Factors Predictive of Bone Mineral Density in Eating-Disordered Women: A Longitudinal Study

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Abstract: **Objective:** *Osteoporosis in eating-disordered women is well established, but factors predictive of this condition have proved elusive. The roles of behavioral factors, weight, menstrual status, and the degree of bone mineral density change over the clinical course of the eating disorder were investigated.* **Method:** *A cohort of 56 eating-disordered women was subjected to bone mineral density measurement at Scan 1 and were followed up between 9 and 51 months later for repeat measurement (n = 10) at Scan 2.* **Results:** *High levels of reduced bone mineral density were observed. Total duration of amenorrhea, body mass index, frequency of vomiting, and cigarette and alcohol consumption accounted for 40% of the variance in spinal bone mineral density measurement at Scan 1. No significant changes in bone mineral density were observed at Scan 2 despite increases in body mass index.* **Discussion:** *The results suggest that increases in weight appear not to be sufficient to increase bone mineral density. © 2000 by John Wiley & Sons, Inc.* Int J Eat Disord 27: 29–35, 2000.

Key words: *bone mineral density; osteoporosis; eating disorders*

INTRODUCTION

The development of osteoporosis in women suffering from anorexia nervosa was first reported in 1984 by Rigotti, Nussbaum, Herzog, and Neer. Later studies have consistently confirmed that compared to age and sex-matched controls, anorectics have significantly lower bone mineral density (BMD; Brotman & Stern, 1985; Hay et al., 1992; Salisbury & Mitchell, 1991). Approximately 50% of those suffering from anorexia nervosa have osteoporosis of the lumbar spine (Biller et al., 1989) and are seven times more likely than normal women to suffer nontraumatic pathological fracture (Riggoti, Neer, Skates, Herzog, & Nussbaum, 1991).

The risk of osteoporosis occurring in other eating disorders has also been investigated. Women formally diagnosed with bulimia nervosa and atypical or eating disorders not

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otherwise specified have been found to have significantly lower BMD than expected compared to control data (Anderson, Woodward, & Lafrance, 1995). These findings are not surprising. It has been calculated that between 50–60% of patients with a current diagnosis of bulimia nervosa have a previous history of anorexia nervosa, while others fluctuate in their presentation of symptomatology, upon which diagnostic criteria for one condition or the other are based (Fairburn & Hope, 1988). Osteoporosis is also evident in women with estrogen deficiencies associated with menopause, oophorectomy, excessive exercise in competitive athletes, and involuntary weight loss. It should not be assumed that the physiological mechanism responsible for osteoporosis in these groups will be identical in eating-disordered women (Anderson et al., 1995).

The two most clinically evident physical manifestations of an eating disorder are a significant reduction in body mass index (BMI) and/or absence of menses. It has been suggested that body weight has an independent effect on BMD as it has been found that BMD can increase following weight gain, prior to the return of menses (Treasure, Russell, Fogelman, & Murby, 1987). Bachrach, Katzman, Litt, Guido, and Marcus (1991) observed that despite an increase in BMD, following weight gain, levels were still below those expected compared to age and sex-matched controls. Rigotti et al. (1991) and Joyce, Warren, Humphries, Smith, and Coon (1990) found no significant change in cortical BMD despite weight gain, conversely, no significant change was evident in those subjects who had lost or maintained weight.

With the additional factor of restoration of menses, significant increases in both trabecular (the more metabolically active) and cortical bone were detected. Forty-seven percent of the variance in BMD was accounted for by duration of amenorrhea and body weight (Seeman, Szmukler, Formica, Tsalamandris, & Mestrovic, 1992). In a longitudinal follow-up study, Rigotti et al. (1991) found no significant BMD changes with the return of menses. Since duration of amenorrhea will be similar to duration of illness, statistical correlations reflect the effects of food deprivation concurrent with low estrogen levels.

Young, Formica, Szmukler, and Seeman (1994) examined the role of weight-bearing exercise, amenorrhea, and low body weight in teenage girls and comparisons were made among ballet dancers, anorectics, and controls. They found that weight-bearing exercise was protective against osteoporosis, but only at weight-bearing sites. This is contrary to Dalsky's (1990) belief that with a low body weight, mechanical stress on the skeleton decreases and may attenuate any potential benefits of exercise. Thus, eating-disordered subjects who exercise vigorously may have "normal" BMD at sites such as the femur while having reduced BMD in the spine. Others claim that only moderate exercise offers some protection (Joyce et al., 1990). Negative correlations between excessive exercise and BMD, especially if amenorrhea was present, have also been reported by Hay et al. (1992). Following the discovery of near-normal BMD in recovered subjects with a shorter duration of illness (Hay et al., 1992), and increased demineralization within the first 2 years of onset of an eating disorder (Brown et al., 1992), it is uncertain whether there is a threshold duration of anorexia nervosa for serious bone loss to occur and whether the age of onset of illness is of significance.

Generally, studies have failed to investigate the etiological role of behavioral factors such as the frequency of binging, vomiting, and laxative ingestion, consumption of alcohol and nicotine, and the percentage of caloric restriction commonly associated with eating disorders. Previous research has failed to provide sufficient insight into the clinical course of osteoporosis in eating-disordered women. This study examines the factors that may be responsible for the development of osteoporosis in clinically diagnosed eating-

disordered women, in an effort to determine the degree of change in BMD over a period of time and the factors that may be responsible for that change.

METHODS

Subjects

Fifty-six female eating-disordered patients who had been routinely subjected to BMD measurement (Scan 1) either on admission to or attendance at the Peter Dally Eating Disorders clinic between November 1992 and August 1996 were investigated. Ages ranged between 17–45 years (M = 26.1). Of the participants, 48 were deemed to be suffering primarily with anorexia nervosa and 8 primarily with bulimia nervosa (ICD 10 criteria). All subjects were actively engaged in similar patterns of disordered eating and associated behaviors and showed no differences in BMI scores. The cohort of 56 women was contacted between 9 and 51 months following Scan 1. Repeat BMD measurement was offered (Scan 2). The mean duration in time from Scan 1 to Scan 2 was 20.8 months. Six subjects refused, 11 were receiving treatment elsewhere, 6 were untraceable, 3 had died and 20 were not eligible due to National Health Service funding status, the remaining subjects agreed to participate (n = 10).

Clinical Data

Following ethical approval, clinical data were obtained during semistructured interviews and case notes were reviewed. Self-reported frequency counts of vomiting, laxative use, binging, and cigarette and alcohol consumption were made on a daily and weekly basis. Caloric restriction was recorded as a percentage of the daily required intake. Measurements pertained to the month preceding each scan. Age of onset for illness and for amenorrhea were in years. Total duration of illness and amenorrhea was measured in months. Weight-bearing exercise was measured in hours per day per week and did not include standing or walking without effort. BMI was calculated by dividing weight (kg) by height squared (m).

Bone Densitometry

Regional bone density (lumbar spine L2-L4 and neck of femur) was measured by dual-energy x-ray absorptiometry using a DPXL Lunar scanner Lunar Corp., Madison, WI. BMD measurements were expressed as grams per square centimeter. Results were compared to the manufacturer's normative data.

Statistical Analysis

Analyses were conducted using SPSS. Multiple regression was utilized to ascertain the effect of predicted risk factors in the development of osteoporosis. Due to the small sample size, entry criteria into the equation was set at 10%. Differences in BMD measurement between Scan 1 and Scan 2 were analyzed using Student's t test for paired samples.

RESULTS

Scan 1

See Table 1 for a description of means (standard deviation) and score ranges of clinical data. Amenorrhea of at least 3 months in duration was present in 54 (96%) of the patients. Low spinal BMD was associated with a longer duration of amenorrhea ($r = -.47$, $p < .001$), greater caloric restriction ($r = -.29$, $p = .015$), and a low BMI ($r = .41$, $p = .001$). Low femoral BMD was also associated with a longer duration of amenorrhea ($r = -.46$, $p < .001$) and an increased consumption of alcohol ($r = -.23$, $p = .046$).

Variables were entered into a stepwise multiple regression. Total duration of amenorrhea, BMI, frequency of vomiting, and alcohol and cigarette consumption were found to be significant factors in the prediction of spinal BMD, accounting for almost 40% of variance ($R^2 = .40$, $F = 8.19$, $p < .001$). Again, total duration of amenorrhea and alcohol consumption were found to be significant predictors of femoral BMD, accounting for 22% of variance ($R^2 = .22$, $F = 8.85$, $p = .005$). Factors of binge frequency, exercise rate, laxative use, age of onset of illness, and diagnosis failed to reach statistical significance.

Scan 2

Amenorrhea continued to be present in 9 (90%) of the patients. BMI had increased in 7 (70%) patients and had decreased in 3 (30%) patients. Mean scores (standard deviation) for age, BMI, and BMD are shown in Table 2.

Statistically significant correlations were found to exist between BMI Scan 1 and Scan 2 ($r = .88$, $p = .003$), spinal BMD Scan 1 and Scan 2 ($r = .977$, $p < .001$), and femoral BMD Scan 1 and Scan 2 ($r = .77$, $p = .010$). A series of t tests for paired samples were performed on the above variables. All failed to reach statistical significance ($t = -1.03$, $p = .330$; $t = -.23$, $p = .825$; $t = 1.48$, $p = .174$, respectively).

DISCUSSION

High levels of reduced BMD were observed at or below the critical fracture threshold of 0.965 g/cm^2 as defined by Riggs et al. (1981). For spinal BMD, 43% ($n = 25$) and for

Table 1. *M* (*SD*) and score range for subjects ($n = 56$) seen at scan 1

Variable	*M*	*SD*	Ranges
Age (years)	26.7	5.86	17–45
BMI (weight/height^2)	16.6	3.38	10.6–25.4
BMD-spine (g/cm^2)	0.990	.15	0.662–1.252
BMD-femur (g/cm^2)	0.840	.15	0.550–1.130
Age of onset - menarche (years)	13.0	1.58	10–18
Age of onset of eating disorder	16.8	3.10	12–25
Total duration of amenorrhea (months)	68.4	51.51	0–216
Total duration of BMI <19 (months)	82.2	57.30	0–240
Total duration of illness (months)	118.4	72.05	14–336
Binge frequency (no. per week)	2.3	4.24	0–21
Vomiting frequency (no. per week)	5.0	9.52	0–49
Exercise frequency (hours per week)	5.8	6.34	0–35
Laxative usage (no. per week)	57.0	136.56	0–700
Alcohol units (per week)	6.1	15.20	0–90

Note: BMI = body mass index; BMD = bone mineral density.

Table 2. Mean scores (*SD*) of clinical data for the subjects seen at both scan 1 and scan 2

	Scan 1 (n = 10)	Scan 2 (n = 10)
Age (years)	26.1 (6.51)	27.8 (7.15)
BMI (weight/height^2)	16.6 (3.38)	17.9 (2.85)
BMD-spine (g/cm^2)	0.925 (0.15)	0.928 (0.16)
BMD-femur (g/cm^2)	0.811 (0.18)	0.755 (0.12)

Note: There are no significant differences between scores. BMI = body mass index; BMD = bone mineral density.

femoral BMD 75% (n = 42) of subjects fell below this level at Scan 1 and 80% (n = 8) and 90% (n = 9), respectively, at Scan 2. Low levels of BMD were found irrespective of diagnosis. Despite lower levels of BMD being present in the majority of subjects at the neck of femur (largely cortical bone), the lumbar spine (largely trabecular) proved to be a more reliable measure of BMD.

Total duration of amenorrhea accounted for 20% of variance of both femoral and spinal BMD. Only 1 subject regained menses for 3 months preceding Scan 2, which may have been too short a time period to have observed any significant changes in BMD. Consistent with other studies (Biller et al., 1989; Rigotti et al., 1991), duration of amenorrhea correlated negatively with BMD. Passloff, Slap, Pertschuk, Attie, and Kaplan (1992) concluded that resumption of menses was an important factor in the prevention of further BMD loss in spite of all their subjects continuing to lose BMD over a 7-year period.

An additional 10% of variance in spinal BMD was accounted for by BMI. Weight increases as measured by BMI did occur between Scan 1 and Scan 2 but failed to reach statistical significance, which may have been due to small subject numbers. Seven subjects increased weight by an average of 4.3 kg while 3 subjects decreased weight by average of 5.7 kg. In agreement with Rigotti et al (1991) and Bachrach et al. (1991), it was found that despite an increase in weight, BMD, at either site, did not reflect this change and remained stable at the lumbar spine and decreased slightly at the neck of femur. Where an increase in BMD occurred, levels were still below those expected based upon age and sex. Treasure et al. (1987) is the only study to have found completely normal BMD following recovery. However, the subjects in their study did not have a baseline measurement and BMD appears to have been measured up to 10 years following recovery.

The behavioral factors of frequency of binge eating, vomiting, laxative ingestion, caloric restriction, and exercise were all significantly correlated with each other. Frequent vomiting was associated with higher levels of spinal BMD and BMI, a pattern consistent with bulimic-type behavior and supporting the importance of weight maintenance to prevent reduced BMD. All other behavioral factors failed to meet the entry criteria and were not included in the regression. The failure to find significant associations even when subjects engaged in high levels of exercise was surprising given previous findings (Hay et al., 1992; Joyce et al., 1990). Nicotine and alcohol consumption again were significantly correlated and were included as factors predictive of BMD. Forty percent of the subjects smoked and 30% used alcohol. In agreement with Passloff et al. (1992), high levels of nicotine and alcohol were associated with low femoral BMD. High alcohol usage appears to be associated with higher spinal BMD. Whether or not alcohol provides some protective factor in trabecular bone warrants further investigation.

The mean duration of illness at 118 months was high, reflecting the type of treatment-resistive patients that are common to the clinic. Although found to be of significance by

some authors as a predictor of BMD, it is often unclear if duration of illness is separated from duration of amenorrhea and may be a reflection of the two factors combined. Mean age of onset of illness was 16.8 years. Again, this factor failed to be of significance. It may be that peak bone mass is attained between 13 and 15 years of age, which was often prior to the onset of illness.

Analysis of factors responsible for the recovery from osteoporosis was not possible due to no significant change occurring in BMD measures and too few subjects. Failure to detect change may have also been due to the study not being carried out over a long enough period of time and because only 1 subject regained menses. BMD may be recoverable, although very slowly (Rigotti et al., 1991), and the risk of nontraumatic pathological fracture may be a long-term consequence.

Duration of amenorrhea, low body weight, and the behavioral factors of vomiting, nicotine, and alcohol intake are significant predictors of high levels of reduced BMD. In addition, this study also demonstrated that an increase in weight may not be sufficient in itself to increase BMD, but is a safe way to ameliorate further BMD loss. Clinicians may need to monitor more closely BMD levels over the course of the eating disorder as it cannot be assumed that BMD will increase with weight gain or spontaneously recover.

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