Influence of cognitive eating restraint on total-body measurements of bone mineral density and bone mineral content in premenopausal women aged 18–45 y: a cross-sectional study[1,2]

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ABSTRACT

Background: We examined the relation between cognitive eating restraint (CER) and total-body measurements of bone mineral density (BMD) and bone mineral content (BMC).

Objective: Our objective was to determine whether women with CER had lower total-body BMD and BMC than did other women.

Design: Premenopausal women, 90–150% of ideal weight, had measurements of their BMD and BMC made and completed questionnaires on physical activity, weight history, body size satisfaction, dieting history, eating behavior, and childbearing history. Bone measurements were examined for differences between groups with low and high CER scores by using analysis of covariance and quartiles of body weight to adjust for body size differences. CER was assessed by using the Three-Factor Eating Inventory and was defined as a score ≥ 9; normal eating restraint (NER) was defined by a score <9. Total-body BMC, BMD, and fat and lean masses were measured by dual-energy X-ray absorptiometry.

Results: Fifty-two percent of the women were classified as having CER. Women with CER were significantly more dissatisfied with their bodies. Analysis of covariance, with weight as the covariate, indicated a significant difference in BMC between women in preplanned pairs from the 5 lowest and 5 highest CER levels. No significant differences in BMD were observed between groups. Significantly lower BMC was found in women with high CER scores and body weights <71 kg than in those with high CER scores and weights ≥ 71 kg.

Conclusions: BMC was significantly differently between women with low and high CER scores. BMC was significantly lower in women with body weights <71 kg and classified with CER. Lower BMC in women with high CER scores may indicate an increased risk of osteoporosis. *Am J Clin Nutr* 2000;72:837–43.

KEY WORDS Cognitive restraint, premenopausal women, whole-body bone mineral density, bone mineral content, body fat, fat-free mass, eating restraint, Three-Factor Eating Inventory

INTRODUCTION

The prevalence of obesity and societal pressure to be thin has resulted in a preoccupation with dieting. Cognitive eating restraint (CER), which is defined as the intent to limit food intake to prevent weight gain or to promote weight loss, is encountered frequently in women— overweight and normal-weight alike. Herman and Polivy (1) defined restrained eaters as individuals who are consciously aware of monitoring their food intake to meet a self-imposed or socially imposed target weight. Other characteristics associated with CER include great variability in energy intake, a tendency to avoid fat intake, frequent use of energy-reduced foods, episodic dieting or weight cycling, and possibly impairment of the psychophysiologic regulation of food intake (2, 3). Lowe (4) suggested a model of dieting behavior that includes interactions with body weight, types of dieting, and mediating mechanisms. Lowe postulated that a cycle of chronic dieting causes overeating and overeating results in more chronic dieting. The effect of restrained eating on other physiologic processes remains largely unexplored but it is possible that bone mineral status is compromised in individuals with characteristics of CER.

Intake of nutrients (especially micronutrients), exercise, and hormonal changes also contribute to bone mass. Individuals with characteristics of CER may have low mineral intakes. However, epidemiologic studies have shown that populations accustomed to a low calcium intake adapt to achieve calcium balance (5). But erratic fluctuations in calcium intake, as might occur with CER, may compromise the adaptation process. Exercise, however, involves a mechanical force or load on bones to increase bone mineral content (BMC) and bone mineral density (BMD); weight loss may play a role in eroding BMC when less mechanical force is applied to the bones. Hormonal factors also contribute to skeletal development and maintenance. Schweiger et al (6) and Barr et al (7) found that women with high CER scores experienced changes in their menstrual cycles and in some reproductive hormones. Schweiger et al (6) reported a shorter total cycle, shorter luteal phase, and lower progesterone concentrations in women with high CER scores. Similarly, Barr et al (7) found shorter luteal phases in women with CER scores in the upper tertile of the sample. The results from these 2 investigations suggest that CER may trigger changes in womens' reproductive hormones that may result in lower bone density. In a

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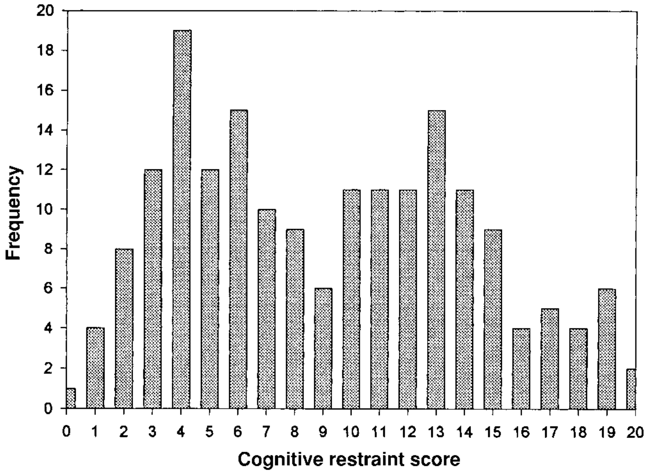

FIGURE 1. Distribution of cognitive eating restraint scores in a sample of 185 premenopausal women aged 18–45 y.

second study by Barr et al (8), spinal BMD was measured in women with high CER scores but no significant differences were found between women in the upper and lower tertiles of restraint score. The lack of a significant finding may have been because of a small sample (*n* = 27). Therefore, our purpose was to examine the association between CER score and BMC and BMD in a large group of premenopausal women.

SUBJECTS AND METHODS

Subjects

Premenopausal women aged 18–50 y were recruited from the general population of the San Francisco Bay Area. Women were selected if they were within the appropriate age range and if their body weight was within the range of 90–150% of ideal weight for height on the basis of the Metropolitan Height and Weight Table (9). Initial exclusion criteria included age or body weight outside the designated ranges; pregnancy; and use of bisphosphonate, glucocorticoid, anticonvulsive medication, or other medications known to alter bone metabolism. The research protocol was approved by the Institutional Review Boards of the University of California, Davis, and the US Department of Agriculture. Each woman was informed about the objectives of the study and the procedures involved. Written, informed consent was obtained before participation in the study. Demographic information collected included historical body weight information, a description of typical physical activity (type, frequency, duration, and intensity), dieting or weight loss history, and childbearing history.

Women were selected from the pool of candidates who were applying for other nutrition research studies and from the general public. Recruitment was accomplished through advertisements in local newspapers and distribution of fliers to local universities and community organizations. Once women were enrolled in the study, secondary exclusion criteria included being too large for dual-energy X-ray absorptiometry (DXA) measurements and being perimenopausal. Subsequently, all women aged >45 y were deemed perimenopausal and were excluded.

Three-Factor Eating Inventory

CER was evaluated by using the Three-Factor Eating Inventory of Stunkard and Messick (10). In addition to CER, the questionnaire also assesses disinhibition and hunger. Women were classified as having normal eating restraint (NER) if the score on the Cognitive Restraint Factor was <9 or as having CER if the score was ≥ 9. A restraint score ≥ 9 was selected because it was the median score for this data set (**Figure 1**). Coincidentally, Allison et al (11), in a group of 900 college students, also had a median score of 9 on the Three-Factor Eating Inventory.

Anthropometry and physical activity

Body weight of subjects wearing cotton surgical scrubs, without shoes, and free of any metal, was measured to the nearest 0.1 kg on an electronic scale. Height of subjects without shoes was measured to the nearest 0.5 cm with a wall-mounted stadiometer. Physical activity was assessed by using a modified Paffenbarger questionnaire (12), which also included drawings of different body shapes and size.

Bone and body-composition measurements

Total-body BMC, BMD, fat mass, and bone-free lean mass were measured with a Lunar dual-energy X-ray absorptiometer (DPX; Lunar Corp, Madison, WI) by using software version 3.6z (13). All scans were performed and analyzed by 2 cross-trained laboratory technicians. All scans of the research volunteers were performed on the same day as that on which all questionnaires and other study-related procedures were completed.

Percentage body fat (%BF) was calculated as the DXA-derived fat tissue divided by body weight as follows:

$$\%BF = (Fat_{DXA}/weight) \times 100 \qquad (1)$$

Fat-free mass (FFM) from DXA was calculated as the sum of DXA bone-free lean tissue and BMC:

$$FFM_{DXA} = \text{DXA bone-free lean mass} + \text{BMC} \qquad (2)$$

DXA quality control within subjects and between technicians was assessed by performing scans on 5 laboratory staff members over 3 d (Monday, Wednesday, and Friday). No significant differences were observed in total-body BMC (3-d means ranged from 2341 to 2373 g), BMD (3-d means ranged from 1.134 to 1.138 g/cm^2), or FFM (3-d mean was 39.6 kg). Similarly, no significant differences were found in the repeated assessment of percentage body fat, with the average for 3 d ranging from 27.0% to 27.2%. The repeated scans on the laboratory personnel were also analyzed by 2 DXA operators. Analysis of variance (ANOVA) indicted no significant differences in results between operators. Repeated measurements of the calibration phantom gave CVs for large bone mass and width, respectively, of 0.29% and 0.27%; those for medium bone mass and width were 0.43% and 0.16%; and those for small bone mass and width were 0.82% and 0.32%.

Adjustment of bone measurements for body size

The use of DXA for the determination of bone density is not without its problems. The technique relies on software algorithms for the accurate detection of bone edges and for conversion of the X-ray attenuation values to BMC and bone area. Corrections are then made for soft tissue overlying the bone and values are expressed as BMC for the region. DXA data are also expressed as BMD. BMD, however, is an areal measurement (g/cm^2) rather

TABLE 1
Physical characteristics of women by cognitive eating restraint score[1]

	Value	CV
		%
NER (*n* = 89)		
Age (y)	30.7 ± 7.2 (20–45)	23.6
Height (cm)	164.7 ± 6.5 (150–184)	4.0
Weight (kg)	61.9 ± 10.6 (44–92)	17.1
BMI (kg/m^2)	22.8 ± 3.6 (16.9–29.7)	15.6
FFM (kg)	41.7 ± 4.3 (32.9–52.8)	10.4
Fat (kg)	19.9 ± 8.4 (7.5–44.7)	42.5
Restraint	4.7 ± 2.0 (0–8)	42.4
Disinhibition	5.4 ± 3.6 (1–15)	66.1
Hunger	4.9 ± 3.0 (0–14)	61.3
CER (*n* = 96)		
Age (y)	30.8 ± 7.7 (18–45)	25
Height (cm)	164.4 ± 7.2 (142–182.6)	4.4
Weight (kg)	64.4 ± 9.3 (44.8–82.0)	14.4
BMI (kg/m^2)	23.8 ± 3.1 (17.8–30.0)	12.9
FFM (kg)	42.6 ± 4.8 (32.5–54.1)	12.9
Fat (kg)	21.2 ± 7.6 (5.3–35.9)	35.7
Restraint	13.4 ± 3.0 (9–20)	22.2
Disinhibition	7.5 ± 3.9 (1–16)	51.8
Hunger	5.2 ± 3.3 (0–13)	62.6

[1] $\bar{x}$ ± SD. NER, normal eating restraint on the basis of a cognitive restraint score <9; CER, cognitive eating restraint on the basis of a cognitive restraint score ≥9. There were no significant differences between groups with ANOVA. Restraint, disinhibition, and hunger were determined with the Three-Factor Eating Inventory (10). FFM, fat-free mass.

than a density measurement (g/cm^3) and, although shown to be a good predictor of fracture risk and osteoporosis, it can be misleading when used in research studies because it assumes that BMC is proportional to bone area or bone width. In cases in which body weight changes, BMC may not change but the detection of bone edges may, the net result being a spurious change in BMD with no corresponding change in mineral content of the skeleton. Thus, the observed change in BMD is an artifact of limitations of the instrument in accurately detecting bone edges or bone area (14). To correct for a lack of linearity between BMD and BMC, we followed the procedures of Prentice et al (15), in which the relation between BMC and bone area was determined by regressing BMC on bone area. Similarly, the relation between BMD and BMC and bone area was determined by regressing BMD on BMC and bone area. The resulting regression coefficients were used to correct BMC and BMD to their true values.

Statistical analysis

The final sample of women who completed all procedures in this study was 185, which was determined to have a power of 0.80. Descriptive statistics were used to characterize the sample. Bone measures are highly related to body weight; therefore, we used 2 approaches to analyze the data. Analysis of covariance (ANCOVA) was used to determine whether significant differences existed in BMD and BMC when either weight or BMI was used as a covariate and CER was used as either a categorical or continuous variable. The Bonferroni post hoc test was used to assess significance in main effects and controls for experiment-wise error (type I). Additional analysis to examine the relation between CER score and BMD and BMC, while adjusting for body size effects, was with quartiles of body weight. ANOVA was used to test for significant differences in BMD and BMC between women with CER and NER in each quartile of body weight. Pearson correlation coefficients were examined for associations between CER scores and BMD and BMC. Significant differences between women with CER and NER in the number of sessions per week of physical activity, hours of physical activity, metabolic equivalents (METs) of activity, number of children, weight changes, and body size perception and satisfaction were examined with use of *t* tests. Finally, multiple stepwise regression analysis was used to determine which variables made significant contributions to the prediction of BMC and BMD in women with CER and NER. Variables offered in the multiple regression prediction were CER score as a continuous variable, age, height, weight, body mass index (BMI; in kg/m^2), fat mass, percentage body fat, lean mass, FFM, number of children, METs of physical activity, and number of weight loss cycles. The number of weight loss cycles was calculated as the total number of weight loss episodes for each woman in which she lost from 5 lbs (2.3 kg) to 40 lbs (18.6 kg). Statistical analyses were conducted by using SAS (16).

RESULTS

From the initial sample of 245 women, 53 women were excluded because of size (an inability to fit within the DXA scan area). Another 7 women were deemed to be perimenopausal, on the basis of being aged >45 y, and were excluded. The final sample size, on which all analyses were performed, was 185. In the sample of 185 women, 52% were classified as having CER characteristics with a Cognitive Restraint Factor score ≥9; the remaining women were classified as having NER. Mean age, height, and weight were similar for both groups (those with CER and NER), as were measures of body composition, including FFM and percentage body fat (**Table 1**). Although CER scores differed significantly between the 2 groups as defined, there were no significant differences between groups in scores of disinhibition or hunger. No significant differences were observed between the 2 groups for body weights at 20, 25, 30, 35, 40, and 45 y of age, highest body weight, or body size perception. Displayed in **Table 2** are the results from a diet history in which the women were asked, "How often have you lost 5 lb (2.3 kg), 10 lb (4.5 kg), 20 lb (9.1 kg), 30 lb (13.6 kg), and 40 lb (18.2 kg)?" Seventy-six percent of the women with CER responded as having lost 5 lb (2.3 kg), compared with 63% of those with NER. The women with CER also lost 5 lb (2.3 kg) 25.2 different times compared with only 10.6 times for those with NER. In other words, the women with CER lost 5 lb (2.3 kg) 2.4 times more often than did

TABLE 2
Weight loss history for subjects with cognitive eating restraint (CER) and normal eating restraint (NER) classifications

Weight loss in lbs (kg)	NER (*n* = 89)		CER (*n* = 96)	
	Respondents	Times	Respondents	Times
5 (2.3)	56	10.6	73[1]	25.2[1]
10 (4.5)	47	2.9	67[1]	7.6[1]
20 (9.1)	28	1.8	38[1]	3.1[1]
30 (13.6)	7	1.1	17[1]	3.1
40 (18.2)	7	1.7	8	1.7
Average number of weight cycles	3.6		8.2[1]	

[1] Significantly different from NER, $P < 0.05$.

TABLE 3

Physical activity characteristics and number of children for groups with cognitive eating restraint (CER) and normal eating restraint (NER)[1]

	NER (n = 89)	CER (n = 96)
Physical activity characteristics		
Sessions per week	6.4 ± 5.6[2]	5.0 ± 4.6
Hours per week	6.4 ± 5.7	5.4 ± 5.0
METs per week	84.1 ± 143.4	53.9 ± 80.1
Children[3]	24	24

[1] There were no significant differences between groups. METs, metabolic equivalent hours.

[2] $\bar{x}$ ± SD.

[3] The total number of children born to women in the group.

those with NER. Similarly, a significantly greater number of CER-classified respondents reported losing 10 (4.5 kg), 20 (9.1 kg), and 30 (13.6 kg) lb than did NER-classified respondents. The frequency of these weight loss episodes at the 10- (4.5 kg), 20- (9.1 kg), and 30- (13.6 kg) lb levels was also significantly greater for the women with CER; they were >2 times more frequent for the women with CER than for the women with NER.

No significant differences in physical activity were observed between women with NER and CER as an average number of activity sessions per week, hours per week in physical activity, or METs per week (**Table 3**). Likewise, no significant differences were observed in the number of children born to women with CER compared with those with NER. No differences existed between the 2 groups in the number of participants tested at various times during the year. For the women with NER, 65% of the sample was tested during the summer months, when the effects of sunlight on vitamin D metabolism would be the greatest. Similarly, 62% of the women with CER were tested during the same period. For both groups, most of the data were collected in the spring and summer months (77.5% of those with NER, 76% of those with CER; April–September).

Because body weight has a strong influence on BMD, relations among CER score and BMD and BMC were examined by using ANCOVA. First, CER was used as a categorical variable (0 or 1) and weight or BMI was the covariate followed by the same analysis with CER score as a continuous variable (0–20). No significant differences were observed in either BMD or BMC when CER was expressed as a categorical variable and either weight or BMI were covariates. However, when CER was expressed as a continuous variable (0–20) and body weight was the covariate, differences were observed in BMC for preplanned comparisons between the 5 lowest CER scores and the 5 highest scores. No differences were observed in BMD when ANCOVA was used. When BMI was used as the covariate to adjust for both weight and height effects on bone, and CER was a continuous variable, no significant differences by CER score were observed for either BMD or BMC.

Further analysis of the BMD and BMC data was conducted by quartile of body weight. Quartiles of body weight were 1, ≥44, ≤56 kg; 2, >56, ≤62 kg; 3, >62, ≤71 kg; and 4, >71 kg. Weight was held constant (covariate) within each quartile and CER was a continuous variable. No main effect of CER was observed on BMD; however, significant effects were observed on BMC (**Table 4**). With use of the Bonferroni post hoc test for comparisons between groups with CER and NER within weight quartiles, BMC in the first quartile of weight was significantly lower for women with high restraint scores (data not shown). The values for BMC in the first quartile of weight were also lower than those in the second, third, and fourth quartiles (**Table 5**). Highly restrained women in the second and third quartiles of weight also had BMC values lower than did those in the fourth quartile but not different from each other. Women in the fourth quartile of weight had the highest BMC values. A significant negative correlation was found between BMC and CER score in the lowest weight quartile ($r = -0.29$, $P = 0.03$) (**Figure 2**). A similar correlation was observed between bone area and CER score in the lowest weight quartile ($r = -0.29$, $P < 0.03$) but not for BMD. Women with high CER scores had significantly lower BMC values in 3 of 4 weight quartiles. A high CER score was not indicative of a lower BMC for women who weighed ≥71 kg. For example, the group in the first weight quartile consisted of 55 women or 29.7% of the total sample and those classified as having CER made up 36% of the quartile. Absolute BMC for this group was 2241 g, which was 214 (9.5%), 235 (10.5%), and 368 (16.4%) g lower than that for the second, third, and fourth quartiles, respectively. Within this weight quartile, BMC ranged from 1750 to 2390 g for the CER-classified women, whereas BMC ranged from 1856 to 2566 g for NER-classified women in the same weight quartile. Similarly, women with high CER scores in the second and third weight quartiles also had lower BMC values than NER-classified women in the same weight quartile.

Multiple regression analysis was performed to determine which variables made significant contributions to the estimation of BMC and BMD. A stepwise regression procedure was used with age, height, weight, BMI, fat mass, percentage body fat, lean mass by DXA, FFM, CER score as a continuous variable, METs of physical activity, number of children, and weight cycling as variables. The regression analysis was done for the total data set by CER classification; results are shown in **Table 6**. In the total sample of 185 women, the best predictors of BMC were height, CER score (0–20), FFM, and percentage body fat. The resulting correlation was 0.75. This regression analysis, however, accounted for only 56% of the variance in BMC with 44% unexplained by these variables. For the estimation of BMD for the total sample, only weight was a significant predictor with a correlation of $r = 0.36$, explaining only 13% of the variance in BMD. When regression analysis was done on the separate CER- and NER-classified groups, the predictors of BMC for the NER-classified women were the same as those for the total sample (height, CER score, FFM, and percentage body fat) with a

TABLE 4

Differences in total-body bone mineral density (BMD) and bone mineral content (BMC) between women classified with CER and NER by using ANCOVA to adjust for body weight, quartile of weight, and CER score as a continuous variable[1]

Dependent variable	df	Sum of squares	Mean square	P
BMD				
CER score	20	0.129549	0.006820	0.1232
Quartile of weight	3	0.112802	0.037600	0.0001
Weight	1	0.156206	0.156206	0.001
BMC				
CER score	20	2007489	100374	0.0331
Quartile of weight	3	4090158	1363386	0.0001
Weight	1	5489562	5489562	0.0001

[1] CER, cognitive eating restraint; NER, normal eating restraint.

TABLE 5

Significant differences in total-body bone mineral content (BMC), bone area (BA), and bone mineral density (BMD) by quartile of body weight[1]

	BMC	BA	BMD
	g	*cm^2*	*g/cm^2*
First quartile: 44–<56 kg (*n* = 55)	2241.9 ± 204^{a}	1961.2 ± 150.6^{a}	1.127 ± 0.06
Second quartile: 56–<62 kg (*n* = 41)	2455.8 ± 224^{b}	2119.1 ± 165.8^{b}	1.128 ± 0.09^{a,b}
Third quartile: 62–<71 kg (*n* = 44)	2476.7 ± 172^{b}	2134.5 ± 127.1^{b}	1.182 ± 0.07^{b,c}
Fourth quartile: ≥71 kg (*n* = 45)	2609.7 ± 282^{c}	2232.7 ± 208.5^{c}	1.191 ± 0.06^{c}

[1] $\bar{x}$ ± SD. Values with different superscript letters are significantly different, $P < 0.05$.

correlation of 0.75. For the CER-classified group, however, the best predictors of BMC were weight and FFM, with a correlation of 0.77. The prediction of BMD by restraint group resulted in only FFM being a significant predictor in the women with NER ($r = 0.38$), whereas BMI and FFM were the best predictors of BMD for the women with CER ($r = 0.46$). Regression analysis was not done by quartiles of body weight because of the small sample in each quartile and the number of variables offered in the multiple regression analysis. Throughout the multiple regression analysis, no single variable or set of variables predicted BMD as well as they predicted BMC.

DISCUSSION

The results of the present investigation showed that CER characteristics are widespread, occurring in more than half (52%) of the women in this study. This investigation was the first of its kind to show a significant negative association between CER and BMC. However, no significant differences between women with CER and NER were observed in FFM, percentage body fat, or other physical characteristics. When examined by quartile of body weight, only women in the highest quartile (≥71 kg) showed no effect on BMC of high CER scores. We also observed a significant negative relation between CER score and BMC. ANCOVA showed significant differences in preplanned comparisons for BMC, but not BMD, when adjusted for body weight. Relative to other factors in the Three-Factor Eating Inventory, Lautenbach et al (17) found no differences in disinhibition or hunger between individuals with and without CER. Our results confirmed these findings.

Lautenbach et al also found no differences in perception of body size between individuals with ($n = 21$) and without ($n = 20$) CER, but significant differences existed between the 2 groups in body satisfaction. The findings in our study were similar to those of Lautenbach et al for body size perception and for body satisfaction. For body size satisfaction, we analyzed for differences between groups in the number of women dieters and the number of times an individual dieter lost 5 (2.3 kg), 10 (4.5 kg), 20 (9.1 kg), 30 (13.6 kg), or 40 (18.2 kg) lb. In our investigation, the number of respondents who indicated they lost 5 (2.3 kg), 10 (4.5 kg), 20 (9.1 kg), 30 (13.6 kg), or 40 (18.2 kg) lb was significantly higher for the group with CER than for the group with NER. The number of times that a respondent lost 5 (2.3 kg), 10 (4.5 kg), 20 (9.1 kg), or 30 (13.6 kg) lb was also significantly higher for the group with CER than for the group with NER.

Other factors that may influence BMC include physical activity, hormonal changes as a result of childbearing, and possibly the time of year at which the DXA measurements were done. We observed no significant differences between the groups with CER and NER in physical activity, number of children, or the time of year at which DXA measurements were made. Our findings of no differences between women with CER and NER are consistent with the findings of Tepper et al (18) and Klesges et al (19).

Other possible explanations for the lower BMC in the lowest weight quartile are hormonal and menstrual cycle disturbances in women with CER (20, 21). Prior et al (21) examined changes in ovulatory function of 66 women during exercise training for 1 y. The women had normal menstrual cycles and luteal phases of normal length for ≥2 mo before study participation and were divided into 3 groups: normally active women, consistent runners, and marathon runners. On the basis of data from all 66 women, normal menstrual cycle length was defined as ranging from 21 to 36 d, with a normal luteal phase length of 10–16 d. The luteal phase index was defined as the number of days in the luteal phase divided by the total number of days in the menstrual cycle. Serum concentrations of luteinizing hormone, follicle-stimulating hormone, estradiol, progesterone, and prolactin were measured. The average cycle length during the year was 28.2 d and the average luteal phase length was 10.1 d. The mean luteal phase length and hormone concentrations did not differ significantly among the 3 groups; however, there was an observed decrease in bone density of $3.0\ \mathrm{mg \cdot cm^{-3} \cdot y^{-1}}$. This average percentage decrease was not significantly different among the groups, although a significant relation between change in bone density and luteal phase index was observed ($r = 0.54$, $P < 0.001$).

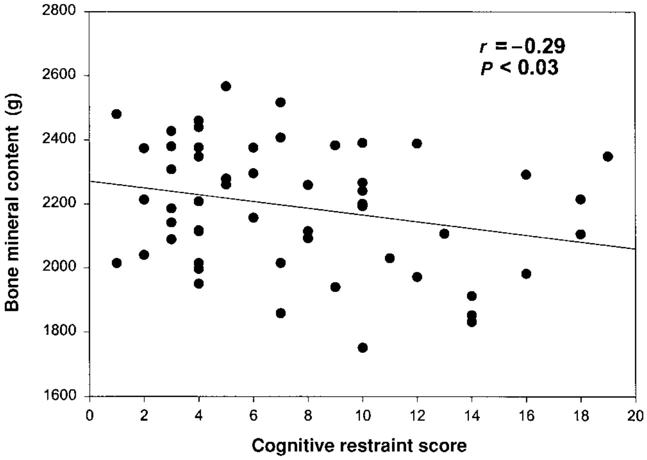

FIGURE 2. Relation between cognitive eating restraint and bone mineral content in the first quartile of body weight (44–56 kg).

TABLE 6
Multiple regression analysis to determine significant contributors to the estimation of bone mineral content (BMC) and bone mineral density (BMD)[1]

Estimation of variable	Total sample ($n = 185$)	NER ($n = 89$)	CER ($n = 96$)
BMC			
Intercept	−1225.2068	−1632.2913	339.3925
Height	11.7500	15.3829	—
Weight	—	—	15.2533
CER score	−5.8029	−28.4691	—
FFM	34.5751	34.7124	26.0267
Percentage body fat	10.4011	7.6389	—
R^2	0.56	0.56	0.60
BMD			
Intercept	0.9829	0.8607	0.7978
Weight	0.0027	—	—
BMI	—	—	0.0094
FFM	—	0.0072	0.0030
R^2	0.1327	0.1474	0.2149

[1] NER, normal eating restraint; CER, cognitive eating restraint; FFM, fat-free mass.

The mean serum progesterone concentration in the luteal phase was also significantly related to the 1-y change in bone density ($r = 0.25$, $P < 0.05$). Results from this investigation showed clearly that even without symptoms of ovulatory disturbances, women may have luteal phase changes that affect BMD. The effect of luteal cycle changes may be explained, at least partially, by changes in progesterone concentration. Progesterone facilitates bone formation but it also increases bone turnover. The increased rate of bone remodeling could result in a loss of bone mineral even with normal production of estradiol.

Research efforts (6–8, 21) that focused on CER documented changes in luteal phase length. Schweiger et al (6) established menstrual cycle characteristics in a group of German women and found that those of women with low restrained eating scores included a peak serum estradiol concentration >440 pmol/L, a peak serum progesterone concentration >19 nmol/L, and a luteal phase length between 9 and 11 d. In contrast, only 2 women with high restraint scores (>10) had normal menstrual characteristics, whereas highly restrained women had low progesterone concentrations (18 compared with 35 mmol/L) and a shortened luteal phase length (9 compared with 13 d). Additionally, the total cycle was also shorter (24 compared with 31 d) in the most highly restrained women. These findings show that women with CER have lower progesterone concentrations than do women with NER and that women with CER may be at risk of decreased BMD.

A study by Barr et al (7) examined the relation between CER, menstrual cycle, luteal cycle length, and bone mineral in women. Similar to the results of Schweiger et al, Barr et al found a significantly shorter luteal phase in highly restrained women. Although the women in the study by Barr et al had higher restraint scores than did those in the study by Schweiger et al, no significant differences were observed in BMD. The lack of a significant difference in BMD values in the Barr et al study, compared with our recent findings, may be the result of a small sample. The Barr et al study included only 27 women—not a large enough sample to have statistical power high enough to detect changes in BMD between restrained and nonrestrained women. The sensitivity of DXA to detect differences in BMD is ≈1–2%, necessitating a sample size of ≥175 for a power of 0.8. In contrast with the approach of Barr et al, we examined the relation between CER and both BMD and BMC by using weight and BMI as covariates with CER as both a categorical and a continuous variable. Additionally, we used quartiles of body weight to correct for body size effects. Using both of these approaches, we found that BMD and BMC were significantly different between women with low and high CER scores.

In summary, this investigation was the first to show significantly lower BMC values in women with high CER scores. The most probable explanation for these lower BMC values is lower progesterone concentrations because of a shorter luteal phase (6, 7, 21); however, menstrual cycle and hormonal differences were not examined in this study. Nonetheless, the results of this study do suggest that those with high CER scores may compromise their long-term bone health. To more fully answer these questions, research is needed that integrates measures of eating behavior, menstrual cycle and phase lengths, hormone concentrations, BMC, BMD, and markers of bone turnover.

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