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The development of satiation in Bulimia Nervosa

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Abstract

Bulimia nervosa (BN) is characterized by the recurrent consumption of excessive amounts of food (binge eating) followed by inappropriate compensatory behaviors. A leading hypothesis is that the persistence of BN may be due, in part, to a disturbance in the development of satiation. Because patients with BN consume larger meals than controls, previous studies have not been able to directly compare the development of satiation. In order to address this problem, subjects consumed large meals of predetermined size without knowing when they would be stopped. Twenty-one women with BN and 13 control women participated in a study in which they rated hunger and fullness during the course of a 975 g liquid meal eaten from an opaque reservoir. Subjects' ratings were obtained after each 75 g increment of consumption. There were no statistically significant differences between the two groups in the mean ratings of hunger or of fullness before, after, or during the meal. Individuals with BN consumed the meal more rapidly than control participants. These results suggest that, when individuals with BN are not instructed to binge eat and do not control meal size, they do not manifest a disturbance in reported satiation over the course of a large liquid meal.

Keywords

bulimia nervosa; eating laboratory; eating disorders; satiation; meal

Introduction

Bulimia Nervosa (BN) is an eating disorder characterized by recurrent episodes of out-of-control eating during which excessive amounts of food are consumed (binge eating) and by the use of inappropriate methods, such as self-induced vomiting, to avoid weight gain following these episodes¹. Over the last two decades, a leading hypothesis regarding the persistence of this behavior is that individuals with BN have a disturbance in satiation. Evidence supporting this hypothesis includes documentation of the consumption of very large amounts of food during binge meals in laboratory settings^{2–5} and diminished release of the hormone cholecystokinin (CCK) that normally aids the development of satiation^{6–8}. In addition, during the course of meals during which subjects were asked to binge eat and allowed to consume food *ad libitum*, individuals with BN reported achieving a maximum level of fullness comparable to that of controls only after the consumption of substantially larger amounts of

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food⁹. We interpreted these results as suggesting a deficit in the development of satiation. However, because patients with BN typically consumed much larger meals than controls when binge eating, these studies did not directly compare the responses of patients with BN with those of normal control subjects to similar amounts of food.

Only a few studies have investigated hunger and fullness among individuals with BN during a meal in which the amount of food eaten was fixed, and the results have varied. These studies have all focused on the release of meal-related hormones and used a fixed size meal as the stimulus. Questions about hunger and fullness were asked before and after the meals, but the development of these sensations was not the focus of these studies. In an important early study, Geraciotti and Liddle⁶ found that patients with BN reported lower sensations of fullness following a mixed liquid meal (662 Kcal). However, Pirke et al.¹⁰ reported significantly greater sensation ratings following an 800 Kcal liquid meal (Nutricomp® and cream) among patients with BN compared to controls. Devlin et al.⁷ did not find any baseline or postmeal differences between patients and controls in sensation ratings following liquid meals (Ensure Plus®) of 300, 600 and 900 Kcal. Keel et al.¹¹ found no differences between patients with BN and controls on reports of hunger and fullness following a 900 Kcal liquid meal (Ensure Plus®), but patients with BN reported significantly lower satiation. To summarize, studies of satiation in patients with BN using a fixed meal have found greater satiation, less satiation and no difference in satiation, compared to normal controls. The reason for these different findings is unclear. However, it is worth noting that these studies used the fixed meals as a stimulus for hormone release, and subjects likely could see the contents of the meals they were consuming.

The current study attempted to overcome limitations of prior studies by asking patients with BN and normal control subjects to rate hunger and fullness levels before, during and after a large liquid meal of predetermined size while providing no information prior to the meal regarding how much they would be eating. By reducing the participants' expectations of when the meal would end, as well as their control over the meal size, we hoped to obtain a measure of participants' responses to food consumption less influenced by *a priori* psychological and cognitive factors. We hypothesized that patients with BN would be less sensitive to the filling effects of food, consistent with a deficit in the development of satiation.

Methods

Participants

Twenty-one adult women meeting DSM-IV criteria for BN were recruited to participate in this study. These individuals were seeking in- or out-patient treatment for their eating disorder, were between the ages of 18 and 45 years and between 80 and 120% of ideal body weight for their height¹². Patients used vomiting as one of their primary methods of compensating for binge eating, and were currently free of psychotic illness, drug abuse and significant suicidal ideation. Patients were required to be free of medications other than oral contraceptives for at least 2 weeks (for at least 6 weeks for fluoxetine), and were studied before the initiation of treatment for their eating disorder. Thirteen women meeting the same age and weight criteria were recruited through advertisements as healthy control subjects. Control subjects participated in a screening interview, including an abbreviated SCID which focused on the assessment of mood, substance use, and eating disorders and were without a history of eating disorders or of other significant psychiatric disorders. Control participants were taking no medications other than oral contraceptives for at least two weeks prior to the study. Both patients and controls were in good general physical health. This study was reviewed and approved by the Institutional Review Boards of the New York State Psychiatric Institute/Columbia University and St. Luke's-Roosevelt Hospital Center. Written informed consent was obtained from all participants. Patients with BN were offered free treatment for their eating disorder in exchange for participation; normal controls were paid for their participation.

Daily Procedure

Following an initial visit to assess diagnostic status and obtain informed consent, participants reported to the eating laboratory for two test days, an adaptation day and a test meal day. Subjects were told in the consent form, and again at the time of each study, that they would be asked to eat from an opaque container, would be stopped after different amounts of time had passed on each day, and they would not know how much they had eaten. On each day, participants reported in the morning after an overnight fast and were given a standardized 300 kcal breakfast consisting of one Thomas' English muffin with 1½ pats of butter, and 250 g of apple juice, and were asked to eat all of it. Participants were asked to return 5½ h later for the test meal, without eating or drinking anything other than water in the interim. When participants returned, they were instructed via tape recording to eat a yogurt shake, pausing to fill out a rating form each time they heard a tone, and continuing to eat until the researcher returned to the eating room. On the adaptation day, participants were interrupted to fill out a rating form after each 75 g increment of intake and stopped after five aliquots (375 g) had been consumed. Only participants who rated the shake at least a '6' (= "like slightly") on a 9-point category scale of liking, and were able to follow the procedures, were asked to return for the subsequent test day, which took place at least two days later but within a week. On the experimental day, participants were given the same instructions and were interrupted after each 75 g increment, but were not stopped until they had consumed 13 aliquots (975 g). Patients with BN were given access to a private bathroom after each meal.

The test meal consisted of a strawberry yogurt shake (1.04 kcal/g) which we have used in previous studies^{4,13}. The yogurt shake was served in an opaque container, accompanied by a straw, placed on a universal eating monitor, a specially constructed table with an electronic balance concealed beneath a false panel¹⁴. A pump which was remotely controlled by the investigator delivered 75 g aliquots to the container, which contained a small reserve quantity of shake. Meals were consumed alone in a private room, and were monitored via a closed-circuit TV monitor. Participants were told they were being monitored via TV for their safety and to ensure that directions were followed. During the meal, the weight of the container on the balance was transmitted to a computer. An observer in an adjacent room monitored the participant on the TV and signaled the participant to stop eating and fill out a questionnaire after 75 g was consumed. Because subjects differed in how quickly they stopped drinking when they were signaled by the experimenter, there was a small amount of variability in the size of each aliquot. The total meal size approximated 975 g (see results). There was no time limit put on participants, and all subjects completed the study meal within 20 minutes.

The questionnaires asked subjects to rate how hungry they were and how full they were using the generalized Labeled Magnitude Scale (gLMS) developed by Green¹⁵, which was created to permit a more valid comparison of subjective ratings among individuals¹⁶. The scale was comprised of 150 mm lines, anchored (left to right) by "barely detectable," "weak," "moderate," "strong," "very strong" and "strongest imaginable sensation of any kind," with the anchors appearing at empirically determined positions such that "very strong" was positioned in the center of the line, allowing ample space for responses between "very strong" and "strongest imaginable sensation of any kind". To orient participants to the scale before the meal, subjects were asked to use the scale to rate a variety of common food experiences, such as eating a typical dinner, or eating the largest meal they had ever eaten. Participants were instructed to make ratings comparing their feelings to the strongest imaginable sensation of any kind that they could imagine (i.e. pain, sound, light, etc.). Participants were instructed to place a vertical line on the scale to answer the following questions: "how hungry are you?" and "how full do you feel?"

Experimental Design and Data Analysis

The outcome measures were meal duration and change in subjective ratings during the course of the meal. The changes in ratings during the meal (hunger, fullness) were calculated as the slopes of the best fit straight lines of ratings of hunger and fullness versus grams of food consumed. Statistical comparisons were made using an independent-samples t-test; SPSS v15 was used for statistical calculations.

Results

The data are summarized in Table 1. One normal control subject did not complete the 975 g meal, and her data are not included here. Patients and controls were comparable in BMI, but patients with BN were older. Because patients with BN were significantly older than normal control subjects, all analyses were repeated using an analysis of covariance with age as the covariate, and results were essentially unchanged. Patients with BN were ill for a mean of 8.5 years (range 1 to 23). Patients with BN reported a mean binge and purging rate of 10.4 times per week (range 3–32). The patients mean score on the Eating Attitude Test¹⁷ was 44.8 ± 4.5 and on the Beck Depression Inventory¹⁸ was 19.2 ± 2.2 .

There was no statistically significant difference between patients and controls in hunger and fullness at the beginning of the meal, at the end of the meal or over the course of an approximately 1000 g meal. There was a trend towards patients with BN reporting less change in hunger per gram consumed ($p=.07$). The patients with BN ate significantly more rapidly and consumed marginally more than the normal control subjects. However, there were no differences between the groups in the average ratings of hunger or fullness before or after the meal, nor in the change in ratings per increment of food consumption.

A bivariate correlation was calculated in the BN group and there was no relationship between rate of consumption and rate of change in subjective ratings of hunger and fullness per gram of food (for hunger: $r = -0.32$, $p=0.15$, for fullness: $r = 0.67$, $p = 0.77$).

For the whole group, BMI was not correlated with any outcome measure, although among the patients with BN the initial hunger reports were correlated with BMI ($r=.45$, $p=0.042$). Similarly, within the BN group, there was a correlation between BMI and the change in hunger ratings per gram consumed that did not reach significance ($r= -.41$, $p=0.064$). However, correlations between BMI and fullness ratings did not approach statistical significance (for initial fullness: $r=-.126$, $p=0.59$; for change in fullness per gram consumed: $r=.09$, $p=0.71$).

Conclusion

The goal of this study was to examine whether patients with BN reported a smaller change in hunger and fullness during a meal when the amount consumed was predetermined and subjects did not know how much they would be asked to eat. This study failed to find any statistically significant difference between patients and controls in hunger and fullness at the beginning of the meal, at the end of the meal or over the course of an approximately 1000 g meal. There was a trend towards patients with BN reporting less change in hunger per gram consumed. Since there was no corresponding difference in fullness ratings, and since levels of significance were calculated without correction for multiple comparisons, these data do not provide robust evidence for a substantial difference between patients and controls in the development of satiation during a meal.

Patients with BN ate at a significantly faster rate: consumption was almost twice as rapid in patients with BN than in normal controls. Patients with BN also tended to consume slightly more than controls, i.e. they did not stop eating immediately when they were signaled to stop

at each 75 g aliquot. Consequently, the mean amount consumed by patients with BN was 1001 g while control subjects consumed a mean of 978 g (NS). Nonetheless, there were no statistically significant differences in ratings of hunger or fullness at the beginning of the meal, at the end of the meal, or in changes of ratings over the course of the meal. There was also no significant correlation between the rate at which subjects ate and the changes in hunger and fullness ratings during the meal.

In order to maximize sensitivity to changes in subjective ratings, we selected the gLMS rating scale for this study. The gLMS was designed to be more sensitive to differences between participants, and across groups of participants that may have different sensory experiences¹⁶. By using “strongest imaginable sensation of any kind” as the anchor representing extreme sensation instead of asking participants to make ratings relative to their own experience of “extreme” fullness, this scale attempts to normalize ratings for groups with differing prior experience of the sensation being rated. This scale has been particularly useful in the assessment of taste perception^{15,16,19}

It is possible that the use of the gLMS affected the results obtained. However, in preliminary work prior to the initiation of the current study, we collected data from patients and controls using similar procedures to those described here, but using a standard visual analog scale (VAS). These preliminary data also suggested there was no difference between patients with BN and controls in the change of fullness and hunger per gram of food consumed, prompting us to employ the more sophisticated gLMS in the current study. These data, while preliminary, suggest the current findings are not likely due to the rating scale used. Nonetheless, another method of assessing subjective sensations of hunger and fullness might yield different results than those presented here.

The result of this study, that patients with BN displayed no difference in the ratings of hunger and especially of fullness per gram of food consumed, was unexpected. Our previous studies allowed subjects to consume as much as they liked, and, when asked to binge eat, patients with BN reached levels of fullness similar to controls after eating markedly larger volumes of food compared to controls⁹. We hypothesized that patients with BN were less sensitive to the satiating effects of food, consistent with other data suggesting a deficit in the development of satiation assessed via subjective ratings of fullness. The current study fails to support a deficit in satiation, assessed via subjective ratings of fullness during food consumption, when the subject does not determine the amount of food consumed. These results are similar to a parallel study of patients with binge eating disorder (BED), performed with the same methods. No differences in reports of hunger and fullness were found between patients with BED and similarly obese control subjects without BED²⁰.

To reconcile these somewhat disparate findings, we suggest that the subjective rating of fullness among individuals with BN is determined not solely by the amount of food consumed, but by a number of other factors. These factors may include *a priori* estimates of meal size based on portion served, the observed disappearance of food as it is consumed, and the individual's intentions and emotional state (e.g., whether an individual with BN is inclined to binge eat, or has been asked to do so as part of an experimental study⁹). Rolls et al.²¹ presented normal subjects with four different sizes of sandwiches and found that, despite consuming significantly more food as the size of the sandwiches increased, there were no differences in hunger and fullness ratings after the three largest sandwich sizes were consumed. In another study, Rolls et al.²² presented participants with four different amounts of macaroni and cheese. Although food intake increased as the amount presented increased, ratings of hunger and fullness did not differ. Similarly, Wansink et al.²³ manipulated the visual cues related to portion size presented to subjects consuming bowls of soup. Subjects who ate from soup bowls that were imperceptibly refilled ate 73% more than subjects who ate from normal bowls, but there was

no difference between the groups in reports of hunger and fullness. In these studies of subjects without eating disorders, end of meal fullness reports did not increase when subjects ate more food.

This study, and the work of Devlin et al.⁷ and Keel et al.¹¹ find that when patients with BN and normal control subjects are given meals of the same size, and when no instructions are provided to produce binge or non-binge conditions, there is no difference between the groups in subjective ratings of hunger and fullness. Two studies^{6,11} do report a difference in post-meal satiety ratings between patients with BN and control subjects. However, the preponderance of the evidence suggests that, regardless of whether or not the experimental paradigm is specifically designed to remove cues regarding the amount consumed or expectations of the amount to be consumed, as it was for the current study, patients with BN do not display a marked abnormality in the development of fullness in a meal of predetermined amount.

There are, however, consistent indications that patients with BN have physiological disturbances related to their eating disorder. These include blunted release of cholecystokinin^{6,7,10,11}, slowed gastric emptying⁷ and impaired gastric accommodation reflex²⁴. Several studies have reported that patients with BN display reduced sensitivity to the filling effects of food^{9,25}. It is possible that these and other physiological disturbances may promote disturbances in eating behavior even in the absence of abnormalities in the subjective ratings of hunger and fullness during a meal. However, a causal link between these physiological disturbances and disturbances in eating behavior has not been conclusively established.

Limitations of this study, in addition to those already mentioned, include the possibility that our sample of patients is unusual, given their willingness to participate in a study involving eating unknown quantities of food. In addition, we did not control rate of eating and cannot speculate on the differences between patients and control subjects in the development of satiety were they to eat at the same rate. Finally, other types of foods and experimental settings might yield different results.

The finding of a faster rate of eating in the patients with BN is consistent with clinical reports and with the results of several other studies^{2,3}. However, a study in which we directly tested the effect of eating rate on binge size found that rate of eating did not affect binge size in patients with BN but did affect the amount eaten by normal controls¹³. Studies of normal controls do not show consistent results: rate is sometimes, but not always, related to feelings of fullness and amount of food consumed^{26,27}. Additional studies may be useful in determining whether rate of eating has an effect on the development of satiation in patients with BN or plays an important role in predisposing to excessive food consumption.

In summary, the current study found that, when not instructed to binge eat and not in control of meal size, individuals with BN, while they ate more rapidly than control participants, did not manifest an abnormality in the subjective sense of satiation over the course of a large liquid meal. Previous studies found that, during the course of an *ad lib* binge meal, individuals with BN reported less change in hunger and fullness per gram of food consumed than controls. The current finding of no difference between patients and controls suggests that a simple model in which abnormal subjective sensations of fullness reflecting abnormal gastrointestinal biology lead directly to binge eating in BN is unlikely to be correct. Finally, these findings regarding development of fullness over the course of a meal that is consumed in the absence of instruction or expectation may usefully inform treatment. Given the lack of demonstrable abnormality in meal-related perceptions under these conditions, it appears that for individuals with BN, the signaling mechanisms needed for a normal subjective satiety response to a large meal are not disturbed. This suggests that the regulation of eating may be best accomplished by building on

healthy signaling mechanisms, i.e. by increasing attention to or altering interpretation of meal-related perceptions over the course of meal.

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Table 1

Means and Standard Errors of the Mean for age, BMI, amount consumed, duration of eating, rate of eating, and ratings of hunger and fullness, among participants with bulimia nervosa and normal controls.

	Normal Control (n=13)	Bulimia Nervosa (n=21)	t	p
Age (years)	24.8 ± 0.6	28.1 ± 1.2	2.01	0.05
BMI (kg/m ²)	21.7 ± 0.4	22.4 ± 0.5	0.86	0.39
Amount Consumed (g)	978 ± 9	1001 ± 13	1.29	0.21
Duration of Eating (sec)	781 ± 136	418 ± 84	2.40	0.02
Rate of Eating (g/sec)	1.91 ± 0.37	3.67 ± 0.41	2.95	0.01
Baseline Hunger (mm)	77.1 ± 6.0	62.3 ± 7.6	1.37	0.18
End of Meal Hunger (mm)	4.39 ± 1.27	5.76 ± 2.08	0.49	0.63
Pre-Post Hunger Difference (mm)	72.7 ± 6.1	56.6 ± 7.0	0.59	0.12
Baseline Fullness (mm)	5.62 ± 0.78	9.7 ± 2.13	1.47	0.15
End of Meal Fullness (mm)	78.8 ± 10.0	86.8 ± 8.3	0.61	0.55
Pre-Post Fullness Difference (mm)	73.2 ± 10.0	77.1 ± 7.8	0.31	0.76
Change in Hunger (mm/g intake [*])	-0.077 ± 0.006	-0.058 ± 0.007	1.89	0.07
Change in Fullness (mm/g intake [#])	0.035 ± 0.016	0.052 ± 0.013	0.79	0.44

* Changes in hunger ratings are based on slopes of least squared estimates of straight lines. R-squared values were 0.86 for normal controls and 0.74 for BN participants.

Changes in fullness ratings are based on slopes of least squared estimates of straight lines. R-squared values were 0.90 for normal controls and 0.86 for BN participants.