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Energy density effects on food intake, appetite ratings, and loss of control in women with binge eating disorder and weight-matched controls

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Abstract

Individuals with binge eating disorder have increased gastric capacity and may require excessive food intake and increased volume in the stomach to produce satiation. The present study examined whether lower energy density (ED) meals lead to lower energy intake more than higher-ED meals in women with binge eating disorder (BED) and weight-matched controls. Women with BED ($n=15$) and healthy weight-matched controls ($n=15$) were instructed to consume as much as they wished during two test meals on non-consecutive days. Participants were served two hedonically similar versions of a pasta salad (19% protein, 50% carbohydrate, 31% fat): low-ED (1.0 kcal/g) and high-ED (1.6 kcal/g), and food intake and appetite ratings were assessed. Energy intake was significantly lower in the low-ED condition than in the high-ED condition across all participants. BED participants were more likely to report greater prospective consumption, desire for dessert, loss of control over eating, and less enjoyment after meals. Decreasing the energy density of food consumed may help target disturbances in satiation in women with frequent binge eating.

Keywords: Energy density; Eating disorders; Binge eating disorder; Obesity; Test meals; Loss of control

1. Introduction

Binge eating disorder (BED) is characterized by recurrent binge eating, uncontrolled episodes of eating large amounts of food (American Psychiatric Association, 2000). Individuals with BED have marked disturbances in the development and perception of satiation that may account for their frequent binge eating. They consume more food both throughout the day (Rossiter, Agras, Telch, & Bruce, 1992) and during binge eating episodes (Guss, Kissileff, Zimmerli, Walsh, & Devlin, 2002; Yanovski et al., 1992) than control subjects. Women with BED also consume more food than weight-matched controls at non-binge episodes (Guss et al., 2002; Yanovski et al., 1992). In addition to

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comorbid psychological problems (Crow, Agras, Halmi, Mitchell, & Kraemer, 2002; Martin, Williamson, & Thaw, 2000) BED is frequently accompanied by obesity (Wilfley, Wilson, & Agras, 2003).

Obese individuals with concurrent BED also have an increased gastric capacity relative to obese individuals without BED (Geliebter & Hashim, 2001). The greater gastric capacity of obese individuals with BED is similar to individuals with bulimia nervosa (BN), whereas obese individuals without BED are similar to lean, healthy controls. This disturbance may greatly interfere with their ability to respond with normal gastric distension following food intake. Gastric distension is involved in the development of satiation, and stomach capacity corresponds with the volume needed in the stomach to suppress food intake (Geliebter, 1988). Mean intake during binge episodes is highly correlated with gastric capacity (Geliebter et al., 1992; Geliebter, Yahav, Gluck, & Hashim, 2004). Geliebter and Hashim (2001) have proposed that a self-perpetuating cycle may maintain binge eating: over time, binge episodes increase gastric capacity, and enlarged gastric capacity may lead to slowed gastric emptying (Geliebter et al., 1992). This in turn may delay the release of cholecystokinin (CCK) and contribute to blunted CCK response and deficient satiation during meals, perpetuating binge eating. CCK is a gut peptide that is released into the blood after food ingestion and acts as a satiety agent. CCK reduces food intake in humans when administered by intravenous infusion or when endogenously released (Liddle, 1997).

There is extensive evidence that diets low in energy density lead to reduced short-term energy intake (Yao & Roberts, 2001). Both lean and obese individuals have been found to consume fewer calories when given lower energy density foods (Bell, Castellanos, Pelkman, Thorwart, & Rolls, 1998; Bell & Rolls, 2001). The effect has been replicated over a range of diets varying in fat content (Bell & Rolls, 2001; Stubbs, Johnstone, Harbron, & Reid, 1998). It is possible that lower energy density diets may be satiating due to their greater effect (per kilocalorie) on gastric distension. However, past studies examining the effects of energy density have typically excluded participants with binge eating or other evidence of eating disorders (Bell & Rolls, 2001; Stubbs et al., 1998). It is possible that diets low in energy density would enable individuals with BED to consume a greater volume of food (per unit of energy) and thus more readily achieve gastric distension and satiation.

The present study examined the effect of energy density on food intake in women with binge eating disorder and weight-matched controls. It was hypothesized that meals lower in energy density would lead to decreased consumption relative to meals higher in energy density. Although previous research has shown that women with BED consume more food at both binge episodes and non-binge meals than control women, it was predicted that the effect of energy density would be found in both women with and without eating disorders.

2. Methods

2.1. Participants

Posters and flyers for research on “eating patterns in women” were used to recruit participants. Initial telephone screening assessed exclusionary criteria including: substance use, physical conditions known to influence appetite, serious psychiatric problems, pregnancy or lactation, and chronic medical problems. During this screening, women who reported binge eating were invited for an in-person interview conducted by trained assessors.

These participants were interviewed using the Eating Disorders Examination (EDE; Fairburn & Cooper, 1993); a reliable and widely used instrument for the diagnosis of eating disorders (Rivzi, Peterson, Crown, & Agras, 2000). They were administered the Eating Attitudes Test (EAT; Garner & Garfinkel, 1979), a 26-item screening measure that detects for general eating disturbance, and the Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995), a 42-item measure of symptoms of depression, anxiety, and perceived stress. Their height and weight were measured using a digital scale, and dislike for or allergies to any of the foods offered in the study was assessed. Criteria for BED were established based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association, 2000).

Following the recruitment of eating-disordered participants, a group of weight-matched controls were recruited. This group was recruited so that participants in each group would have similar mean and range of body mass index (BMI; kg/m^2) and group differences would not be attributable to weight. Initial telephone screening to assess approximate height and weight was carried out. Each control participant needed to be within one BMI point of one eating-disordered participant and have no history of an eating disorder. The above-mentioned exclusionary criteria were also assessed. If potential participants reported no current binge eating and/or compensatory behaviors during phone screening, they were invited to take part in an in-person interview using the EDE. After this interview they were administered the EAT and DASS, and their height and weight were measured. Control participants needed to score below 20 on the EAT and below 15 on the DASS. They were also required to have had no more than one objective bulimic episode (OBE), two subjective bulimic episodes (SBE), and one episode of compensatory behavior (e.g., vomiting or laxative abuse)

in the past month. (An OBE is defined as the experience of a loss of control over eating while consuming a large amount of food, and SBE is the experience of a loss of control over eating while consuming a moderate amount of food (Fairburn & Cooper, 1993). These types of episodes comprise the two common variants of binge eating in women with BED (Latner & Wilson, 2002). Women who met these inclusion and exclusion criteria for controls were invited to participate. One control participant was recruited to be matched with each eating-disordered participant, until all BED participants were matched.

2.2. Procedures

Using a repeated-measures design, participants attended two test-meal sessions, conducted between 11 a.m. and 3 p.m. on two non-consecutive days no more than 10 days apart. Both sessions were at the same time for individual participants. Participants were instructed that they would be required to keep their eating and exercise patterns as similar as possible on both days of the study and not to eat or drink anything but water from three hours prior to their sessions. They were also asked to refrain from consuming alcoholic beverages from 5 p.m. on the evening before their sessions. Participants were telephoned the evening before each session and reminded of these instructions. Prior to the start of each test session, participants were asked to fill out a diary briefly noting their food and beverage consumption and exercise patterns from the previous 24 h, to ensure that these instructions had been followed. Participants also completed a questionnaire assessing potential current physical symptoms (e.g., nausea, stomach upset, dizziness, sleepiness) on a 10-point scale. Any participants endorsing symptoms (above 5) were deemed unfit to participate and rescheduled for another day.

Just before being served each of the two test meals, participants tasted and rated a 10 g sample of the same type of test meal they were about to consume during that day's test meal (e.g., participants in the low-energy density (ED) condition had a low-ED-sample). They rated the foods for prospective consumption ("How much of this food could you eat?"), and estimated calorie content ("How many calories do you think this food has?"), and for the pleasantness of the taste and texture of the food, on 160 mm visual analogue scales (VAS; Flint, Raben, Blundell, & Astrup, 2000; Stubbs et al., 2000). Before and after the presentation of each test meal, participants rated the extent of their current hunger, fullness, prospective consumption, excitement about eating, satisfaction, thirst, and nausea, desire to eat a meal, and desire to eat a dessert, on 160 mm VAS. VAS questions were anchored at the left with the words *Not at all/None* and at the right with *Most imaginable.*

Meals were served to participants individually in a private room, and participants were not permitted to read or engage in other activities during the meal period. Participants were instructed as follows: "Relax and let yourself eat as much or as little as you feel like eating, taking as much or as little time as you wish. Allow yourself to eat whatever you feel like eating right now." These instructions were designed to give participants the freedom to either binge eat or not to. They were then instructed that when they were finished, they should knock on the door where they had initially met the investigator down the hall.

The post-meal VAS was identical to the pre-meal VAS, with two additional questions: "How much did you enjoy the meal you just ate?" and "How pleasant have you found the food?" Participants were also administered additional questions after meals to assess the extent to which they experienced a subjective sense of loss of control over eating: "Did you have a sense of loss of control at the time you were eating?" with responses including *yes* or *no*, in keeping with accepted assessment measures (e.g., Fairburn & Cooper, 1993) and the DSM-IV description of this criterion for binge-eating episodes. Participants were also asked how much they felt their recent eating episode had been typical of a meal, and how much it was typical of a binge ("How typical is the eating you just completed of a regular meal for you?" and "How typical is the eating you just completed of a binge for you?") with responses on a 5-point scale from *Not at all typical* to *Extremely typical*. They were also asked whether they felt they had eaten too much, with responses on a 7-point scale from *Nothing at all* to *So much I can't go on*. On the day following completion of each test meal, participants were contacted by telephone and asked to report the details of what they had eaten and drunk during the remainder of the experimental day, and whether they had experienced a sense of loss of control over eating at each episode of eating.

2.3. Test meals

The test meals were formulated based on previous research demonstrating that single-item meals can elicit binge eating in women with eating disorders (Anderson, Williamson, Johnson, & Grieve, 2001), along with research of Bell et al. (1998) that used pasta dishes to vary energy density by changing the ratio of pasta to low-fiber vegetables. The test-meal used in the present study similarly consisted of a pasta salad which varied in the ratio of pasta to low-fiber vegetables (tomato and zucchini) but held weight and macronutrient composition constant. The low-ED meal contained less pasta relative to vegetables, and the high-ED meal contained more pasta relative to vegetables, resulting in a 40% increase in ED. Other ingredients included shredded mozzarella cheese, garbanzo beans, and balsamic vinegar dressing (recipes available upon request from the corresponding author). The two meals were also similar in volume, as indicated by the identical heights they reached in the serving bowl, and in visual appearance. Nutrient composition of ingredients and foods was obtained from manufacturers' information and the U.S. Department of Agriculture National Nutrient Database for Windows (Version 1.0, HealtheTech, Inc.). The dietary composition and amount served of the two meals is indicated in Table 1. The meals were presented in counterbalanced order, with participants assigned to condition order in

Table 1
Nutritional composition of test meals

Food	Amount served (g)	PRO (% of energy)	CHO (% of energy)	Fat (% of energy)	Energy density (kcal/g)
High-ED meal	1095	19.6	48.8	31.6	1.60
Low-ED meal	1095	19.2	49.2	31.6	1.00

alternating fashion (i.e., the first participant was assigned to the low-ED meal first, the second participant to the high-ED meal first, etc.). Meals were served along with a 750 ml bottle of spring water, serving utensils, and a plate. Meals were timed and food was weighed on a digital scale to the nearest .1 g before and after meals, and pre- and post-meal food weights were recorded.

2.4. Statistical procedures

In order to test the hypothesis that energy density would affect food intake among both BED and control participants, a 2 (meal condition) X 2 (participant type) factor ANOVA, with repeated-measures on the first factor, was conducted to examine possible main effects for meal condition and participant type, and interaction effects. This analysis was conducted for two dependent variables: (1) energy (kcal) of food consumed, computed based on grams eaten (i.e., difference between pre- and post-meal weights), and (2) weight (grams) of food consumed. Two-factor ANOVA was also used to detect differences across groups and across conditions in hedonic responses, and in hunger, fullness, and related variables, before and after test meals. Chi-square analyses were conducted to compare the self-reported occurrence of a loss of control over eating across conditions, both during meals and on the remainder of test-meal days. Finally, the intake of participants who reported binge eating or a loss of control at test meals was compared to those who did not, in order to examine the association between perceived binge eating and food intake. An alpha level of .01 was used to reduce the risk of Type I error due to multiple comparisons. Data were analyzed using SPSS statistical software, version 14.0 (Chicago, Illinois).

These procedures were approved by the Human Ethics Committee of the University of Canterbury, and all participants gave informed consent. Participants were reimbursed for their participation in the study. Following participation, participants were debriefed, and BED participants were given information about treatment resources for their eating disturbances.

3. Results

3.1. Participant characteristics

Approximately 150 women were screened by telephone as possible BED participants or weight-matched controls. Sixty of these women were interviewed, and 33 women met inclusion criteria and were invited to participate. Three participants withdrew either due to scheduling conflicts or without giving a reason. Thus, 30 women completed the study, 15 participants with BED and 15 control participants. As shown in Table 2, significant differences between BED and control participants were found on EAT scores, DASS subscale scores, and binge eating frequency. As shown in Table 2, the significantly higher scores on the EAT among the BED group suggest agreement in the EDE and EAT methods of identifying eating disorders, although the average EAT score of BED participants (17.99) was not above the suggested cut-off score of 20 for detecting possible eating disorders (Garner & Garfinkel,

Table 2
Means (SD) of participant characteristics and differences between BED and control participants

	BED participants	Control participants	*t*-value
BMI	28.99 (6.74)	27.21 (5.94)	.77
Age	29.93 (8.66)	24.07 (6.88)	2.05
Eating pathology	17.99 (10.95)	7.87 (6.20)	3.12[a]
Depression	.89 (.60)	.31 (.20)	3.56[a]
Anxiety	.85 (.60)	.27 (.22)	3.52[a]
Stress	1.24 (.53)	.43 (.35)	4.92[a]
OBE frequency	14.27 (5.92)	.07 (.26)	9.28[a]
SBE frequency	2.73 (6.60)	.40 (1.30)	1.34

Note: Eating pathology as measured by Eating Attitudes Test (EAT); depression, anxiety, and stress as measured by their respective subscales of the Depression, Anxiety and Stress Scales (DASS); OBE and SBE frequency as measured by the Eating Disorders Examination (EDE) as the number of days out of the past 28 on which these behaviors occurred.

[a] $p < .01$.

1979). The mean age of the sample was 27.0 (SD = 8.25). Its ethnic composition was 63.3% European, 10% New Zealand Maori/part Maori, 6.7% Pacific Islander/part Pacific Islander, 6.7% Asian/part Asian, 6.7% Indian, and 6.7% other ethnicities.

Among the BED participants, four were currently taking psychotropic medications prescribed by their physicians. (None of the control participants were taking psychotropic medications.) These participants had been taking a stable dose for at least two weeks and remained at this dose throughout the study. However, none of the participants were currently being treated for their eating disorder, as in all cases the psychotropic medications prescribed were for conditions other than disturbances in eating (specifically, depression and anxiety). Participants on medications did not differ from those not on medications in intake, pre-prandial or post-prandial hunger or fullness in either condition, based on independent-samples *t*-tests; similarly, re-running the analyses with these participants excluded did not alter the results. Chi-square analysis revealed no differences between BED and control participants in the presence or absence of breakfast (consumed by 86% of participants). As one participant (from the BED group) consumed the entire amount of food served in both conditions, data were analyzed both with and without this participant's data. No differences in results were found between the two sets of analyses, and this participant was retained. All other participants consumed less than 800 g of food (of the 1095 served) in both conditions.

3.2. Hedonic responses to test meals

Between the high- and low-ED conditions, there were no significant differences in VAS hedonic ratings of the sample meals: pleasantness of taste, texture, prospective consumption, and estimated calories. There were also no main effects for participant type in reactions to sample meals. The hedonic responses of participants were also examined following the meals by comparing their post-meal VAS responses on enjoyment of their meal and pleasantness of the food. There were no main effects for meal condition, but significant main effects for participant type showed less enjoyment ($F(1,28) = 9.65$, $p < .005$) and pleasantness ($F(1,28) = 10.83$, $p < .005$) among BED participants than control participants.

3.3. Intake at test meals

Two-factor ANOVA revealed a significant main effect of meal condition on energy intake ($F(1,35) = 12.26$, $p < .001$). There was no significant main effect for participant type and no interaction effect. Across participants, energy intake was 38.69% greater during the high-ED test meal than the low-ED test meal, as shown in Fig. 1. There were no significant main effects of meal condition or participant type, and no interaction effects, on grams of food consumed, time taken for meals, or water consumed.

3.4. Appetite ratings before and after meals

Before test meals, there were no significant main effects of meal condition on VAS ratings of hunger or fullness (see Fig. 2), or on prospective consumption, excitement about eating, satisfaction, thirst, nausea, desire to eat a meal, or desire to eat a dessert.

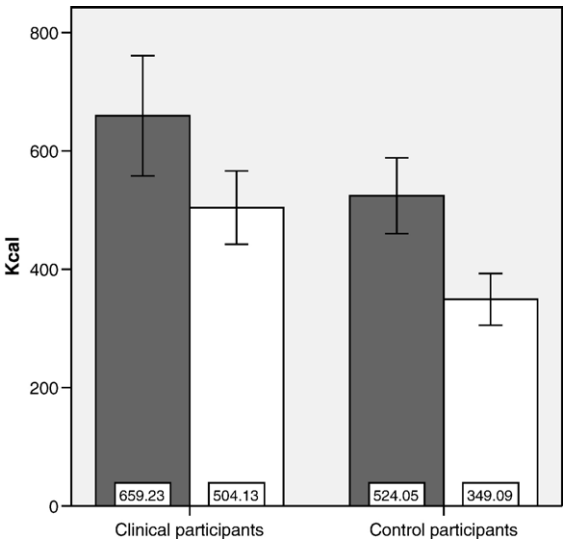

Fig. 1. Test meal intake (SEM) at high-ED meals (dark bars) and low-ED meals (light bars) by participants with BED and healthy weight-matched control participants.

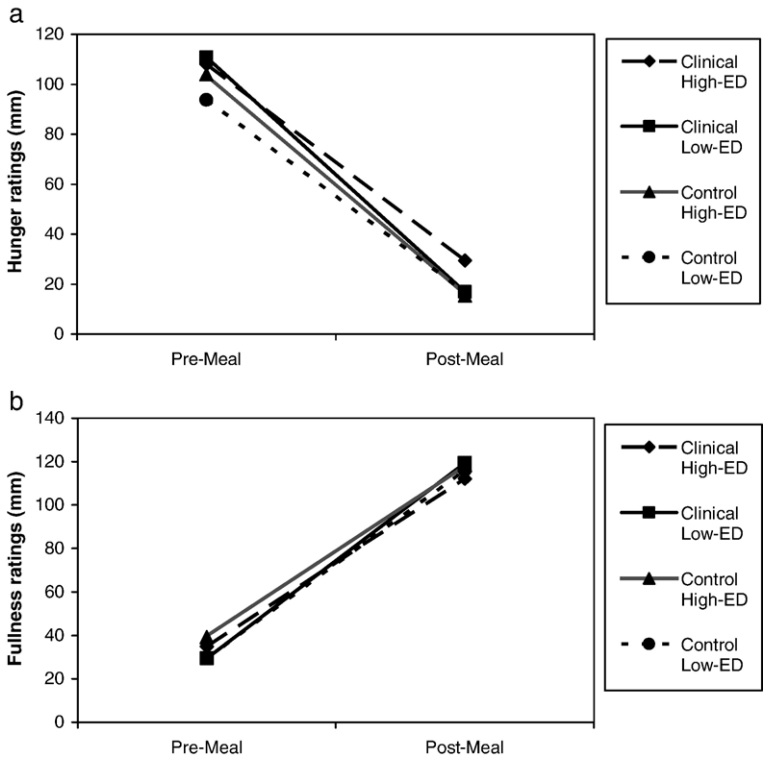

Fig. 2. Hunger (a) and fullness (b) ratings, by BED and control participants, on visual analogue scales (mm) in high-ED and low-ED conditions before and after meals (Fig. 1).

However, a significant main effect for participant type emerged for prospective consumption ($F(1,28)=7.26$, $p=.01$) and desire to eat a dessert ($F(1,28)=12.22$, $p<.005$); BED participants thought they could eat more food than control participants and had a greater desire for dessert. No other main effects or interaction effects emerged for pre-meal VAS ratings. After meals, no significant main effects for meal condition or interaction effects emerged in VAS ratings. A main effect for participant type revealed that BED participants continued to desire dessert more than controls after meals ($F(1,28)=22.20$, $p<.001$). No other main effects for participant type emerged for post-meal appetite ratings.

3.5. Loss of control

A number of participants reported having a sense of loss of control while eating in the high-ED condition (53.33% of BED, and 6.67% of control participants) and in the low-ED condition (26.67% of BED, and zero control participants). The proportions across meal conditions were not significantly different from expected proportions, according to chi-square analysis. However, differences between participant types were significant ($\chi^2(1)=11.63$, $p<.001$). Two-way ANOVA also examined the degree to which participants felt they ate too much and that their eating was typical of a meal and typical of a binge across conditions and participant types. A main effect for participant type emerged for perceiving that the eating was typical of a binge, where BED participants rated their eating as more binge-like ($F(1,28)=7.87$, $p<.01$); no main effect for meal condition emerged. No main effects or interaction effects emerged for perceived eating too much or feeling that the eating was typical of a meal.

On the day following each test meal, participants self-reported by telephone their intake on the rest of the test-meal day and whether they had experienced a loss of control at each eating episode that day. From this data, it was possible to ascertain the frequencies of OBEs and SBEs using the classification system outlined by Fairburn, Cooper, and Shafran (2003). A limited number of participants reported an OBE following high-ED meals (15.38% of BED participants, and zero controls) and low-ED meals (16.67% of BED participants, and zero controls); chi-square analyses showed no differences in these frequencies between meal conditions and no significant differences between BED and control participants. A proportion of participants also reported SBEs (range=1 to 4 episodes) following high-ED (76.92% of BED participants, 7.14% of controls) and low-ED meals (41.67% of BED participants, and zero controls); chi-square analyses showed no differences between meal conditions, but a significant difference emerged between participant groups ($\chi^2(1)=8.68$, $p<.01$).

Finally, to examine the link between loss of control, perceptions of binge eating, and food intake, the intake of participants who reported a loss of control at test meals was compared to those who did not. Those who reported losing control in the high-ED condition had a mean intake of 716.52 kcal (447.82 g) in this condition, compared to 538.13 kcal (336.33 g) for those who did not lose control. Those who reported losing control in the low-ED condition had a mean intake of 498.53 kcal (ED=1 kcal/g) in this condition, relative to 415.54 kcal for those who did not lose control. (Participant numbers were small in these comparisons, as reported above, and these differences were not significant.) Participants who reported a loss of control at each meal also reported that their eating at this meal was more typical of a binge than participants not reporting a loss of control (high-ED means: 2.44 vs. 1.19; $t(28)=3.60$, $p<.001$; low-ED means: 3.25 vs. 1.19, $t(28)=5.27$, $p<.001$). Similarly, participants who responded that their eating was moderately, very, or extremely typical of a binge were compared to those who responded that it was not at all or slightly typical of a binge. In the high-ED condition, the three "binge-eaters" (all BED participants) consumed nearly twice as much as non-binge-eaters; 1036.48 kcal (647.80 g) vs. 542.22 kcal (338.89 g). Despite the small sample, this difference was significant ($t(28)=2.71$, $p=.01$). In the low-ED condition, the four binge-eaters (all BED participants) consumed 596.70 kcal, while non-binge eaters consumed 400.44 kcal (n.s.).

4. Discussion

The present study showed that lower energy density meals led to lower short-term energy intake, even in an overweight, psychiatric sample characterized by frequent uncontrolled intake of large amounts of food: women with BED. These findings extend previous research with non-clinical samples to a population in which frequent binge eating is often associated with impaired quality of life (Rieger, Wilfley, Stein, Marino, & Crow, 2005), comorbid depression and obesity (Devlin, Goldfein, & Dobrow, 2003), and the need for specialized psychological treatment (Wilfley et al., 2003). The reduced intake at low-ED meals was not due to differences in hunger or fullness prior to test meals. The similar post-meal ratings of hunger, fullness, and related measures across meal conditions suggest that similar volumes of food produced similar levels of satiety despite the differences in calories consumed. These differences also were not due to macronutrient content, which was held constant across conditions. The present results suggest that despite their disturbances in appetitive and satiety functioning (Walsh & Boudreau, 2003), individuals with BED are still receptive to the effect of energy density on caloric intake.

Several significant differences emerged between BED and non-BED participants. In their hedonic ratings after meals, BED participants reported less enjoyment and lower pleasantness of the food. This may seem surprising given that BED participants consumed a (nonsignificantly) larger amount of food at test meals. However, it is possible that these hedonic ratings actually reflected a degree of negative affect or regret associated with perceptions of binge eating or losing control. Compared to controls, BED participants rated their eating episodes as more closely resembling a binge and were more likely to report a loss of control over eating. BED participants also reported a greater desire to eat a dessert both before and after meals. This finding is consistent with research showing that when asked to binge, BED patients consume more dessert and snack foods than weight-matched controls (Yanovski et al., 1992). Prior to meals, BED participants believed that they could eat more food (greater prospective consumption). Their prediction was partly correct: although the difference was not significant, they did consume more than controls on average (a difference demonstrated in previous research, as discussed above).

Participants who lost control over eating considered their eating to be significantly more binge-like than those who did not. Those who perceived their episodes as binges ate more than those who did not, especially in the high-ED condition. This finding is consistent with previous research suggesting that a proportion (43%) of women with BED defined their eating episodes as binges based on whether a large quantity of food was consumed (Telch, Pratt, & Niego, 1998). Similarly, both eating-disordered and non-disordered participants were more likely to label an eating episode as a binge as the amount of food believed to be consumed increased (Guertin & Conger, 1999). Although BED participants were twice as likely to experience a loss of control in the high-ED than in the low-ED condition, and 35% more BED participants experienced SBEs following high-ED than following low-ED meals, these differences did not reach statistical significance. The experience of a loss of control over eating is a major component of binge eating, central to its definition in the DSM-IV. The loss of control over eating is associated with eating-disorder related psychopathology, general psychopathology, and impaired quality of life (Latner, Hildebrandt, Rosewall, Chisholm, & Hayashi, 2007; Mond et al., 2006) regardless of whether a large or small amount of food is eaten. SBEs appear to respond to treatment for BED more slowly than other symptoms (Hildebrandt & Latner, 2006; Niego, Pratt, & Agras, 1997) and to persist following treatment termination in BN, despite remission of other symptoms (Walsh, Fairburn, Mickley, Sysko, & Parides, 2004).

The effects of energy density on food intake might interact with psychological processes, such as the experience of loss of control, as well as physiological ones. Research in women with BN has found other psychological correlates of consumption of energy dense foods; the foods classified by these women as "forbidden" had a higher caloric density than foods classified as "safe" (Kales, 1990). Eating episodes followed by self-induced vomiting were higher in energy density than those not followed by vomiting (Alvarenga, Negrao, & Phillippi, 2003). On the other hand, the macronutrient composition of food may have little influence on subjective judgments of the loss of control over eating. In an extension of research showing that protein was more satiating than carbohydrates in women without eating disorders (Latner & Schwartz, 1999), women with BED or BN whose diets were supplemented with protein over a two-week period showed substantially reduced OBEs – but not SBEs – relative to when their diets were supplemented with carbohydrates (Latner & Wilson, 2004). Macronutrient content may have reduced binge episodes primarily through its impact on the amount of food consumed, with less effect on the subjective experience of loss of control.

The present results may have significant clinical implications. As part of a comprehensive treatment program for BED, an explicit focus on addressing appetite deficiencies could possibly enhance treatment efficacy (Latner & Wilson, 2000); this hypothesis should be examined in future research. Such a focus might also facilitate weight-loss, an important priority for these patients. Evidence-based psychotherapy for BED, such as cognitive-behavior therapy (CBT; Wilson & Fairburn, 2002) does not typically produce clinically significant weight loss (Wilson, 2005), and treatment strategies that improve weight outcomes are critically needed. CBT and other treatments might be enhanced by introducing psychological, cognitive, and nutritional strategies for improving patients' deficits in appetite functioning (Craighead & Allen, 1995; McIntosh, Jordan, Carter, Latner, & Wallace, 2007; Ventura & Bauer, 1999). Such interventions could emphasize including more satiating foods in the diet, such as low-ED meals and snacks.

Two issues may present challenges to the potential clinical utility of this approach. First, although research suggests that low-ED diets might be useful for longer-term weight management for individuals without eating disorders (Ello-Martin, Roe, Ledikwe, Beach, & Rolls, 2007; Rolls, Roe, Beach, & Kris-Etherton, 2005), the long-term effects of low-ED diets for managing binge eating and weight in patients with BED are unknown. Second, an important part of CBT is re-introducing patients' "forbidden" foods into the diet in a controlled manner (Fairburn, Marcus, & Wilson, 1993). This treatment procedure is essential to prevent feared foods, such as those high in energy density (Kales, 1990), from triggering the perception of failure or a belief that one has lost control, as well as the disinhibited eating that can follow these perceptions. Practitioners may need to strike a careful balance between prescribing moderate portions of energy dense foods in a controlled setting, in order to alter patients' dysfunctional cognitions about these foods, while also recommending low-ED foods and other highly satiating foods as staples of patients' diets, in order to enhance patients' satiety and appetite functioning.

A limitation of the present study was that the effect of energy density on food intake was assessed in a short time frame. The longer-term effects of low-ED diets in women with eating disorders should be examined in future research. In addition, the present research did not examine the possible mechanisms of the effects of energy density on food intake. Another limitation is that a few participants were taking psychotropic medications for depression or anxiety; for ethical reasons, these participants could not be asked to discontinue these treatments. In addition, a standardized breakfast, which might have reduced variability in meal consumption, was not provided. The generalizabilty of these findings to other populations is unknown. Future research should examine the effects of ED on food intake in other clinical groups, such as BN and other individuals who overeat. Research should also test these effects in men and older populations. Finally, the assessment of the loss of control over eating was limited by our current understanding and available self-report measures of this construct. The DSM-IV (American Psychiatric Association, 2000) describes the loss of control over eating in binge episodes as a dichotomous variable (i.e., either present or absent), and state-of-the-art assessment measures such as the EDE (Fairburn & Cooper, 1993) accept participants' subjective reports of the presence or absence of loss of control as the definitive assessment method. However, the understanding and assessment of the construct of loss of control would benefit from the development of more subtle and sophisticated measures of this clinically significant symptom.

Research is needed to identify the longer-term effects of low-ED diets in the context of treatment for BED. It is possible that the satiety functioning of BED patients and their longer-term treatment outcome might be improved by encouraging the consumption of low-ED foods. In obese patients, greater weight-loss was achieved after one year on a low-fat, low-ED diet relative to a low-fat but higher-ED diet. Though binge eating problems were mild in this sample, there was also a significant reduction in the severity of binge eating problems in the low-ED group (Ello-Martin et al., 2007). A sizable proportion of patients with BED are able to achieve long-term remission from binge eating with

psychological treatment (Wilson, Grilo, & Vitousek, 2007), and a low-ED diet might potentially improve treatment outcome for the minority of patients who do not respond to treatment or for the majority of patients who do not lose significant weight in treatment. It is also important that future research identify the physiological mechanisms for the effect of energy density on food intake in women with BED. It may be that like individuals without eating disorders (Rolls et al., 1998), those with frequent binge eating regulate the amount they eat according to volume or weight, rather than energy, as suggested by the present findings. It may also be that a greater volume of food consumed, regardless of the food's energy density, may be needed to fill BED patients' increased gastric capacity and thus produce satiation. It is possible that lower-ED foods may enable these women to reach this satiated state while consuming fewer calories.

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