Binge Eating and Satiety in Bulimia Nervosa and Binge Eating Disorder: Effects of Macronutrient Intake

Janet D. Latner[1]* and G. Terence Wilson[2]

[1] Department of Psychology, University of Canterbury, Christchurch, New Zealand
[2] Graduate School of Applied and Professional Psychology, Rutgers University, Piscataway, New Jersey

Accepted 8 March 2004

Abstract: **Objective:** *The current study tested the hypothesis that supplemental dietary protein would reduce binge eating frequency and test meal intake in women with bulimia nervosa (BN) or binge eating disorder (BED).* **Method:** *Eighteen women with BN or BED ingested high-carbohydrate or high-protein supplements (280 kcal) three times daily over two 2-week periods. On the morning after each period, participants were given a high-protein or high-carbohydrate supplement (420 kcal) 3 hr before an ad libitum meal.* **Results:** *Binge eating episodes occurred less frequently during protein supplementation (1.12 episodes per week) than during carbohydrate supplementation (2.94 episodes per week) or baseline (3.01 episodes per week). Participants reported less hunger and greater fullness, and consumed less food at test meals, after protein than after carbohydrate (673 vs. 856 kcal).* **Discussion:** *Adding protein to the diets of women with BN and BED reduced food intake and binge eating over a 2-week period. These findings may have implications for the longer-term treatment of these disorders.* © *2004 by Wiley Periodicals, Inc.* Int J Eat Disord 36: 402–415, 2004.

Key words: *bulimia nervosa; binge eating disorder; satiety; macronutrients; protein*

INTRODUCTION

Binge eating is defined as the consumption of an unequivocally large amount of food accompanied by a sense of loss of control over eating (American Psychiatric Association [APA], 1994). These episodes have also been termed objective bulimic episodes

Parts of this manuscript have been presented at the International Conference on Eating Disorders, Boston, MA, April 28, 2002.

Supported by an Individual National Research Service Award from the National Institute of Mental Health (NIH F-31 MH12224-02).

The authors gratefully acknowledge the scholarly assistance of Harry R. Kissileff and George Collier in the development of this research. They also thank Ross Laboratories for donating the supplements used in this study.

Correspondence to: Janet D. Latner, Department of Psychology, University of Canterbury, Private Bag 4800, Christchurch, New Zealand. E-mail: janet.latner@canterbury.ac.nz

Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/eat.20060

(OBE; Fairburn & Cooper, 1993). The sense of loss of control over eating can also occur when only a small to moderate amount of food is consumed, and these smaller episodes have been termed subjective bulimic episodes (SBE; Fairburn & Cooper, 1993). The study of factors that control food intake and the termination of eating may be crucial to the understanding and effective treatment of the eating disorders in which binge eating is a central characteristic, bulimia nervosa (BN) and binge eating disorder (BED).

Hill and Blundell (1986) showed that a high-protein test meal produced stronger subsequent feelings of fullness and suppression of the desire to eat than a high-carbohydrate test meal. These findings are consistent with other studies showing that high-protein meals produced greater self-reported fullness than low-protein meals, over periods of up to 24 hr (Spring, Maller, Wurtman, Digman, & Cozolino, 1983; Stubbs, van Wyk, Johnstone, & Harbron, 1996). High-protein meals have also been found to suppress subsequent food intake more than high-carbohydrate meals in both lean and obese individuals (Hill & Blundell, 1989). Participants consumed less energy at dinner after a protein lunch (943 kcal) and after a mixed lunch of protein and carbohydrate (1,034 kcal) than after a carbohydrate lunch (1,239 kcal; Latner & Schwartz, 1999). The greater suppression of food intake after a mixed lunch of protein and carbohydrate compared with after a pure carbohydrate lunch indicated that the satiating effect of protein is evident even in the presence of carbohydrate, and that the addition of protein to a balanced meal can increase the level of subsequent satiety.

Longer-term studies of the effects of nutrient composition on intake are consistent with most brief investigations. Over a 9-week period, low-protein diets were found to leave 12 men continually hungry, whereas a diet low in carbohydrates was ranked the most satiating (Fryer, Moore, Williams, & Young, 1955). A study of ad libitum energy intake over a 7-day period found a hierarchical suppressive effect on subsequent energy intake, that is, protein suppressed subsequent intake to a greater extent than carbohydrate, which had a greater suppressive effect than fat (Stubbs, Harbron, Murgatroyd, & Prentice, 1995). Only ingested protein determined self-reported satiety (DeCastro & Elmore, 1988) and was significantly and negatively related to subsequent meal size (DeCastro, 1987) during 9 days of spontaneous feeding. A study of 160 women weighing their intake over 16 days showed that whereas carbohydrate (as a percentage of energy intake) did not correlate at all with total energy intake, fat correlated slightly positively ($r = .18$) and protein correlated negatively ($r = -.45$) with total intake (Bingham et al., 1994). Similarly, during a 5-day protocol, high-protein diets led to reports of greater fullness and less hunger than high-fat and high-carbohydrate diets (Johnstone, Harbron, & Stubbs, 1996). Despite the low energy levels of very low-calorie-diets (VLCDs), which typically contain large quantities of protein (National Task Force on the Prevention and Treatment of Obesity, 1993), they have been found to produce satiety during the treatment of obesity. A 1,200-kcal diet providing approximately 45 g of protein daily led patients to report substantially more hunger and preoccupation with eating than a 500-kcal diet providing between 60 and 75 g of protein daily (Wadden, Stunkard, Day, Gould, & Rubin, 1987).

Protein is one of the most potent stimulants of cholecystokinin (CCK; Liddle, Goldfine, Rosen, Taplitz, & Williams, 1985), a satiety agent shown to reduce food intake in humans when administered by intravenous infusion and when endogenously released (Liddle, 1997). The level of pancreatic glucagon, a hormone proposed as a satiety agent (Geary & Smith, 1982) and repeatedly shown to inhibit feeding (Geary, 1990), sharply increases in the plasma after the ingestion of a protein meal (Pek, Fajans, Floyd, Knopf, & Conn,

1971), but decreases after a carbohydrate meal (Muller, Faloona, Aguilar-Parada, & Unger, 1970).

Individuals with BN and BED exhibit disturbed satiety responses. Compared with controls, patients with BN reported lower satiety at both 5 and 45 min after eating. The same group of patients showed a blunted release of CCK (Geracioti & Liddle, 1989). Regardless of whether a soup preload (8% protein, 75% carbohydrate, 17% fat) was large or small, food intake and self-reported fullness of women with BN at a subsequent meal did not vary. When subsequently asked to binge eat, they consumed nearly twice as much food as controls, despite similar hunger and fullness levels (Hadigan, Walsh, Devlin, LaChaussee, & Kissileff, 1992). Like those with BN (Weltzin, Hsu, Pollice, & Kaye, 1991), individuals with BED also consume more food than controls throughout the day (Rossiter, Agras, Telch, & Bruce, 1992) and during binge episodes compared with controls asked to binge eat (Yanovski et al., 1992).

The dietary patterns of individuals who binge eat may reflect a higher than normal percentage of intake from fats and a low percentage of intake from protein. Binge episodes (which constitute a large proportion of the total dietary intake) consist primarily of carbohydrates and fats, with little relative protein (Van der Ster Wallin, Noring, & Holmgren, 1994), often in the form of dessert and snack foods (Rosen, Leitenberg, Fisher, & Khazam, 1986). Throughout the day, the proportion of total energy from protein intake has been shown to be lower for women with BN than for controls (Hetherington, Altemus, Nelson, Bernat, & Gold, 1994). Moreover, women with BN were found to begin both binge episodes and meals by consuming dessert and snack foods and delaying the intake of fish and meat, whereas controls began with meat consumption. This early consumption of high-protein foods by controls may have led to the development of satiety later on in the course of the meal (Hadigan, Kissileff, & Walsh, 1989). Women with BED have been found to consume a greater proportion of energy from fat and a lower proportion from protein than weight-matched controls when instructed to binge eat, as well as more dessert and snack foods (Yanovski et al., 1992). BED patients also consumed a greater proportion of energy from protein on nonbinge days than during binge episodes, which were typically high in carbohydrates (Rossiter et al., 1992). The intake of sufficient protein both at the beginning of meals and across daily intake may be a protective factor preventing overconsumption. Individuals with BN or BED may not receive sufficient amounts of dietary protein, or they may need amounts even greater than those needed by nonclinical controls, for this protective effect to occur.

Protein intake may, therefore, protect both eating-disordered and non–eating-disordered individuals from overeating or binge eating, as evidenced by the higher protein intake among controls throughout the day (Hetherington et al., 1994) and at the beginning of meals (Hadigan et al., 1989), and among BED patients on days when they do not binge eat (Rossiter et al., 1992). For individuals who binge eat, the marked contrast in the satiating power of macronutrients could be a significant variable in the loss of dietary control. However, there have been no direct studies of the effect of protein on individuals with eating disorders, and long-term research is needed to assess whether the satiating effect of protein persists over time in these individuals. The purpose of the current study was to test the hypothesis that supplementing the diet with protein would reduce binge eating and increase satiety in women with BN or BED.

The current study compared the binge eating, intake at an ad libitum test meal, and self-reported satiety in women with BN or with BED, during the regular administration of high-protein supplements over a 2-week period versus during the administration of high-carbohydrate supplements over a 2-week period, in a repeated-measures,

counterbalanced design. It was predicted that relative to baseline and to carbohydrate supplementation, protein supplementation would reduce the food intake, hunger, and frequency of binge eating episodes.

METHODS

Participants

Participants were recruited through advertisements offering $50 and free treatment after the study. Individuals who reported binge eating during an initial phone screening were invited for an interview. The Eating Disorders Examination (EDE; Fairburn & Cooper, 1993) was used to diagnose patients according to diagnostic criteria for BN and research criteria for BED in the 4th ed. of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA, 1994). Use of the EDE has been well supported in tests of its reliability (Rivzi, Peterson, Crown, & Agras, 2000) and concurrent validity (Rosen, Vara, Wendt, & Leitenberg, 1990). Participants were administered the Beck Depression Inventory-II (BDI-II; Beck, Steer, Ball, & Ranieri, 1996), and the PRIME-MD to detect suicidal ideation, mood and anxiety disorders, substance abuse, and somatoform disorders (Spitzer et al., 1994). Women who met criteria for either BN or BED and reported no substance abuse, suicidal ideation, or physical conditions or treatments known to influence eating or weight, were invited to participate.

Procedures

Diets

Participants received 2 weeks of high-protein liquid supplements and 2 weeks of high-carbohydrate liquid supplements in counterbalanced order, separated by a 1-week washout period. Participants were asked their typical meal times and were then requested to consume three supplements daily 1 hr before these times. To maximize participants' flexibility in choosing when to eat, participants were asked to consume supplements at the same time every day regardless of when other eating actually occurred. Participants who did not eat meals at appropriate or regular times were instructed to ingest supplements 1 hr before generally accepted meal times (e.g., 7 a.m., 12 p.m., and 5 p.m.).

The high-carbohydrate supplements were prepared using 210.5 g Polycose glucose polymers (Ross Laboratories, Columbus, OH) derived from corn starch (800 kcal), with nondairy creamer (8 g; 40 kcal) to increase their opacity. The high-protein supplements were prepared with 105.7 g ProMod (Ross Laboratories), a whey protein and soy lecithin concentrate (420 kcal), and 112 g HealthSource (Ross Laboratories), a soy protein concentrate (420 kcal). The carbohydrate or protein powders were blended into 900 ml water and combined with flavor extracts (McCormick, Sparks, MD), food coloring, and aspartame (Nutrasweet, The Nutrasweet Company, Chicago, IL). These were evenly divided into three plastic cups, a single day's supply. The Polycose, ProMod, and HealthSource powders have a mild taste that does not alter the flavor of food, and supplements were balanced for fiber, volume, appearance, and sweetness. Table 1 describes the nutritional composition of these supplements. Participants were required to pick up a 4-day supply of supplements (12 cups) at the Rutgers Eating Disorders Clinic (Piscataway, NJ) on every fourth day (starting on the second day of each period). One day's supplements (three cups) were chilled and ready for consumption, and the other 3 days of supplements (nine cups) were frozen. Participants were instructed to keep these

Table 1. Nutrient composition of supplements

Supplement Type	Energy (kcal)	Protein (g, % of Energy)	Carbohydrate (g, % of Energy)	Fat (g, % of Energy)
High protein	280	53.33 (75.47%)	7.57 (10.31%)	4.53 (14.23%)
High carbohydrate	280	0	67.30 (95.73%)	1.33 (4.26%)

supplements frozen until the day before consumption, when they were to transfer one day's supply to a refrigerator. Participants were specifically prohibited from using supplements as a sole source of nutrition.

Adherence

To maximize adherence, the flavors of the supplements were changed daily for variety and palatability. Participants were required to return all of their used empty cups when picking up new supplements. To monitor compliance and prevent the purging of supplements, participants were required to ingest all three supplements at the clinic on the first day of each dietary period, accompanied by an investigator during intake and throughout the following hour. Supplements were also ingested in the presence of an investigator the following day and every fourth morning thereafter (when they were picked up). Although the contents of supplements were not revealed, participants were informed that supplements were low in fat, sucrose free, and mineral rich.

Measures

Self-Reported Binge Eating Episodes

Participants were trained in keeping detailed food records of all food intake. They recorded each time and place they ate or drank (including supplements), the amount eaten, whether they considered the bout to be a snack, meal, or binge, and whether or not vomiting or other compensatory behaviors occurred, in accordance with past procedures (Elmore & DeCastro, 1991). They also recorded whether or not they had experienced a loss of control over eating. After these procedures were introduced, participants were telephoned the following day to review the information, correct any problems, and answer any questions. They began keeping these diaries 1 week before beginning their first dietary phase.

Test Meals

On the morning after each 2-week period, participants consumed one 420-kcal protein or carbohydrate supplement (of the same composition as those given during that phase) in the presence of the investigator, after an overnight fast. Three hours later, a buffet was served that included foods typical of both meals and binges, varying in macronutrient composition and energy density (Table 2). It was not possible for the investigator administering test meals and supplements to be blind to participants' experimental condition. Meals took place in a private room at the Rutgers Eating Disorders Clinic, and participants were instructed, ''Eat as much or as little as you feel like right now, taking as much or as little time as you wish,'' to allow for the intake of either a normal meal or a binge. Intake was timed and measured to the nearest 0.1 g by subtracting the weights of leftovers from original serving weights. Participants were given a questionnaire after the meal to assess whether they had experienced a loss of control over eating.

Table 2. Weight and nutrient composition of test meal foods

Food	Amount Served (g)	Energy (Kcal/g)	Protein (% of Energy)	Carbohydrate (% of Energy)	Fat (% of Energy)
Cheese	225	3.95	19	5	76
Chocolate cake	310	3.83	3	57	40
Oreo cookies	225	4.81	2	58	40
Wheat bread	136	2.51	19	66	15
White bread	86	2.45	11	76	13
Potato chips	450	5.5	5	36	59
Ice cream	424	2.55	7	33	60
Apples	645	0.60	1	94	5
Cucumber	225	0.13	20	80	0
Tomato	200	0.22	14	80	6
Turkey breast[a]	170	0.96	85	15	0
Turkey bologna[a]	225	1.86	23	8	69
Eggs[b]	225	1.54	33	4	63
Tuna[b]	170	3.09	23	0	77
Beans[c]	260	0.69	23	77	0
Peanut butter[c]	108	5.22	16	13	71

[a]Served to meat eaters.
[b]Served to vegetarians.
[c]Served to vegans.

Self-Report Measures of Satiety

Before and after each test meal, participants completed eight 160-mm visual analog scales (VAS; Hill & Blundell, 1983), anchored at the ends by the words ''most imaginable'' and ''least imaginable.'' Questions asked participants to rate their hunger, fullness, the strength of their desire to eat, the amount of food they believed they could eat, their satisfaction, excitement over eating, desire to eat a meal, and desire to eat a dessert. After the meal, additional questions asked them to rate their enjoyment of the meal and how pleasant they had found the food. At the end of both phases, participants completed a questionnaire asking them to compare their levels of hunger, satisfaction, interest in food, temptation to binge, and feelings of sickness across the two phases, on 3-point scales anchored with ''no difference,'' ''slightly more,'' and ''much more'' during either phase. They were asked whether they distinguished any difference between the two supplements, and if so, to describe it. Participants were also asked to write down what they believed was the purpose of the study.

Statistical Procedures

Paired-sample *t* tests were used to detect differences between the protein phase and the carbohydrate phase in participants' binge eating frequency, energy intake at test meals, and hunger and satiety levels before test meals. Binge eating frequency during each phase was also compared with baseline frequency. Chi-square tests were used to assess the proportion of participants rating their hunger, satiation, interest in food, and desire to binge as different across phases. Independent-sample *t* tests were used to explore possible differences between participant groups, BN and BED. Due to the repeated-measures study design, data from participants who did not complete both phases and test meals were not included in the analyses.

Power, Effect Size, and Sample Size

The predicted effect size for the hypothesized difference in test-meal intake was calculated based on previous data (Latner & Schwartz, 1999) using differences between means of meal sizes (kcal) after a high-protein lunch and after a high-carbohydrate lunch

(repeated measures), and this resulted in an effect size of .56 (mean difference = 295.67 kcal, pooled $s = 314.43$). For a two-tailed test and 5% p level, 80% power for this effect size required 18 participants. This estimate did not include the potential effects on binge eating over the 2-week phases. Although the methods in the current study differed from those used in a previous dietary intervention study with BN patients (Dalvit-McPhillips, 1984), an effect size calculated from the means and standard deviations of these data was .91 (mean difference = 3.44 binges per week, pooled $s = 1.1$).

RESULTS

Participants

Of 96 women interviewed, 30 met criteria for BN ($n = 12$) or BED ($n = 18$) and agreed to participate in the study. Two additional women met BN or BED diagnostic criteria but were referred for immediate treatment because they reported suicidal ideation. Twelve participants dropped out before completing the study—3 terminated their participation due to mild adverse reaction to the supplements, and 9 either did not provide a reason for dropping out or felt that they did not have time to continue participation. The 11 women with BED and 7 with BN who completed participation had a mean age of 34.78 ± 9.80 years. The women with BN had a mean body mass index (BMI) of 22.79 ± 2.44 kg/m^2 and the women with BED had a mean BMI of 31.13 ± 4.94 kg/m^2, $t(16) = 4.13$, $p < .005$. Also, the women with BN had a mean BDI-II score of 33.43 ± 7.04 and the women with BED had a mean BDI-II score of 20.64 ± 13.90, $t(16) = 2.29$, $p < .05$. Two participants received antidepressant medications, which was monitored by their personal physicians. Their medication doses remained stable throughout the study.

Binge Frequency

During the baseline week and both phases of nutritional supplementation, participants' food diaries were reviewed during each of their visits to the clinic. Participants were generally compliant in keeping diaries, with only 2 participants missing a total of 5 days of self-monitoring, which all occurred during the washout period. OBEs and SBEs were identified from initial interviews and from food records based on the definitions of Fairburn and Cooper (1993). The mean weekly frequency of binge eating at baseline (i.e., the number of OBEs reported on baseline self-monitoring divided by the number of days in the baseline period and multiplied by 7) was 3.01 ± 2.87 OBEs per week. Self-monitored frequency was significantly lower than the mean frequency of OBEs on initial EDE interviews (5.67 ± 4.97 OBEs per week), $t(17) = 3.34$, $p < .005$.

The mean weekly OBE frequency during each phase of nutritional supplementation was calculated by dividing the total number of episodes by the number of days in each phase ($M = 13.34 \pm 0.40$; a range of phase length of 12–15 days was necessary to accommodate the variation in participants' schedules). During nutritional supplementation of protein, the average weekly OBE frequency decreased below the baseline level to 1.12 ± 1.40 OBEs per week, $t(17) = 2.98$, $p < .01$. During carbohydrate supplementation, binge eating remained at 2.94 ± 2.31 OBEs per week, $t(17) = 0.18$, not significant (Figure 1). The frequency of binge eating was significantly lower during the protein phase than during the carbohydrate phase, $t(17) = 4.58$, $p < .001$. The number of days on which OBEs occurred (''binge days''), divided by the total number of days in each phase, was also lower during protein supplementation than during carbohydrate supplementation, $t(17) = 5.39$, $p < .001$.

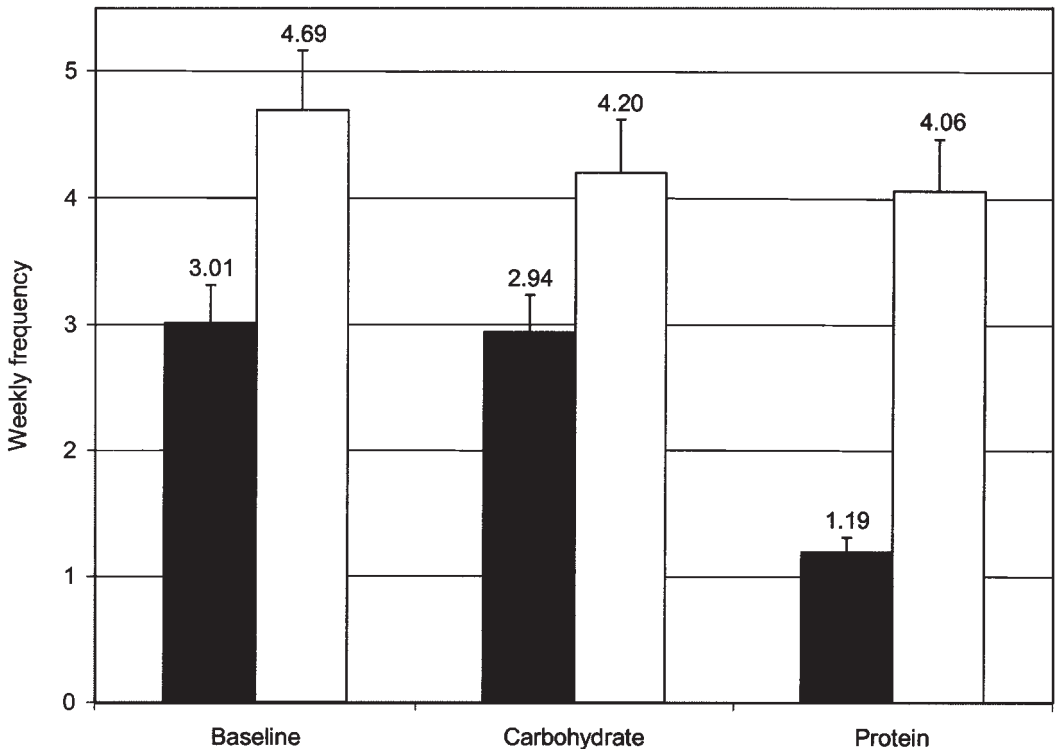

Figure 1. Mean weekly frequency of objective bulimic episodes (OBE) and subjective bulimic episodes (SBE) during the baseline phase and during protein and carbohydate supplementation. Black bars = OBE; white bars = SBE.

During baseline self-monitoring, the mean weekly frequency of SBEs was 4.69 ± 4.76 SBEs per week. The frequency did not significantly change during supplementation of either protein (4.06 ± 6.51 SBEs per week) or carbohydrate (4.20 ± 9.38 SBEs per week), and there was no difference in frequency between the two phases. These frequencies include only those episodes that participants specifically considered to be a binge. For all episodes where participants lost control over eating a normal amount of food and had labeled the episodes as either a meal, snack, or ''binge, there was no change in frequency from baseline (10.15 ± 6.51 SBEs per week) to either protein (7.35 ± 7.84 SBEs per week) or carbohydrate (7.35 ± 9.38 SBEs per week), and there was no difference in the frequency of all such episodes between the two phases. A greater weight gain occurred during the carbohydrate phase than during the protein phase (1.06 vs. 0.27 kg gained), $t(17) = 2.92$, $p < .01$. The gain during the carbohydrate phase was significantly greater than zero, $t(17) = 3.78$, $p < .005$; whereas the gain during protein was not, $t(17) = 0.85$, not significant. Among participants with BN, the frequency of purging behavior, including self-induced vomiting and laxative abuse, did not differ between the carbohydrate and protein phases, $t(6) = .81$, not significant.

Test Meal Intake

At the ad libitum test meal, participants consumed less food 3 hr after protein intake (673 ± 410 kcal) than after carbohydrate intake (856 ± 549 kcal), $t(17) = 2.75$, $p < .02$, as

Table 3. Responses ($M \pm SD$), compared using paired t tests, 3 hr after either protein or carbohydrate ingestion

	Protein	Carbohydrate
Hunger (0–160)*	78.89 ± 50.23	103.39 ± 46.14
Fullness (0–160)*	57.44 ± 49.85	36.06 ± 37.83
Total intake (kcal)**	672.75 ± 410.44	856.40 ± 538.90
Carbohydrate intake (kcal)	289.93 ± 193.81	348.82 ± 240.32
Fat intake (kcal)*	301.54 ± 202.87	383.25 ± 277.40
Protein intake (kcal)**	84.88 ± 39.36	124.33 ± 53.63
Weight of food (g)**	312.07 ± 129.12	389.61 ± 169.15
Time spent eating (minutes)**	14.44 ± 5.59	17.61 ± 6.57

Note: Hunger and fullness (before test meals) were rated on 160-mm visual analog scales.
*Significantly different at $p \leq .05$.
**Significantly different at $p \leq .01$.

shown in Table 3. Less total protein, $t(17) = 4.58$, $p < .05$, and marginally less total fat, $t(17) = 2.08$, $p = .05$, and carbohydrate, $t(17) = 1.99$, $p = .06$, were consumed after protein. A lower weight of food was consumed after protein intake than after carbohydrate intake, $t(17) = 3.66$, $p < .005$. Neither the macronutrient proportions of the meals nor the total energy density of the meals (energy divided by weight) differed significantly between conditions. Less time was spent eating in the protein condition than in the carbohydrate condition, $t(17) = 3.43$, $p < .005$. Water intake did not differ by condition. In each condition, 6 participants reported experiencing a loss of control over eating at the test meal (4 of these overlapped across conditions). In the carbohydrate condition, participants who reported a loss of control consumed similar amounts to those who did not (942 ± 347 vs. 814 ± 623 kcal), $t(16) = .46$, not significant, whereas in the protein condition, those who did not experience a loss of control ate significantly less than those who did (491 ± 274 kcal vs. 1,036 ± 413), $t(16) = 3.36$, $p < .005$.

Satiety Ratings

Before the test meal on the day after each phase, the average score for all eight VAS combined was not significantly different 3 hr after protein or after carbohydrate intake. However, as shown in Table 3, the first two items on the scale each differed between conditions: Hunger was higher, $t(17) = 2.32$, $p < .05$, and fullness was lower, $t(17) = 2.25$, $p < .05$, after carbohydrate intake than after protein intake. Satisfaction was marginally lower after carbohydrate intake, $t(17) = 2.06$, $p = .05$. VAS after the test meals yielded no significantly different responses between conditions. After both phases of nutritional supplementation, 14 of 18 participants retrospectively reported a difference in their hunger levels between the two phases; 11 of these reported greater hunger during the carbohydrate phase and 3 were hungrier during the protein phase, $\chi^2(2) = 6.33$, $p < .05$. Thirteen participants reported differences in satiety between the two phases; 11 of these were less satiated during the carbohydrate phase and 2 were less satiated during the protein phase, $\chi^2(2) = 7.00$, $p < .05$. Ten participants felt more tempted to binge eat during a particular phase; 9 of these were more tempted during the carbohydrate phase, $\chi^2(2) = 6.33$, $p < .05$. There were no significant differences in the proportion of participants in each response category for interest in food or feeling sick.

Manipulation Check

In the questionnaire administered after the completion of both phases of the study, participants were asked whether or not they had been able to distinguish a difference between the two supplements. All participants answered ''yes'' to this question. Participants were also asked to write down what they believed was the purpose of the study. No participants guessed that the purpose was to compare two types of supplements or to assess the effects of supplements on any of the dependent variables examined.

Between-Group Analyses

There was a significant difference in the frequency of OBEs during baseline self-monitoring between participants with BN (4.90 $\pm$ 3.64 OBEs per week) and BED (1.75 $\pm$ 1.33 OBEs per week), $t(16) = 2.64$, $p < .05$. However, there was no difference between the average of binge frequencies between the two groups during either nutritional phase or across the two phases combined, nor were there any group differences in weight change. Similarly, there were no differences between groups for energy intake at test meals during either phase or across the two phases combined. There were also no group differences in hunger or fullness ratings before or after either meal or in enjoyment or pleasantness ratings of the meals.

DISCUSSION

In women with BN or BED, the frequency of binge eating episodes was 62% lower during a 2-week period of protein supplementation than during a 2-week period of carbohydrate supplementation. Only protein supplementation decreased binge eating frequency from a baseline period of self-monitoring. Three hours after a high-protein meal, participants reported greater fullness and less hunger and consumed 21% less food at an ad libitum test meal than they did 3 hr after a high-carbohydrate meal. Despite their reduced test-meal consumption after protein intake, participants did not report more hunger or less fullness after the smaller postprotein meal. This suggests that they needed to consume less food after the protein than after the carbohydrate intake to feel as satiated. A significant majority of participants reported feeling less hungry, more satiated, and less tempted to binge eat during the period of protein supplementation as compared with the period of carbohydrate supplementation. A hypothesized mechanism of action for the effect of protein on binge eating is shown in Figure 2. Possibly as a result of the differences in the amount of food ingested over the course of the two nutritional phases, participants gained a significant amount of weight during the carbohydrate phase, whereas their weight remained stable during the protein phase.

The current study replicated and extended a previous report of a nonclinical sample. In that earlier study (Latner & Schwartz, 1999), food intake after protein consumption amounted to 76% of intake after carbohydrate consumption, comparable to the 79% found in our study. In the Latner and Schwartz study, participants also reported more excitement about eating and enjoyment of test meals after carbohydrate intake than after protein or mixed intake. This suggested that carbohydrate was less effective than protein at suppressing the hedonic anticipation and enjoyment of eating. In contrast, in the current study, women with eating disorders showed no difference between the carbohydrate and protein conditions in their level of excitement about eating before meals.

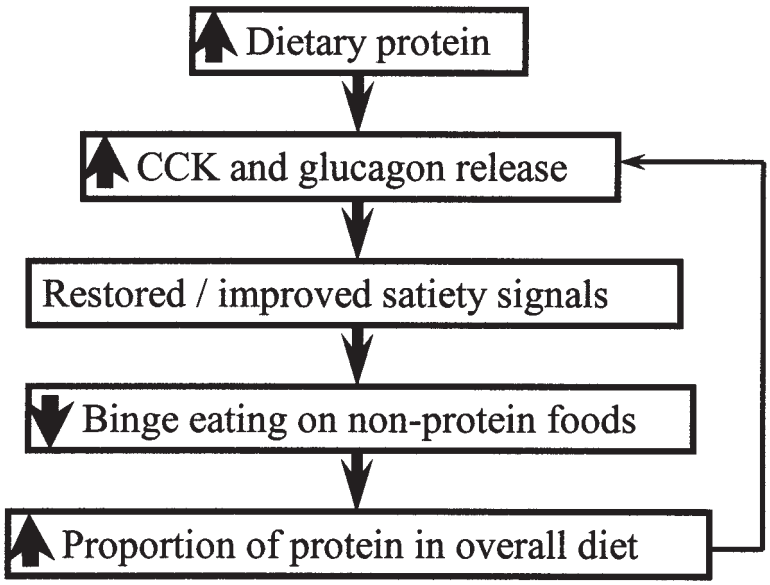

Figure 2. Hypothesized mechanism of action for protein's suppressive effect on binge eating. An increase in the proportion or total amount of dietary protein could potentiate the release of satiety agents known to be secreted in response to protein ingestion (i.e., cholecystokinin [CCK] and glucagon). This could help to restore or improve satiety functioning. Binge eating on foods high in fat and carbohydrate would, in turn, be reduced and the overall protein in the diet would remain at adequate levels to perpetuate this positive cycle.

There were also no differences between conditions in the hedonic responses to meals, the extent to which participants rated meals as enjoyable and pleasant. It stands to reason that hedonic responses to food in women with BN or BED would be subject to many simultaneous influences from internal and external stimuli. These responses might, therefore, be more susceptible to emotional events and dysfunctional cognitions compared with nonclinical subjects whose eating-related cognitions might more predominantly consist of simple reflections of their hunger state. Also in contrast to previous research (Mitchell et al., 1999), there were no group differences between participants with BN and BED in their hedonic responses to food intake.

Protein supplementation did not cause any reduction in the frequency of SBEs, episodes in which the consumption of a small or moderate amount of food is accompanied by a feeling of loss of control. Similarly, an equal proportion of participants in each experimental condition experienced a feeling of loss of control at the test meal. This suggests that the greater satiating capacity of certain macronutrients may have had little impact on the subjective (or psychological) experience of loss of control over eating that can occur outside the context of excessive food consumption. Protein may decrease the frequency of binge eating through a physiologic process that reduces the overall amount consumed during an episode. It is possible, therefore, that protein decreased the number of OBEs by reducing their size and turning them into SBEs. However, if this had been the case, a greater number of SBEs might have been expected in the protein condition. Instead, SBE frequency was nearly identical between conditions. This suggests that a proportion of OBEs in the protein condition were not merely reduced in size to become SBEs, but eliminated altogether. Thus, because a certain number of episodes that involved a loss of control were eliminated,

protein supplementation may have reduced in frequency the seemingly cognitive or emotional sensation of loss of control.

One limitation of the current study was that the protein supplements contained a higher proportion of energy from fat than the carbohydrate supplements (14% vs. 4%). Therefore, it is possible that the results may be partly attributable to the variation in the fat content of the supplements rather than solely to the different proportions of carbohydrate and protein. However, Blundell and MacDiarmid (1997) have suggested that the delayed satiating effects of fat are too weak to prevent overconsumption at later meals. Moreover, dietary fat is negatively correlated with satiety scores (Holt, Brand-Miller, Petocz, & Farmakalidis, 1995). Therefore, if additional fat had affected the satiating efficiency of the protein supplements, it might have made them less satiating. Despite this potential disadvantage, protein led to greater satiety. This is consistent with previous findings that fat combined with protein was satiating, whereas fat combined with carbohydrate led to overconsumption (Cotton, Burley, & Blundell, 1993). The finding that protein increases satiety in the presence of carbohydrate (Latner & Schwartz, 1999) also lends support to the hypothesis that adding protein to mixed-macronutient foods increases their satiating efficiency. This is significant because real foods contain a combination of macronutrients, and protein in foods is usually accompanied by some fat or carbohydrate.

Another limitation was that although the supplements were balanced for caloric content, volume, fiber, sweetness, and appearance, and both had a mild flavor, participants were able to distinguish the two drinks. Participants were asked to describe this difference, and protein was perceived as grittier or chalkier and carbohydrate as smoother. In preparing the supplements, it was not possible to completely eliminate their difference in texture, even though supplements were thoroughly blended in an electric blender. It is possible that participants' perceptions of texture differences between the supplements may have influenced their satiety and binge eating during each phase of the study. However, this perceptible difference appears not to have influenced participants' expectations about the effects of the supplements on their behavior. Before being debriefed, participants were also asked to write down what they believed was the purpose of the study. Not a single participant guessed the true purpose of the study (comparing protein and carbohydrate supplements). Surprisingly, no participant even thought that the study was designed to compare the effects of two different types of nutritional supplements.

The current findings suggest several directions for future research. It is important to identify the physiologic mechanisms that mediate the effect of protein on satiety. For example, a CCK antagonist was found to block the suppression of food intake after protein intake in animals, but not after intake of other macronutrients, indicating that CCK mediates protein's satiating effect (Trigazis, Orttmann, & Anderson, 1997). This line of research could be extended from animals to humans. In addition, glucagon antagonists could be used to test glucagon's role as a potential mediator in the same manner. Another direction for further research is the identification of other aspects of foods that increase satiety in patients with eating disorders. For example, numerous characteristics of foods positively correlate with satiety, such as volume, fiber content, and temperature (Holt et al., 1995). These characteristics could be addressed through shorter-term nutritional interventions with eating-disordered patients, in designs parallel to that used in the current study, and findings from such research could ultimately inform a longer-term treatment intervention directed at restoring satiety.

The current study demonstrates that protein was more satiating than carbohydrate in women who binge eat, and that supplementing the diet with protein reduced binge

episodes over a 2-week period. It would be useful to examine the longer-term clinical implications of these findings for the treatment of eating disorders. Increasing the level of protein in the diet of patients with BN and BED may facilitate their reduction of binge eating and their ability to remain on a schedule of regular, controlled meals and snacks over the long-term. The inability of a nutritional intervention to reduce participants' perceptions of normal food intake as out of control, despite its ability to reduce OBEs, underscores the need for interventions that can address both the psychologic and nutritional deficits of patients. The current findings highlight that any nutritional intervention used with eating-disordered patients must occur within the broader context of treatment targeting their cognitive and other behavioral dysfunctions. They also argue for greater emphasis on macronutrient composition in patients' diets within the course of standard treatment.

REFERENCES

American Psychiatric Association. (1994). Diagnostic and statistical manual of mental disorders (4th ed.). Washington, DC: Author.

Beck, A.T., Steer, R.A., Ball, R., & Ranieri, W.F. (1996). Comparison of Beck Depression Inventories-IA and -II in psychiatric outpatients. Journal of Personality Assessment, 67, 588–597.

Bingham, S.A., Gill, C., Welch, A., Day, K., Cassidy, A., Khaw, K.T., Sneyd, M.J., Key, T.J.A., Roe, L., & Day, N.E. (1994). Comparison of dietary assessment methods in nutritional epidemiology: Weighed records v 24 h recalls, food-frequency questionnaires and estimated-diet records. British Journal of Nutrition, 72, 619–643.

Blundell, J.E., & MacDiarmid, J.I. (1997). Fat as a risk factor for overconsumption: Satiation, satiety, and patterns of eating. Journal of the American Dietetic Association, 97, S63–S69.

Cotton, J.R., Burley, V.J., & Blundell, J.E. (1993). Fat and satiety: Effect of fat in combination with either protein or carbohydrate. International Journal of Obesity, 17, 63.

Dalvit-McPhillips, S. (1984). A dietary approach to bulimia treatment. Physiology and Behavior, 33, 769–775.

DeCastro, J.M. (1987). Macronutrient relationships with meal patterns and mood in the spontaneous feeding behavior of humans. Physiology and Behavior, 39, 561–569.

DeCastro, J.M., & Elmore, D.K. (1988). Subjective hunger relationships with meal patterns in the spontaneous feeding behavior of humans: Evidence for a causal connection. Physiology and Behavior, 43, 159–165.

Elmore, D.K., & DeCastro, J.M. (1991). Meal patterns of normal, untreated bulimia nervosa and recovered bulimic women. Physiology and Behavior, 49, 99–105.

Fairburn, C.G., & Cooper, Z. (1993). The Eating Disorder Examination (12th ed.). In C.G. Fairburn & G.T. Wilson (Eds.), Binge eating: Nature, assessment, and treatment, (pp. 317–332). New York: Guilford Press.

Fryer, J.H., Moore, N.S., Williams, H.H., & Young, C.M. (1955). A study of the interrelationship of the energy-yielding nutrients, blood glucose levels, and subjective appetite in man. Journal of Laboratory and Clinical Medicine, 45, 684–696.

Geary, N. (1990). Pancreatic glucagon signals postprandial satiety. Neuroscience and Biobehavioral Reviews, 14, 323–338.

Geary, N., & Smith, G.P. (1982). Pancreatic glucagon and postprandial satiety in the rat. Physiology and Behavior, 28, 313–322.

Geracioti, T.D., & Liddle, R.A. (1989). Impaired cholecystokinin secretion in bulimia nervosa. New England Journal of Medicine, 319, 683–688.

Hadigan, C.M., Kissileff, H.R., & Walsh, B.T. (1989). Patterns of food selection during meals in women with bulimia. American Journal of Clinical Nutrition, 50, 759–766.

Hadigan, C.M., Walsh, B.T., Devlin, M.J., LaChaussée, J.L., & Kissileff, H.R. (1992). Behavioral assessment of satiety in bulimia nervosa. Appetite, 18, 233–241.

Hetherington, M.M., Altemus, M., Nelson, M., Bernat, A.A., & Gold, P.W. (1994). Eating behavior in bulimia nervosa: Multiple meal analyses. American Journal of Clinical Nutrition, 60, 864–873.

Hill, A.J., & Blundell, J.E. (1983). Nutrients and behaviour: Research strategies for the investigation of taste characteristics, food preferences, hunger sensations and eating patterns in man. Journal of Psychological Research, 17, 203–212.

Hill, A.J., & Blundell, J.E. (1986). Macronutrients and satiety: The effects of a high-protein or high-carbohydrate meal on subjective motivation to eat and food preferences. Nutrition and Behavior, 3, 133–144.

Hill, A.J., & Blundell, J.E. (1989). Comparison of the action of macronutrients on the expression of appetite in lean and obese human subjects. Annals of the New York Academy of Science, 575, 529–534.

Holt, S.H., Brand-Miller, J.C., Petocz, P., & Farmakalidis, E. (1995). A satiety index of common foods. European Journal of Clinical Nutrition, 49, 675–690.

Johnstone, A.M., Harbron, C.G., & Stubbs, R.J. (1996). Macronutrients, appetite, and day-to-day food intake in humans. European Journal of Clinical Nutrition, 50, 418–430.
Latner, J.D., & Schwartz, M. (1999). The effects of a high-carbohydrate, high-protein, or balanced lunch upon later food intake and hunger ratings. Appetite, 33, 119–128.
Liddle, R.A. (1997). Cholecystokinin cells. Annual Review of Physiology, 59, 221–242.
Liddle, R.A., Goldfine, I.D., Rosen, M.S., Taplitz, R.A., & Williams, J.A. (1985). Cholecystokinin bioactivity in human plasma: Molecular forms, responses to feeding, and relationship to gallbladder contraction. Journal of Clinical Investigation, 75, 1144–1152.
Mitchell, J.E., Mussell, M.P., Peterson, C.B., Crow, S., Wonderlich, S.A., Crosby, R.D., Davis, T., & Weller, C. (1999). Hedonics of binge eating in women with bulimia nervosa and binge eating disorder. International Journal of Eating Disorders, 26, 165–170.
Muller, W.A., Faloona, G.R., Aguilar-Parada, E., & Unger, R.H. (1970). Abnormal alpha-cell fuction in diabetes: Response to carbohydrate and protein ingestion. The New England Journal of Medicine, 283, 109–115.
National Task Force on the Prevention and Treatment of Obesity. (1993). Very low-calorie diets. Journal of the American Medical Association, 270, 967–974.
Pek, S., Fajans, S.S., Floyd, J.C., Knopf, R.F., & Conn, J.W. (1971). Effects upon plasma glucagon of infused and ingested amino acids and of protein meals in man. Diabetes, 18, 328.
Rivzi, S.L., Peterson, C.B., Crown, S.J., & Agras, W.S. (2000). Test-retest reliability of the eating disorder examination. International Journal of Eating Disorders, 28, 313–316.
Rosen, J.C., Leitenberg, H., Fisher, C., & Khazam, C. (1986). Binge-eating episodes in bulimia nervosa: The amount and type of food consumed. International Journal of Eating Disorders, 5, 255–267.
Rosen, J., Vara, L., Wendt, S., & Leitenberg, H. (1990). Validity studies of the Eating Disorders Examination. International Journal of Eating Disorders, 9, 519–528.
Rossiter, E.M., Agras, W.S., Telch, C.F., & Bruce, B. (1992). The eating patterns of non-purging bulimic subjects. International Journal of Eating Disorders, 11, 111–120.
Spitzer, R.L., Williams, J.B., Kroenke, K., Linzer, M., DeGruy, F.V., Hahn, S.R., Brody, D., & Johnson, J.G. (1994). Utility of a new procedure for diagnosing mental disorders in primary care: The Prime-MD study. Journal of the American Medical Association, 272, 1749–1756.
Spring, B., Maller, O., Wurtman, J., Digman, L., & Cozolino, L. (1983). Effects of protein and carbohydrate meals on mood and performance: Interactions with sex and age. Journal of Psychiatric Research, 17, 155–167.
Stubbs, R.J., Harbron, C.G., Murgatroyd, P.R., & Prentice, A.M. (1995). Covert manipulation of dietary fat and energy density: Effect on substrate flux and food intake in men eating ad libitum. American Journal of Clinical Nutrition, 62, 316–329.
Stubbs, R.J., van Wyk, M.C.W., Johnstone, A.M., & Harbron, C.G. (1996). Breakfasts high in protein, fat or carbohydrate: Effect on within-day appetite and energy balance. European Journal of Clinical Nutrition, 50, 409–417.
Trigazis, L., Orttmann, A., & Anderson, G.H. (1997). Effect of a cholecystokinin-A receptor blocker on protein-induced food intake suppression in rats. American Journal of Psysiology, 272, R1826–R1833.
Van der Ster Wallin, G., Noring, C., & Holmgren, S. (1994). Binge eating versus nonpurged eating in bulimics: Is there a carbohydrate craving after all? Acta Psychiatrica Scandinavica, 89, 376–381.
Wadden, T.A., Stunkard, A.J., Day, S.C., Gould, R.A., & Rubin, C.J. (1987). Less food, less hunger: Reports of appetite and symptoms in a controlled study of a protein-sparing modified fast. International Journal of Obesity, 11, 239–249.
Weltzin, L.K., Hsu, L.K.G., Pollice, C., & Kaye, W.H. (1991). Feeding patterns in bulimia nervosa. Biological Psychiatry, 30, 1093–1110.
Yanovski, S.Z., Leet, M., Yanovski, J.A., Flood, M., Gold, P.W., Kissileff, H.R., & Walsh, B.T. (1992). Food selection and intake of obese women with binge eating disorders. American Journal of Clinical Nutrition, 56, 979–980.