most relevance for individuals restricting their intake for weight loss and hence also faced with high hunger levels.

Methods

Participants

Participants were recruited in Auckland, New Zealand between April and October 2012, through poster, newspaper and electronic advertisement. They came fasted to the appetite research centre at the University of Auckland Human Nutrition Unit (HNU) as previously described (Lithander et al., 2008; Strik et al., 2010) for screening and to be registered for the trial. Body weight and height were then measured, and demographics and a short medical history were obtained. Exclusion criteria included restrained eating as defined by the three factor eating questionnaire (TFEQ), restraint >12; (Stunkard & Messick, 1985), participation in a current diet program, cigarette smoker, hypertension, cardiovascular disease, diabetes mellitus or any other significant metabolic, endocrine or gastrointestinal disease. None of the participants were taking medications known to affect appetite or weight regulation. Ethical approval for this study was obtained from the national Health and Disabilities Ethics (Northern X) Committee, Auckland, New Zealand and written consent to participate was obtained from each of the study volunteers.

Study design

This was a cross-over study conducted at the appetite research unit of the Human Nutrition Unit on 2 separate days, with a minimum 3 day washout between each study day. On each occasions participants were randomly assigned to eat lunch using either a small (19.5 cm) or a large (26.5 cm) diameter dining plate. Prior to the study, participants were informed as to the nature of the plate size intervention, however they were not alerted on the day of study as to the plate size being used on that occasion, nor were they allowed to see and/or compare the size of dining plates in advance of each study day.

Procedures

The protocol used in this study was based upon the recent European consensus document which outlines recommendations for postprandial studies assessing appetitive ratings and eating behaviour (Blundell et al., 2010). On each study day participants were asked to fast from 8 pm the previous evening and to avoid morning exercise. The daily study protocol showing the timing of the breakfast and the *ad lib* lunch is shown in Fig. 1. At 0845h baseline VAS rating feelings of hunger, fullness, satisfaction and current thoughts of food (TOF) were completed (Flint, Raben, Blundell, & Astrup, 2000). Thirst and nausea were also assessed using VAS. Breakfast was served at 0900h and participants were asked to consume the meal in full, but at their own pace, within 15 min. No further foods or beverages were allowed during the morning. VAS ratings were measured throughout the morning and for 2 h after completion of the *ad lib* lunch. At 1200h, 180 min after the breakfast, the *ad lib* buffet-style lunch was served to each participant in individual dining rooms. Participants were required to stand up and walk across the room to a separate dining table on which the buffet meal was placed whenever they wanted to refill their plate. Participants were asked to eat until they felt comfortably full, and no distractions such as newspapers, laptop computers or mobile phones were allowed during the 30 min lunch period. There was no limit to the number of times that individuals were able to visit the buffet table in order to refill their dining plate. Portion size, the crockery upon which the buffet items were served, and the cutlery used to both serve and eat the lunch meal were identical on all occasions.

Participants remained at the HNU throughout each study day and were allowed to read, use laptop computers or undertake other similar sedentary activities but were not allowed to sleep at any time during the study day.

Breakfast preloads

The 0.5 MJ breakfast meal comprised a small bowl of dairy yoghurt which was required to be eaten in full at 0900h. Participants arrived at the HNU appetite research unit fasted prior to the breakfast meal. The energy and macronutrient composition of the breakfast meal was calculated using the dietary program FoodWorks™ (Professional Edition, Version 5, 1998–2007, Xyris Software, Australia).

Visual analogue scales (VAS)

Participants rated their hunger, fullness, satisfaction and TOF using VAS. The questions asked were "How hungry do you feel?", "How full do you feel?", "How satisfied do you feel?" and "How much do you think you can eat now?" Ratings were recorded by placing a vertical line onto 100 mm scales, anchored at either end by statements; "I am not hungry at all/ I am not full at all/ I am completely empty/ nothing at all" on the left and "I am as hungry as I have ever been/ I am totally full/ I cannot eat another bite/ a large amount" on the right. VAS were completed when the participants were fasted prior to the breakfast meals and then at 15, 30, 45, 60, 90, 120, 150, 180 [*ad lib* lunch], 210, 240, 270 and 330 min

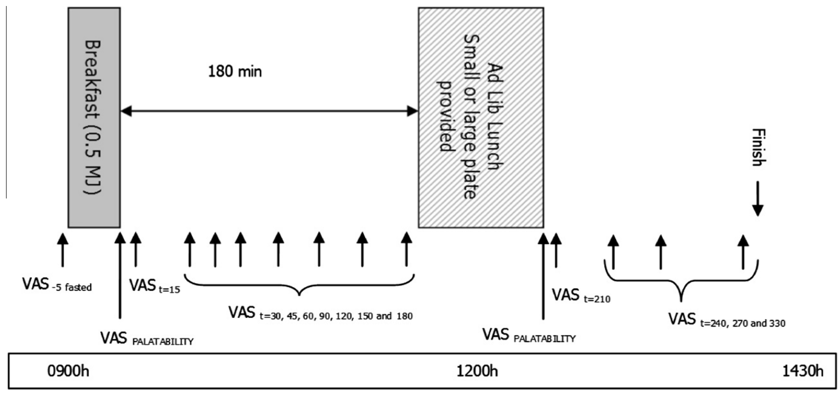

Fig. 1. Daily protocol for the study. Participants were given a standard low energy breakfast (0.5 MJ) on both occasions, and then allowed to serve themselves from a multi-item buffet lunch using either a small (19.5 cm) or a large (26.5 cm) diameter dining plate. The study day was highly controlled with participants restricted to the appetite research centre and allowed to consume only foods and beverages provided by the study.

after the breakfast was served. Palatability of the breakfasts and the *ad libitum* lunches was measured immediately following each respective meal (breakfast, $t = 15$mins; lunch, $t = 210$ min). Participants rated the pleasantness, visual appeal, smell, taste, aftertaste and overall palatability of the meals on separate 100-mm VAS. These questions were anchored on the left by the statements "not at all pleasant (pleasantness)/bad (visual appeal, smell, taste, palatability)/none (aftertaste)" and on the right by the statements "as pleasant as I have ever tasted (pleasantness)/good (visual appeal, smell, taste, palatability)/much (aftertaste)".

Ad libitum buffet lunch

The *ad lib* lunch comprised a multi-item, free choice buffet meal previously used in our laboratory to assess eating behaviour (Wiessing et al., 2012). It comprised a hot item of pasta and meat sauce plus sliced bread, cold chicken and ham, cheese, salad items, Madeira cake, tinned peaches, margarine, mayonnaise and bottled water. On each occasion small or large dining plates were arranged in a stack within a lunch booth onto which the participants were required to serve their food choices. The buffet meal was arranged on a separate dining table within the same room. Participants were asked not to move the large serving dishes, but rather to visit the buffet fill their plate as they chose. They were also advised that they had 30 min for lunch, could eat as much or as little as they chose, and should eat until they felt comfortably full. The items presented at the lunch meals with details of serving weight, energy and macronutrient content are shown in Table 1. All discrete items (bread, chicken, ham, cheese, cake, peaches) were presented as small bite size portions, and all items were served in moderate excess with the intent that participants would not consume the entirety of any single item. All lunch items were weighed before and after the meal to the nearest 0.5 g (Sartorius AG, Goettingen, Germany), and energy and macronutrient content of the foods consumed was calculated using the commercial dietary program FoodWorks™ (Professional Edition, Version 5, 1998–2007, Xyris Software, Australia).

Statistical analyses

Energy and macronutrient intake at the *ad lib* lunch meal was analysed using SAS:PROC MIXED (SAS version 9.2, SAS Institute Inc., Cary, NC, USA, 2002–2008) at a single time point, as was VAS data assessing the palatability of the breakfast and lunch meals. VAS data assessing postprandial feelings of hunger, fullness and other appetite related sensations throughout each study visit were analysed using repeated measures Linear Mixed Model ANOVA (SAS: PROC MIXED). The participant, study day and visit number were included in the procedure, in addition to the treatment/time interaction which addressed whether the trajectory over time during the study period differed between the breakfast conditions (diet $*$ time). Statistical significance was based on 95% limits ($P < 0.05$).

Results

Participants

Twenty-eight female participants were screened for this trial, of which 21 were registered and randomised. Seven women were excluded at screening due to BMI > 40 kg/m^2, BMI < 25 kg/m^2, habitual smoker, currently breastfeeding, medical history of depression and current medication, not willing to eat all of the food types to be presented during the study, and not free to participate. One woman withdrew after randomisation, but before her first study visit, and was not replaced in the intervention. Hence 20 overweight and obese, unrestrained female participants completed the 2 study days in random order. The mean age of the group was 34 (9 sd; range 20–51) years, mean BMI was 30 (5 sd; range 25–40) kg/m^2, and waist circumference was 84 (8 sd; range 75–103) cm. All participants were healthy by self report. Blood pressure was 114/68 mmHg, also within the healthy range. None were currently on a weight reduction diet or reported significant (>5 kg) weight loss in the previous 6 months.

Visual analogue scales

Hunger, fullness, satisfaction, TOF

Figure 2 shows VAS-rated hunger and fullness during the 3 h following each of the test breakfasts, and also after presentation of the *ad lib* lunch (at 180 min). Baseline measures for all VAS parameters were assessed following an overnight fast and were not significantly different between study days (all, $P > 0.05$) suggesting a similar level of hunger, fullness, satisfaction and TOF at the start both experimental days. As intended in the design of this study, there was very little suppression of hunger, enhancement of fullness, or change in other VAS-rated appetite measures by the small dairy yoghurt given for breakfast, and all gradually returned to fasting levels through the morning. Participants were supervised throughout the morning and had no access to food. Following the buffet lunch, on both occasions hunger was significantly suppressed and fullness increased, but with no significant difference

Table 1
Energy content and macronutrient composition of foods offered at the *ad lib* buffet-style lunch meal.

Food item	Weight (g)	Energy (kJ)	Energy density (kJ/g)	Protein (g)	Fat (g)	CHO (g)
Meat sauce, beef and tomato	680	2582	4	45	30	38
Pasta, spirals, boiled	1012	5700	6	45	5	277
Bread, multigrain, sliced	120	1164	10	11	3	52
Cheese, cheddar, sliced	65	1079	17	15	22	0.1
Chicken, breast, roasted, shredded	50	271	5	13	1	0.1
Ham, boiled, shaved	50	190	4	9	1	0.5
Capsicum (sweet pepper), red and yellow, raw, sliced	100	146	2	2	0	6
Cucumber, sliced	70	29	0.5	0.4	0	1
Peaches, canned, in juice	542	976	2	3	0.6	52
Cake, Madeira	145	2393	17	8	23	80
Margarine, tub	250	6050	24	0.3	163	0
Mayonnaise, bottle	295	8732	30	3	233	3
Water, still, bottle	1500	0	0	0	0	0
Total	4879	29312		156	482	510

CHO, carbohydrate.

between the small and large plate treatments ($P > 0.05$), indicating that on both occasions participants had as instructed continued to eat from the buffet lunch until they felt comfortably full. Palatability scores following the lunch meal were also not different between the two study arms ($P > 0.05$), again indicating that there were no detectable sensory effects that might have negated the effect of plate size.

Energy intake at ad libitum lunch

Energy intake at the *ad lib* lunch on each of the 2 study days is shown in Fig. 3. There was no evidence that using a smaller dining plate decreased either the weight of food consumed or energy intake from the buffet lunch meal ($P > 0.05$), rather EI was similar on both arms of the study. Mean energy intake was 3975 (239, SEM; range 2113–5674) kJ when small diameter dining plates were provided and 3901 (249, SEM; range 1748–6284) kJ when large diameter dinner plates were provided for the participants. Table 2 shows the individual items consumed at each of the lunch meals, and there was no evidence of a change in food item preference when the plate size diameter was altered. Similar weights were consumed for all of the food items served, other than for sliced cheese which was consumed in greater quantities in the small plate treatment and with an effect size that approached significance ($P = 0.0545$). Bottled water also tended to be consumed in greater quantities at the meal where a small plate was provided ($P = 0.0519$). There was also no detectable difference in the macronutrient composition of the foods chosen from the buffet between the small (mean, SEM; protein: 47, 3 g; fat: 40, 5 g; CHO: 114, 8 g) and the large (mean, SEM; protein: 45, 3 g; fat: 40, 4 g; CHO: 114, 8 g) diameter plate sizes (see Fig. 3).

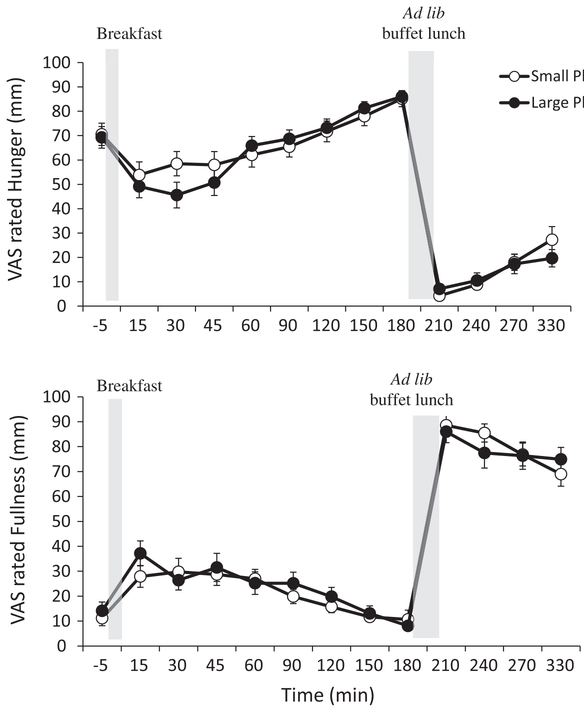

Fig. 2. Mean (SEM) visual analogue scales (VAS) showing scores for hunger and fullness throughout the day, which were not significantly different between the two arms of the study ($P > 0.05$). As expected on both occasions the low energy breakfast had only a modest effect on hunger and fullness after the meal, which rapidly returned to fasting levels by lunchtime. The multi-item buffet lunch was served 3 h after the breakfast. VAS responses immediately after lunch confirmed that the participants had, as instructed on both study arms, continued to eat from the buffet meal until they were comfortably full.

Discussion

In this study we have shown that in a group of overweight but unrestrained women who were allowed to eat freely to appetite, altering the size of dining plate onto which food is self-served at a buffet-style meal did not alter the energy consumed at the meal. The environment in which the participants were placed in our study was one which encouraged overeating. The women were in

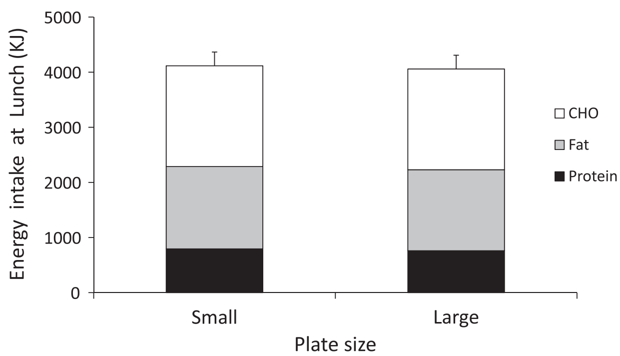

Fig. 3. Mean (SEM) energy intake at the *ad libitum* buffet lunch meal, from which participants were asked to eat freely until they felt comfortably full. There was no evidence that using a smaller diameter (19.5 cm) dining plate decreased energy intake when compared with a larger diameter (26.5 cm) dining plate, nor was there a difference in the macronutrient profile of the lunch consumed on the two study arms (both, $P > 0.05$).

Table 2
Individual food items consumed at the *ad lib* lunch meal when either a small or large diameter dining plate was provided.

Food item	Small plate		Large plate	
	Weight (g)	Energy (kJ)	Weight (g)	Energy (kJ)
Meat sauce, beef and tomato	242	915	226	861
Pasta, spirals, boiled	203	1119	198	1112
Bread, multigrain, sliced	29	278	26	250
Cheese, cheddar, sliced[1]	23	384	19	310
Chicken, breast, roasted, shredded	35	188	35	188
Ham, boiled, shaved	10	38	10	38
Capsicum (sweet pepper), red and yellow, raw, sliced	18	27	18	27
Cucumber, sliced	25	11	31	13
Peaches, canned, in juice	91	164	84	151
Cake, Madeira	40	660	46	751
Margarine, tub	2.1	51	2.7	64
Mayonnaise, bottle	3.9	115	3.8	112
Water, still, bottle[2]	336	0	277	0
Total	1077	3975	991	3901

Paired *t*-test, small vs. large, trend towards significantly different weight and energy of food item consumed.
[1] $P = 0.0545$.
[2] $P = 0.0519$.

a state of hunger, had access to a palatable lunch meal for a relatively long period of 30 min, and were allowed to serve themselves freely from the buffet on as many occasions that they chose. Multi-item buffet meals are well known to cause overconsumption relative to simpler, restricted choice meals (Brondel, Lauraine, Van-Wymelbeke, Romer, & Schaal, 2009; Raynor & Epstein, 2001), an effect that we have also demonstrated in a previous study (Wiessing et al., 2012) using the same large diameter (26.5 cm) dinner plates as in our current intervention. In our plate size study we were interested to determine whether eating from a much smaller diameter dinner plate would in turn suppress the amount of food served and consumed from this buffet meal.

The findings from our study, whilst unexpected, do support those of Rolls et al. (2007a) who have conducted similar interventions altering the size of dining plate at a lunch meal, and which have also failed to result in a significant change in food intake. Their studies suggested that this was a robust finding across a variety of types of lunch meals. Our study, presenting participants with a palatable buffet lunch meal, confirms this outcome. More recently, in a small pilot study, Shah et al., also failed to show an effect on food intake of decreasing plate size in a small group of women who were both lean and overweight (Shah et al., 2011). In this study however only a restricted single item lunch was presented to the participants.

Not all studies have failed to find an effect of plate size however. Koh and Pliner, who showed that eating in the company of a friend rather than a stranger increased both the amount of food served and food consumed and that those who served from a common central serving bowl consumed less than those who served from individual bowls (Koh & Pliner, 2009), also showed in the same study that plate size did alter eating behaviour such that the sharing effect occurred only when participants ate from small diameter dinner plates. The effect was lost when participants were given larger size plates from which to eat. Wansink and colleagues had originally shown that the size of the vessel from which food is eaten does affect intake, in a study where ice-cream self served into a small bowl was shown to decrease the amount eaten compared with participants serving the same dessert into a larger bowl (Wansink et al., 2006).

It is perhaps surprising that altering the size of dining plate did not have an effect on food intake in our study and those of Rolls and colleagues, particularly in light of the strong effect that portion size has on *ad lib* energy intake (Berg et al., 2008; Ello-Martin et al., 2005; Rolls et al., 2006) and also on weight loss (Pedersen et al., 2007). Many studies have now shown that a decrease in portion size suppresses food intake, both in single meal studies (Rolls et al., 2006) and in longer term studies of up to 2 weeks duration (Rolls, Roe, & Meengs, 2007b), and can aid weight loss in the overweight and obese (Pedersen et al., 2007). Portion control plates may be 'calibrated' by gender and food type to provide a strong visual cue as to the amount of the various food groups (e.g. meat, potatoes, pasts, vegetables) that should be served onto the plate at each individual meal. It is extremely clear to the individual if they have excess or deficiency of each item, and hence providing there is sufficient compliance, food intake can be well regulated. In our current study we expected that the smaller plate would act as a form of loosely 'calibrated' portion control system, and hence decrease intake. It seems likely however, although this data was not collected, that the participants in our study simply visited the buffet table on a greater number of occasions when the small plate was provided.

In light of our results and the growing number studies which have failed to show an effect of plate size on energy intake, it may be necessary to consider whether recommendations to decrease plate size in order to aid weight loss really are appropriate. Certainly under the conditions of our trial which was a semi-covert or at least a 'non-overt' manipulation, where the individual has no choice as to plate size, consumes the meal alone, and is exposed to a range of palatable buffet meal items over a relatively extended period of time, we were unable to show that decreasing the plate size helped to decrease energy intake. We cannot determine whether the lack of effect of decreasing plate size may be a consequence of the women in our study truly eating to appetite, with no desire or intent to consciously restrict intake, but it may explain at least in part the inability of smaller plates to decrease intake. Whilst all of the women were overweight or obese, none were currently on any form of energy restriction diet, all were self reported non-restrained eaters, and all reported prior to the study that they were happy to participate in an intervention where they would be asked to eat freely and to appetite. It appears likely from our data that decreasing plate size does not suppress food intake when individuals are not in turn consciously trying to restrict their intake. When questioned after the study, several participants commented that they had realised that they had been presented with plates of differing sizes, and when given the smaller plate chose to make repeat visits to the buffet table to refill until they felt comfortably full. We predict that the outcome of this study may have be quite different should these overweight participants have been actively seeking to suppress their food intake in order to lose weight – under which conditions it seems entirely possible that the use of a smaller plate and the need to actively refill it in order to match intake to that of a larger plate, may be a useful aid for the suppression of food intake. Using the number of servings from a meal as a conscious cue as to when to stop eating.

Conclusions

In conclusion, we found no evidence from this study that a smaller diameter dining plate suppressed food intake in a group of overweight but unrestrained women encouraged to eat freely to appetite from a wide choice of meal items. Based on our expectations of the effect of decreasing plate size on portion size and energy intake, this was an unexpected finding, although one that had previously been shown in a similar laboratory-based intervention in groups of predominantly lean women and men (Rolls et al., 2007a). The fact that decreasing plate size may be a useful cue by which to control food intake in individuals actively restricting intake for weight loss cannot however be ruled out, and requires further investigation.

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