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Satiation Deficits and Binge Eating: Probing Differences between Bulimia Nervosa and Purging Disorder using an *Ad Lib* Test Meal

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Abstract

Purging disorder (PD) has been included as a named condition within the DSM-5 category of Other Specified Feeding or Eating Disorder and differs from bulimia nervosa (BN) in the absence of binge-eating episodes. The current study evaluated satiation through behavioral and self-report measures to understand how this construct may explain distinct symptom presentations for bulimia nervosa (BN) and purging disorder (PD). Women (N=119) were recruited from the community if they met DSM-5 criteria for BN (n=57), PD (n=31), or were free of eating pathology (n=31 controls). Participants completed structured clinical interviews and questionnaires and an *ad lib* test meal during which they provided reports of subjective states. Significant group differences were found on self-reported symptoms, *ad lib* test meal intake, and subjective responses to food intake between individuals with eating disorders and controls and between BN and PD. Further, *ad lib* intake was associated with self-reported frequency and size of binge episodes. In a multivariable model, the amount of food consumed during binges as reported during clinical interviews predicted amount of food consumed during the *ad lib* test meal, controlling for other binge-related variables. Satiation deficits distinguish BN from PD and appear to be specifically linked to the size of binge episodes. Future work should expand exploration of physiological bases of these differences to contribute to novel interventions.

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Keywords

Bulimia nervosa; purging disorder; satiation; Research Domain Criteria (RDoC); binge eating

Introduction

The addition of Purging Disorder (PD), an eating disorder characterized by purging in the absence of objectively large binge episodes (Keel, Haedt, & Edler, 2005), in the DSM-5 (American Psychiatric Association, 2013) introduces an opportunity to examine factors that contribute to excessive food intake during binge eating in bulimia nervosa (BN). One such factor is satiation, a biobehavioral construct that contributes to termination of food intake during a meal (Blundell, Lawton, Cotton, & Macdiarmid, 1996; Wildes & Marcus, 2015). Although previous research supports physiological and self-reported differences in satiation that distinguish BN from PD (Keel, Wolfe, Liddle, De Young, & Jimerson, 2007), no study has addressed whether such physiological differences extend to observed behavioral differences. The purpose of the current study is to evaluate self-reported psychological and observed behavioral features implicated in satiation to understand how these may explain distinct symptom presentations for BN and PD.

Large, out of control binge-eating episodes are a central feature of BN (American Psychiatric Association, 1980; Russell, 1979) that distinguish BN from normal eating patterns (Kaye et al., 1992; Mitchell, Crow, Peterson, Wonderlich, & Crosby, 1998), and several studies support satiation deficits in BN (Geliebter et al., 1992; Hadigan, Walsh, Devlin, LaChaussee, & Kissileff, 1992; Kissileff et al., 1996; Nakai, Kinoshita, Koh, Tsujii, & Tsukada, 1987; Rolls et al., 1992; Walsh, Kissileff, Cassidy, & Dantzic, 1989). Compared to controls, women with BN consume significantly more food during *ad lib* test meals (Geliebter et al., 1992; Hadigan et al., 1992; Kissileff et al., 1996; Nakai et al., 1987; Rolls et al., 1992) but report either similar (Geliebter et al., 1992; Kissileff et al., 1996; Rolls et al., 1992) or lower (Nakai et al., 1987; Walsh et al., 1989) levels of fullness following food intake. These results may differ from findings using a fixed-size test meal (Zimmerli, Devlin, Kissileff, & Walsh, 2010). Observed satiation differences between women with BN and healthy controls may contribute to the presence of binge episodes, or they may reflect the consequences of purging behaviors, dietary restraint, or any of a myriad of features in BN that are absent in controls. Prior research has failed to account for these possible confounds because most studies do not examine phenomena transdiagnostically. Instead, they include a single diagnostic group (e.g., BN) that is compared to controls. For example, no prior study has examined satiation in PD through a behavioral assay, such as an *ad lib* test meal.

In our prior work, women with BN reported lower feelings of satiation before and after a fixed test meal compared to controls and women with PD (Keel, Wolfe, Liddle, De Young, et al., 2007). We also found significantly lower postprandial release of the satiation gut peptide CCK in BN compared to women with PD and controls (Keel, Wolfe, Liddle, De Young, et al., 2007), with the latter finding replicating prior research (Devlin et al., 1997; Geraciotti & Liddle, 1988). Taken together, these findings support distinguishing BN from

both normality and PD based on self-reported and physiological measures, and suggest that binge eating in BN may be specifically linked to satiation deficits.

Current Study

The current study sought to compare individuals with BN, PD, and healthy controls on self-reported symptoms and *ad lib* test meal intake. Data come from a series of nested studies in which we examined factors that might uniquely give rise to binge eating versus purging behaviors. We predicted that satiation deficits would distinguish BN from both control and PD participants, with lower satiation on self-report assessments and greater food intake in an *ad lib* test meal in BN. We also sought to examine dimensional associations among self-reported symptoms and *ad lib* test meal intake, to determine if the size of binge episodes was specifically linked to behaviorally measured satiation. We predicted that self-reported size of binge episodes would be positively associated with *ad lib* test meal intake across PD and BN.

Material and Methods

Participants

Women (N=119) between the ages of 18 and 45 years were recruited from the community to participate in a series of studies examining factors specifically linked to binge eating versus purging in bulimic syndromes. The overarching project involved 4 visits on separate days over the course of a few weeks to evaluate factors linked to satiation, satiety, and hunger, utilizing different test meal designs. Reported here are data from the first two study visits involving psychological and medical evaluation, and a single-item *ad lib* test meal prior to randomization into subsequent evaluation of short-term pharmacologic effects on responses to food intake in a fixed meal design. Participants were not exposed to any study medication / placebo during their participation through completion of Study Visit 2. The study was initiated in Iowa City, IA and then transferred after one year to Tallahassee, FL, where recruitment continued for four additional years. Reflecting differences in duration of recruitment by site, 21 of 119 participants (18%) were recruited in Iowa and 98 (82%) were recruited in Florida. No significant site differences were observed on any variable (participant age, body mass index [BMI], race/ethnicity, study group, or reported rating scale scores) for participants from the two sites (data available upon request). Three groups were recruited: healthy controls (n=31), women with research criteria for PD (Keel & Striegel-Moore, 2009) (n=31), and women with DSM-5 criteria for BN¹ (n=57; 58% purging). Research criteria for PD match the DSM-5 description of PD but include a specific behavioral symptom frequency and duration for purging of at least once per week, on average, for three months to allow for reliable diagnosis across studies (Keel & Striegel-Moore, 2009). Approximately twice as many participants were recruited for the BN group to permit comparisons of individuals using purging versus nonpurging compensatory behaviors to address study aims reported elsewhere. For the current analyses, we found no significant differences between purging and nonpurging BN participants on measures of disinhibition,

¹At the time of study initiation, the DSM-5 workgroup had presented proposed revisions to BN criteria for the DSM-5, which were subsequently adopted (APA, 2013), permitting the study to utilize DSM-5 criteria for current BN from inception.

hunger, binge episode size, *ad lib* test meal intake, or subjective responses to the test meal (data available upon request). Thus, all BN participants were grouped together for this report. Inclusion criteria for all participants were BMI between 18.5 and 26.5 kg/m². In addition, participants had to be free of psychotropic medications for 8 weeks as well as medical conditions or treatments that might influence weight or appetite, could not be pregnant or nursing, and could not have a current major depressive episode or current substance dependence due to the potential influence of these conditions on weight and appetite.

Controls had no history of eating disorder symptoms based upon structured clinical interviews. In addition, controls could not endorse the use of dietary restriction for the purpose of weight loss within the 8 weeks prior to assessment on the Eating Disorder Examination (EDE) interview (Fairburn & Cooper, 1993) and could not score above 9 on the Cognitive Restraint Scale of the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985). To be included in the PD group, women were required to use self-induced vomiting to control their weight or shape at least once weekly for 3 months and to endorse undue influence of weight and shape on self-evaluation. Purging behaviors had to occur in the absence of objectively large binge episodes (OBEs). Women with PD could experience subjective binge episodes (SBEs), defined by loss of control (LOC) while eating an amount of food that was not objectively large (<1,000 kcal and not more than most people would eat under similar circumstances (Mitchell et al., 1998)). Among PD participants, 21 (68%) endorsed experiencing LOC eating episodes; however, *ad lib* intake did not differ between those with (mean[SD]=225.27 [130.38]) and those without LOC eating in the PD group (mean[SD]=238.50[138.69]; $t(28)=-.25$, $p=.80$). As in prior studies (Keel, Wolfe, Liddle, De Young, et al., 2007), PD participants were asked to describe their largest eating episode during telephone screens and during in-person interviews to assess for possible OBEs. Finally, women with PD could not have a history of DSM-IV AN, BN, BED, or recurrent OBEs (maximum frequency of one episode every 3 months and no more than 5 episodes over their lifetime). Consistent with DSM-5 criteria for BN, the minimum frequency of binge eating and inappropriate compensatory behaviors for inclusion in the BN groups was an average of once per week over the prior three months. To minimize diagnostic misclassification, women with BN were required to endorse consuming at least 1500 kcal during binge episodes. Calories consumed during OBEs and SBEs were calculated using nutritional information provided on food companies' websites. If the brand names of food or restaurants were unknown or if their nutritional information was not included on companies' websites, then an online resource for counting calories was used (i.e., CalorieKing Solutions). This resource provides caloric content for a particular food averaged across brands. Reflecting eligibility criteria, women with BN endorsed consuming significantly larger quantities of food when they felt LOC over eating as measured by the Eating Disorder Examination described below (mean[SD]=2,722[1367] kcal) compared to women with PD (mean[SD]=535[490] kcal) ($t(75.98)=8.59$, $p<.001$). Finally, women with BN could not have a history of DSM-IV AN.

Participant groups did not differ significantly on age, BMI (see Table 1), or ethnic/racial background ($\chi^2[6]=5.61$, $p=.47$). Racial/ethnic diversity of the sample resembled that of the

communities from which participants were recruited, 76.5% were white, non-Hispanic, 10.9% were African American, 6.7% were Hispanic, and 5.9% were Asian.

This study was reviewed and approved by the Human Subjects Committee of the IRB at both institutions where data were collected, and participants completed informed consent prior to study participation.

Study Visit 1 Procedures and Measures

During a 2-3 hour in-person session, participants were evaluated with structured clinical interviews and questionnaires. Height, weight, and vital signs were measured, and a medical screen, pregnancy test, and other relevant laboratory tests were used to establish eligibility for study procedures. Participants were given a taste test and screening meal to acclimate them to procedures used in subsequent visits and were scheduled for Visit 2 (see below). Written instructions were given to participants in preparation for Study Visit 2, and participants were paid \$75 for completing Study Visit 1.

Eating disorder diagnosis and symptom levels were established with the Eating Disorder Examination (EDE) interview (Fairburn & Cooper, 1993). Prior studies have demonstrated the reliability, including interrater for diagnoses (Rosen, Vara, Wendt, & Leitenberg, 1990; Wilson & Smith, 1989) and internal consistency for scale scores (Beumont, Kopec-Schrader, Talbot, & Touyz, 1993; Cooper, Cooper, & Fairburn, 1989), and validity of this instrument (Cooper et al., 1989; Fairburn & Cooper, 1993; Rosen et al., 1990; Wilson & Smith, 1989). The main advantages of the EDE for the current study include the clinical rating of binge-eating episodes to distinguish between OBEs and SBEs (key for differential diagnosis of BN and PD), assessment of purging independent of endorsement of OBEs, as well as a distribution of scores produced by non-eating disordered subjects that allow for parametric analyses. In addition to using the EDE to distinguish between OBEs and SBEs for DSM-based analyses, we examined the full range of the amount of food consumed during episodes in which women with BN or PD endorsed LOC over eating, ranging from small in PD (225 kcal) to quite large in BN (6,729 kcal), and we examined the frequency of LOC eating episodes, regardless of size. Interrater reliability in the current study was high (with $\kappa = .90$ for diagnoses of BN, PD, vs. control, and $r > .97$ across EDE subscales), consistent with results from our prior work (Keel, Wolfe, Liddle, De Young, et al., 2007). Internal consistencies for the EDE in the current study were high: Total Score ($\alpha = .96$), Restraint ($\alpha = .88$), Eating Concern ($\alpha = .77$), Weight Concern ($\alpha = .89$), and Shape Concern ($\alpha = .92$).

Lifetime eating disorder diagnoses and both lifetime and current diagnoses of other Axis I disorders were assessed using the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-1) (First, Spitzer, Gibbon, & Williams, 1995). This semi-structured interview includes modules to assess current and lifetime Mood, Substance Use, Anxiety, and Eating Disorder diagnoses. For the current report, the primary use of the SCID was to ensure participant eligibility based on inclusion and exclusion criteria. Interrater reliability across SCID-I diagnoses was high, with $\kappa > .90$ for current and lifetime diagnoses.

As part of a battery of questionnaires, participants completed the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985) to evaluate three dimensions of human

eating behavior: Cognitive Restraint of Eating, Disinhibition, and Hunger. The Cognitive Restraint scale has successfully differentiated between dieters and nondieters for the threshold employed to screen out controls engaging in weight loss diets (Stunkard & Messick, 1985), and Disinhibition and Hunger have distinguished between BN and PD in our prior studies (Keel et al., 2005; Keel, Wolfe, Liddle, De Young, et al., 2007). Internal consistencies for the TFEQ subscales in the current study were $\alpha=.94$ for Cognitive Restraint, $\alpha=.90$ for Disinhibition, and $\alpha=.89$ for Hunger.

Study Visit 2 Procedures and Measures

Consistent with procedures used in other *ad lib* test meal studies (Kissileff et al., 1996; Walsh et al., 1989), participants were instructed to consume a 300 kcal standardized breakfast (1 English muffin, 1 pat butter, and 10 oz. apple juice) provided to them on the morning of Study Visit 2 at home and to eat nothing else until reporting for test meal assessment at 1500 hrs. In addition, participants were asked to refrain from any inappropriate compensatory behaviors during the day leading up to Study Visit 2, including self-induced vomiting, laxative or diuretic use, or use of excessive exercise. A research assistant contacted participants the night before Study Visit 2 to remind them of these instructions. All participants consumed the standardized breakfast before 1200 hrs, and the average time interval between consumption of breakfast and the *ad lib* test meal was 6 hours 43 minutes. Prior to test meal assessment, height, weight, and vital signs were assessed, and a research assistant conducted a screen to ensure that participants followed instructions and remained eligible, consistent with previous research employing this design (Kissileff et al., 1996). Participants were paid \$50 for completing Study Visit 2.

Based on studies establishing increased food intake in BN compared to controls (Hadigan et al., 1992; Kissileff et al., 1996; LaChaussee, Kissileff, Walsh, & Hadigan, 1992; Walsh et al., 1989), we used a single-item *ad lib* test meal. A one-quart (946 ml) serving of vanilla frozen yogurt (approximately 1.5 kcal/g) was placed into a bowl and served at an individual place-setting (Wolfe, Metzger, & Jimerson, 2002). Participants were presented with the test meal and printed instructions to play a recorded message, which stated the following printed instructions, "Please eat until you feel full." We opted to use the word "full" because we felt that this was a simpler term than "satiated" and had demonstrated similar differences between BN and PD in our prior work. Printed instructions and a recorded message were used to ensure standardized instructions across participants. No specific instructions were provided during the study about whether participants would be permitted to vomit following the meal. However, participants were informed that if they left the meal to vomit, the meal would be terminated. No participants interrupted the test meal to vomit, and no participant was prevented from vomiting after completing the meal, similar to previous studies (Hetherington & Rolls, 1991; Rolls et al., 1992; Wolfe et al., 2002). Importantly, we sought to examine satiation in the *ad lib* test meal rather than simulating a binge-eating episodes, which often include amounts of food that far exceed that required to produce a feeling of fullness or satisfaction. Thus, we did not provide enough food to fully simulate self-reported binge episodes in our BN participants but provided enough food to exceed mean *ad lib* intake under instructions to consume a normal meal without binge-eating from other feeding lab studies of BN to minimize ceiling effects in BN participants. One BN participant

consumed the full quart of frozen yogurt, and her post-meal rating of fullness suggested that this amount of food produced the level of “fullness” that others reached without eating the entire test meal. Thus, we included her data in analyses. Moreover, the amount and type of food used matched previous methods successfully demonstrating differences in satiation in a prior *ad lib* test meal study of BN (Wolfe et al., 2002).

Food Intake—Yogurt was weighed twice before and twice after the test meal using a top-loading, self-calibrated electronic balance, and total intake was calculated in grams consumed by taking the difference of the two averaged values.

Subjective Ratings—Printed instructions asked participants to complete Visual Analogue Scale (VAS) ratings immediately before and immediately after consuming the test meal, recording the time for each using a large digital clock in the room. Participants completed ratings for full, hungry, urge to binge, urge to vomit, nausea, stomach discomfort, sad, tense, anxious, preoccupation with weight, and preoccupation with shape, using a 100 mm VAS, anchored from “Not at all/No” to “Extreme/Extremely.” This method has successfully differentiated responses among PD, BN, and control subjects (Dossat, Bodell, Williams, Eckel, & Keel, 2015; Keel et al., 2017; Keel, Wolfe, Liddle, DeYoung, & Jimerson, 2007) and has demonstrated sensitivity in detecting both changes over time and group differences across several studies (Devlin et al., 1997; Kissileff et al., 1996; Rolls et al., 1992). Due to high correlations among conceptually related VAS items and to create more meaningful units of analysis, we averaged VAS scores to create the following composite subjective responses: gastrointestinal distress comprising nausea and stomach ache ($\alpha=.85$), negative affect comprising sad, anxious, and tense ($\alpha=.84$), and body image cognitions comprising preoccupation with weight and preoccupation with shape ($\alpha=.94$).

Data Analyses

Data were assessed normal distributions, including tests of skew and kurtosis, and log transformations to correct for positive skew were employed as needed prior to analyses for the following variables: OBEs per week, LOC per week, purging per week, VAS ratings of Hunger, and VAS ratings of Desire to Vomit. For descriptive purposes, descriptive statistics present untransformed values. ANOVAs were conducted to compare groups. Post-hoc comparisons were Bonferroni-corrected to minimize Type I error. Repeated Measures ANOVA was used to test if changes in subjective ratings following food intake differed across groups. ANCOVA was used to control for differences in food consumption in these analyses.

We conducted correlations to examine associations between behaviorally measured satiation and self-reported features of eating disorder symptoms. This approach follows the framework set forth by the National Institute of Mental Health’s Research Domain Criteria (RDoC) (Insel et al., 2010). Specifically, the RDoC framework focuses on measuring constructs across different units of analyses (i.e., observed behavior and self-report), examining dimensional associations along the full continuum from normality to pathology, and whether these associations explain individual differences in clinical presentation across boundaries of DSM-based diagnoses (e.g., across BN and PD) (Insel et al., 2010). Relevant

to the current paper, “reward satiation” is a construct in the Positive Valence Domain (Delgado et al., 2016). Analyses were run in the full sample and in the subsample of participants with eating disorders. Multiple regression analyses were used to explore the unique influences of variables on key outcome measures.

Results

Comparison of Groups on Symptoms and Psychological Features

Groups were well-matched on BMI, with all groups having a mean BMI within the healthy range (see Table 1). Both eating disorder groups endorsed significantly greater disturbances across measures of eating pathology and body image compared to healthy controls. Similar to prior studies (Keel, Wolfe, Liddle, De Young, et al., 2007), women with BN and PD did not differ significantly on overall eating disorder severity as assessed by the EDE, dietary restraint as measured by the EDE or TFEQ, or shape concern as measured by the EDE. Also similar to prior studies (Keel, Wolfe, Liddle, De Young, et al., 2007), BN participants endorsed greater eating concern on the EDE, and greater disinhibition and hunger on the TFEQ compared to PD participants. Frequency of LOC eating, which represents the combination of OBEs and SBEs, was significantly higher in BN compared to PD, which was entirely accounted for by the absence of OBEs in PD (see Table 1). Despite lowering the minimum threshold for purging to once per week over 3 months to diagnose PD, participants with PD endorsed purging approximately 5-6 times per week, comparable to the frequency observed in prior samples (Keel et al., 2005; Keel, Wolfe, Liddle, De Young, et al., 2007). There was no significant difference in frequency of nonpurging compensatory methods between PD and BN, despite the fact that nonpurging compensatory behaviors were not included in the research criteria for PD as they are in DSM-5 diagnostic criteria for BN.

Comparison of Groups on Age, BMI and Test Meal Intake

Consistent with hypotheses that satiation deficits would be specifically linked to the presence of OBEs, women with BN consumed significantly more frozen yogurt in the *ad lib* test meal to achieve a state of feeling “full” compared to PD participants and healthy controls, who did not differ significantly from one another (see Table 1 and Figure 1). There was a medium effect size from comparisons between BN and controls ($d=0.70$) and PD participants ($d=.61$); whereas, the effect size for the comparison of controls and PD participants was small ($d=.04$). Meal duration did not differ significantly across groups nor did post-prandial subjective ratings of “fullness” (see Table 2), suggesting that groups followed instructions to eat until they felt “full” and stopped eating at a similar threshold of fullness (mean post-meal VAS score of 77 out of 100 across groups).

Table 2 presents mean (SE) VAS ratings by time (pre- and post-meal), by group, and by time within group. For ratings of both “full” and “hunger,” there was a main effect of time; all participants demonstrated a significant increase in feeling full and decrease in feeling hunger after consuming the test meal. For “desire to binge,” there was a significant effect of group, with higher ratings in BN compared to PD and in PD compared to controls before and after the meal. For all remaining subjective reports, there were significant effects of group, time (pre- to post-meal), and group X time interactions (see Table 2). Figure 2 depicts mean (SE)

values for “desire to vomit” for each group before and after the test meal to illustrate the overall pattern of effects for subjective responses with these significant main and two-way interaction effects. Both eating disorder groups endorsed significantly higher desire to vomit before and after the meal as well as a significantly greater increase in desire to vomit following the meal. There were no significant differences between women with PD and women with BN. Other subjective reports followed this general pattern (see Table 2).

Subjective ratings suggest that both eating disorder groups experienced increases in aversive physical (nausea, stomach ache), emotional (sad, anxious, tense), and cognitive states (preoccupation with weight/shape) following consumption of the *ad lib* test meal that were not observed in control participants. Indeed, controls reported slight and nonsignificant decreases in these states. These patterns are particularly remarkable for women with PD who did not differ from controls on the actual amount of food consumed. Controlling for grams consumed did not reduce the significance of group or group X time interactions in these models.

Associations between Behavioral and Self-Report Indices

Bivariate correlations for behavioral (grams consumed) and self-report variables appear in Table 4 both in the full sample (above the diagonal) and the subsample with eating disorders (below the diagonal). BMI was not significantly correlated with any variable in the full sample or in the eating disorder subsample. As expected, grams of food consumed during the *ad lib* meal was positively correlated with OBE frequency in both the full sample and subsample with eating disorders². In addition, it was positively correlated with disinhibition and hunger as measured by the TFEQ in the full sample and eating disorder subsample and negatively correlated with restraint in the eating disorder subsample. Eating disorder symptom frequencies and scale scores were significantly correlated with one another in expected directions (see Table 3).

Given that OBEs represent the combination of two underlying dimensions, including the amount of food consumed and feeling out of control while eating, correlations between these dimensions and grams consumed were examined separately in the eating disorder subsample across the full range of values (including OBEs and SBEs). Both were significantly associated with grams of food consumed during the *ad lib* meal ($r[87]=.37$, $p<.001$ for size of episode; $r[87]=.24$, $p=.03$ for frequency of LOC episodes). A multiple regression was used to determine the contribution of both of these variables along with scores on the TFEQ Restraint, Disinhibition, and Hunger scales in predicting amount of food consumed during the *ad lib* test meal. The overall model was significant ($F[5, 80]=3.99$, $p=.003$), and size of episode was the only significant predictor of grams consumed during the *ad lib* test meal (see Table 4). This finding supports a specific association between our behavioral measure of satiation and the amount of food consumed when women with eating disorders experience LOC over their eating.

²In these analyses, control participants and PD participants had values of 0 due to exclusion criteria for these groups.

Discussion

Consistent with hypotheses, women with BN endorsed greater eating concern, disinhibition, hunger, and consumed more food than PD and control participants in an *ad lib* test meal. In addition, behaviorally measured satiation was significantly associated with size of self-reported LOC episodes as well as OBE frequency. However, when both size and frequency of binge episodes were included in multiple regression analyses, only the self-report size of binge episodes significantly predicted food intake in the *ad lib* test meal.

Despite the BN group consuming significantly more food during the *ad lib* test meal, participants did not differ on pre- or post- meal fullness, suggesting that potential satiation deficits in BN are contributing to group differences in food intake. It is also possible that severity of LOC over eating in BN may have contributed to group differences in intake; however, we do not have information on LOC over eating during the *ad lib* test meal. Desire to binge eat did not decrease following the test meal for the eating disorder groups, even though hunger decreased, feeling full increased, and desire to vomit increased. It is unclear if this finding may be related to volume and density of intake (Latner, Rosewall, & Chisholm, 2008, 2009), shame (Chao, Yang, & Chiou, 2012), or impulsivity (Sysko et al., 2017) as further research is needed to explore such associations in these groups.

Both PD and BN participants reported significantly greater increases in cognitive, emotional, and somatic distress after eating to the point of satiation, all of which may help explain propensity to use inappropriate compensatory behaviors in these eating disorders. In addition, similar to findings from a fixed test meal (Keel et al., 2017; Keel, Wolfe, Liddle, De Young, et al., 2007), PD participants endorsed significantly greater increases in gastrointestinal distress and desire to vomit compared to controls despite no differences in food consumption. These findings do not appear to be explained by physiological differences in CCK response (Keel, Wolfe, Liddle, De Young, et al., 2007) but may be explained by disruption in other gut peptides that influence ingestive behavior (Keel et al., 2017).

This study benefited from several methodological strengths. Key among these strengths was anticipation of DSM-5 diagnostic criteria and transdiagnostic and dimensional assessment of satiation using multiple units of analysis, including self-reported symptoms and behaviorally measured satiation. Our behavioral measure of satiation permitted assessment of the amount of food required to achieve a state of feeling “full,” which differentiates it from prior studies that have sought to simulate binge-eating episodes in a laboratory setting (Guss, Kissileff, Walsh, & Devlin, 1994; Kissileff et al., 1996; Walsh et al., 1989). While lab-based studies of binge behavior are crucial for understanding pathological behaviors, they do not permit evaluation of underlying mechanisms that range from normality to pathology that may contribute to binge eating. A particular advantage of our approach is that it permitted us to observe not only differences between PD and BN on the amount of food consumed to achieve fullness but also differences between PD and controls on subjective responses to the same quantity of food when food intake is self-determined. Our study utilized measures with strong psychometric properties, and samples were well matched on potential confounds, including age and BMI. Finally, we employed large enough samples to detect moderate

effect sizes, even controlling for multiple comparisons in post-hoc analyses and key covariates.

Despite these strengths, the current study had limitations, which should be considered when interpreting results. First, data come from a sample recruited from the community and thus findings may not generalize to more severely ill samples found in clinical settings. This may be particularly true given our exclusion of current comorbid illnesses known to influence weight and appetite. Second, although some portions of the design were longitudinal (e.g., the assessment of self-reported size of LOC episodes on the EDE prior to measurement of *ad lib* test meal consumption, and the assessment of subjective reports before and after consumption of the test meal), the overall design was cross-sectional. Thus, it is not possible to conclude whether satiation deficits give rise to OBEs or whether OBEs contribute to satiation deficits. However, even if the latter were true, this could represent a powerful maintaining factor for syndromes characterized by binge eating. Finally, some eating disorder participants may have engaged in dietary restriction during the meal rather than consuming enough food to achieve a state of feeling full. Importantly, groups did not differ in subjective reports of fullness after the test meal, supporting differences in the amount of food required to reach an equivalent level of fullness across groups.

Conclusions

Findings offer insight into factors that may contribute to differences in clinical presentation between BN and PD. In addition, they provide important clues to the propensity to purge following normal or small amounts of food in PD, including cognitive, emotional, and physical distress that emerge from eating to the point of fullness in this group. Future research should explore a wider range of physiological responses to food intake to evaluate whether PD may be associated with overly sensitive responses in these systems. Future work also may expand exploration of physiological bases of satiation deficits in BN to contribute to novel interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Grams Consumed During *Ad lib* Test Meal.

Figure 2.
Subjective Responses to the Ad lib Test Meal by Group for Desire to Vomit

Table 1

Comparison of Groups on Eating Disorder Features and Test Meal Intake

Measures	Control (n=31) Mean (SE)	PD (n=31) Mean (SE)	BN (n=57) Mean (SE)	F (2, 116)	p
Age (years)	21.3 (0.5)	20.6 (0.5)	20.6 (0.4)	0.62	.541
Body Mass Index (kg/m ²)	22.5 (0.4)	22.7 (0.4)	22.7 (0.3)	0.10	.909
EDE Total	0.1 (0.1) ^a	3.3 (0.1) ^b	3.7 (0.1) ^b	209.34	<.001
Restraint	0.04 (0.2) ^a	3.9 (0.2) ^b	3.9 (0.2) ^b	129.03	<.001
Eating Concern	0.0 (0.2) ^a	1.4 (0.2) ^b	2.3 (0.1) ^c	43.42	<.001
Weight Concern	0.1 (0.2) ^a	3.7 (0.2) ^b	4.2 (0.1) ^c	192.88	<.001
Shape Concern	0.1 (0.2) ^a	3.6 (0.2) ^b	4.0 (0.1) ^b	200.87	<.001
TFEQ					
Restraint	3.5 (0.8) ^a	16.8 (0.8) ^b	15.4 (0.6) ^b	101.59	<.001
Disinhibition	2.1 (0.5) ^a	7.4 (0.5) ^b	12.1 (0.4) ^c	143.53	<.001
Hunger	2.5 (0.6) ^a	5.5 (0.6) ^b	9.2 (0.4) ^c	46.72	<.001
Symptom Frequency				t (df)	p
OBE per week	-	-	2.9 (0.3)	-	-
LOC episodes per week	-	1.2 (0.3)	4.6 (0.5)	6.13 (79) [†]	<.001
Purging per week	-	5.6 (0.8)	3.5 (0.6)	3.41 (86)	.001
Non-purging ICB	-	3.3 (0.6)	4.4 (0.4)	1.70 (86)	.093
Test Meal Results				F (2, 116)	p
Grams Consumed	225.9 (25.8) ^a	230.4 (25.8) ^a	316.3 (19.0) ^b	5.61	.005
Duration of Meal (min)	12.2 (1.0)	12.3 (1.0)	13.5 (0.8)	0.74	.479

NOTE: PD=Purging Disorder; BN=Bulimia Nervosa; EDE=Eating Disorder Examination; TFEQ=Three Factor Eating Questionnaire; OBE=Objective Binge Episode; LOC=Loss of Control; ICB=Inappropriate Compensatory Behavior. Means with different superscripts differ significantly at $p<.016$.

[†]Levene's Test indicated variances were not equal and degrees of freedom were adjusted. Results for Grams Consumed remain the same when including BMI as a covariate: $F(2, 115) = 5.55, p=.005$; Control Mean (SE) = 227.2 (25.7); PD Mean (SE)=229.9 (25.7); BN Mean (SE) = 315.9 (18.9)

Table 2

Subjective Responses to the Test Meal

	Control (n=31) Mean (SE)	PD (n=31) Mean (SE)	BN (n=57) Mean (SE)	Group F(2, 116)	Time F(1, 116)	Group X Time F(2, 116)
Full						
Pre – 20.3 (2.2)	44.9 (2.9)	49.6 (2.9)	51.7 (2.2)	1.82	525.37***	0.55
Post – 77.2 (1.8)	16.5 (4.0)	19.6 (4.1)	24.8 (3.0)			
	73.2 (3.3)	79.6 (3.4)	78.7 (2.5)			
Hunger						
Pre – 59.8 (2.4)	37.9 (2.7)	29.6 (2.7)	33.6 (2.0)	3.36*	400.06***	1.16
Post – 7.7 (1.3)	67.4 (4.6)	55.4 (4.6)	56.4 (3.4)			
	8.4 (2.5)	3.9 (2.5)	10.8 (1.9)			
Desire to Binge						
Pre – 20.7 (2.4)	4.0 (3.5) ^a	17.5 (3.5) ^b	36.7 (2.6) ^c	30.48***	0.59	0.33
Post – 18.1 (2.6)	7.2 (4.4)	17.0 (4.5)	37.9 (3.3)			
	0.9 (4.9)	17.9 (5.0)	35.5 (3.6)			
Desire to Vomit						
Pre – 5.9 (1.2)	1.2 (3.4) ^a	33.2 (3.3) ^b	28.0 (2.5) ^b	34.50***	104.42***	19.78***
Post – 35.6 (2.9)	0.8 (2.3)	9.2 (2.3)	7.8 (1.7)			
	1.6 (5.5)	57.1 (5.4)	48.2 (4.0)			
GI Distress						
Pre – 13.1 (1.6)	6.0 (3.0) ^a	29.4 (3.0) ^b	23.2 (2.2) ^b	17.07***	38.55***	9.88***
Post – 25.9 (2.1)	6.3 (3.1)	18.8 (3.1)	14.1 (2.3)			
	5.6 (4.0)	39.9 (4.0)	32.3 (3.0)			
Negative Affect						
Pre – 20.7 (1.8)	5.0 (3.6) ^a	27.5 (3.6) ^b	38.1 (2.6) ^b	28.03***	14.68***	7.95***
Post – 26.4 (2.2)	6.5 (3.4)	21.9 (3.4)	33.6 (2.5)			
	3.5 (4.2)	33.1 (4.2)	42.7 (3.1)			
Preoccupied w/weight/shape						
Pre – 42.2 (2.0)	2.4 (3.6) ^a	64.3 (3.6) ^b	68.6 (2.7) ^b	117.35***	20.08***	8.46***
Post – 48.0 (2.1)	2.9 (3.8)	60.7 (3.8)	62.9 (2.8)			
	1.9 (3.9)	67.8 (3.9)	74.4 (2.9)			

Note:

* p<.05,

Values associated with different superscripts differ significantly after Bonferroni-correction.

p<.001.

*,1<.01

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Table 3

Correlations in the Full Sample (N=119) Above the Diagonal and in Eating Disorder Participants (N=88) Below the Diagonal.

	1	2	3	4	5	6	7	8
1 Body Mass Index	-	.13	.03	.09	.11	.09	.09	.11
2 Grams Consumed	.13	-	.32***	.07	.10	.01	.27**	.37***
3 OBE per week	.01	.30**	-	.26**	.54***	.32***	.72***	.60***
4 Purging per week	.09	-.04	-.05	-	.55***	.50***	.42***	.25**
5 EDE Total Score	.20	-.14	.22*	.10	-	.83***	.77***	.58***
6 TFEQ Restraint	.08	-.25*	-.16	.08	.48***	-	.53***	.28**
7 TFEQ Disinhibition	.14	.24*	.60***	-.03	.35***	-.18	-	.79***
8 TFEQ Hunger	.18	.37***	.45***	-.12	.22*	-.36***	.69***	-

Note:

* p<.05,

** p<.01,

*** p<.001.

mos=months.

Table 4Regression Model Predicting Food Consumption in *Ad Lib* Test Meal

Predictor	B (SE)	β	t	p
LOC per week	2.74 (31.73)	.01	0.09	.93
Size of LOC episode	0.03 (0.01)	.28	2.20	.03
TFEQ Restraint	-3.53 (3.74)	-.11	-0.95	.35
TFEQ Disinhibition	-6.22 (7.04)	-.15	-0.88	.38
TFEQ Hunger	11.27 (5.96)	.28	1.89	.06

NOTE: LOC=loss of control, TFEQ=Three Factor Eating Question; LOC per week was log transformed prior to analyses