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Fracture Risk and Areal Bone Mineral Density in Adolescent Females with Anorexia Nervosa

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Abstract

Objective—To (i) compare fracture prevalence in adolescent females with anorexia nervosa (AN) vs. normal-weight controls and (ii) examine whether reductions in areal bone mineral density (aBMD) predict fracture risk in females with AN.

Methods—418 females (310 with active AN and 108 normal-weight controls) 12–22 years old were studied cross-sectionally. Lifetime fracture history was recorded by a physician during participant interviews. Body composition and aBMD measurements of the whole body, whole body less head, lumbar spine, and hip were assessed by dual-energy x-ray absorptiometry (DXA), and bone mineral apparent density (BMAD) was calculated for the lumbar spine.

Results—Participants with AN and normal-weight controls did not differ for chronological age, sexual maturity, or height. The lifetime prevalence of prior fracture was 59.8% higher in those with AN compared to controls (31.0 % versus 19.4 %, $p = 0.02$), and the fracture incidence rate peaked in our cohort after the diagnosis of AN. Lower aBMD and lumbar BMAD were not associated with a higher prevalence of fracture in the AN or control group on univariate or multivariate analyses. Compared to controls, fracture prevalence was significantly higher in the subgroup of girls with AN who had normal aBMD or only modest reductions of aBMD (Z-scores > -1 or -1.5).

Discussion—This is the first study to show that the risk of fracture during childhood and adolescence is significantly higher in patients with AN than in normal-weight controls. Fracture

prevalence is increased in this cohort of subjects with AN even without significant reductions in aBMD.

Anorexia nervosa (AN) is reported in 0.3% of young females¹. It is the third most common medical condition among adolescent girls based on one report, and the incidence of AN appears to be increasing in this population². Girls with AN are characterized by low weight and multiple hormonal abnormalities which impact bone metabolism. Some of these alterations include low levels of leptin, hypogonadism, relative IGF-1 deficiency, and hypercortisolism^{3–6}. Markers of bone turnover are suppressed in adolescent girls with AN^{4,7,8}, and bone mineral accrual is reduced^{4,9,10}. Girls with AN consequently have decreased areal bone mineral density (aBMD) compared to normal-weight individuals¹¹. Furthermore, cortical and trabecular microarchitecture is impaired in girls with AN, and finite element-derived estimates of stiffness and failure load are also lower than in controls^{12,13}. However, it is not known whether lower aBMD in adolescents with AN translates to an increased risk for fractures during childhood.

The onset of AN occurs most commonly during adolescence¹⁴. Adolescence is normally marked by rapid bone accumulation¹⁵. Diseases, such as AN, which impair bone accrual during this period can adversely affect attainment of peak bone mass, and therefore BMD later in life. In patients with AN, disease onset prior to the attainment of peak bone mass results in more severe skeletal outcomes compared to disease onset in adulthood¹⁶.

Several studies have demonstrated an increased fracture risk in adults with AN. Fracture incidence increases soon after the diagnosis of AN and remains elevated many years later^{17–19}. However, no prior study has examined the prevalence of childhood and adolescent fracture before or after the diagnosis of AN in adolescents. In addition, although measurement of aBMD is a valuable tool to estimate fracture risk in postmenopausal women²⁰, data demonstrating its ability to predict fractures in children are limited²¹. The relationship between aBMD and fracture prevalence has not been examined in adolescents with AN.

We assessed fracture history and aBMD in a large group of adolescents females with AN and normal-weight controls. The study was conducted to determine whether the prevalence of childhood and adolescent fracture is increased in adolescent females with AN compared to normal-weight controls, and to examine whether reductions in aBMD predict fracture risk in females with AN. We hypothesized that the risk of fracture would be increased among adolescent females with AN compared to controls and that decreases in aBMD would be associated with a history of fracture.

METHODS

Four hundred eighteen females between the ages of 12–22 years were studied; 310 with active AN and 108 normal-weight controls. Participants were recruited through print and electronic advertisements and by referral from regional practitioners and eating disorder treatment centers in the northeastern United States and Ontario, Canada. The clinical characteristics of a small subset of these participants were previously described by Misra et al.¹¹. The diagnosis of AN was confirmed by a study psychiatrist according to DSM-IV

criteria²². Normal-weight controls were required to have a body mass index (BMI) between the 10th and 90th percentiles for age, were eumenorrheic, and did not have a past or present history of an eating disorder. Additional exclusion criteria for controls and participants with AN included medications and diseases affecting bone metabolism (including premature ovarian failure, diabetes, pituitary disease, Cushing's syndrome, renal disease, and untreated thyroid disease), pregnancy, and substance abuse.

The study was performed at the Clinical Research Centers of Massachusetts General Hospital (MGH), Boston, MA, USA and Massachusetts Institute of Technology (MIT), Cambridge, MA, USA and the Clinical Investigation Unit at the Hospital for Sick Children (SickKids), Toronto, ON, Canada. The study was approved by the Institutional Review Board of Partners HealthCare, Boston and the Research Ethics Board (REB) of SickKids, Toronto. Written informed consent was obtained from all individuals 18 and over prior to their participation. Parental consent and subject assent was obtained for participants under the age of 18 years. At SickKids, parental consent was obtained as well as either participant consent or assent based on the participant's capacity to consent, per SickKids REB guidelines.

Body composition and aBMD were determined by dual-energy x-ray absorptiometry (DXA) (Hologic 4500 A, Waltham, MA, USA). DXA measurements were obtained for the whole body, whole body less head, PA lumbar spine, and hip. The measurement of aBMD, especially in children, can be significantly affected by variability in stature and bone size. Bone mineral apparent density (BMAD) is a technique which estimates volumetric bone mineral density from two-dimensional DXA images. Lumbar BMAD was calculated according to previously published methods²³. DXA scanners at MGH and SickKids were cross-calibrated using a Hologic spine and whole-body phantoms from Synarc Inc. (San Francisco, CA, USA). Each site performed ten scans of each phantom, and Synarc Inc. evaluated performance, consistency, and cross-calibration between sites. DXA devices at MGH and MIT were cross-calibrated by performing same-day scans at each facility in twenty adult patients. No adjustments were necessary.

Tanner stage was assessed on physical examination by a study endocrinologist or adolescent medicine specialist. Lifetime fracture history was recorded by a physician during subject interviews utilizing a standardized questionnaire developed for our studies. Parents participated in the interviews for all individuals under the age of 18 years. Fracture history was obtained on the same day aBMD was assessed. Radiologic confirmation of reported fractures was not obtained.

Exercise activity was assessed by the Modifiable Activity Questionnaire (MAQ) in a subset of subjects (126 girls with anorexia nervosa and 55 normal-weight controls).

Statistical analysis was completed using JMP (version 10, SAS Institute, Cary, NC, USA). P values < 0.05 were considered statistically significant. All values are shown as means $\pm$ SEM. Group comparisons for continuous outcomes were performed using two-sided independent samples t-test and those for binary outcomes using the Fisher's exact test, where the effect size was estimated by the odds ratios (OR). Univariate relationships

between continuous outcome variables were evaluated using a Pearson's correlation coefficient. Multiple logistic regression analysis was utilized to examine the effects of potential confounders on fracture prevalence. Multi-collinearity of independent variables was assessed by variance inflation factor (VIF); no VIF value exceeded 3. Fracture incidence rates were calculated by dividing the number of participants with at least one fracture by person-years of observation time. Fracture prevalence was calculated by dividing the number of participants who had sustained at least one fracture prior to study enrollment by the total number of participants in the corresponding AN or normal-weight control group.

RESULTS

Clinical Characteristics and aBMD

Participants with AN and normal-weight controls did not differ for chronological age, sexual maturity, or height. Mean values for BMI and percent ideal body weight (IBW) were significantly lower in participants with AN compared to controls, as expected. Menarche occurred at a slightly older age in females with AN, and the duration since the most recent menstrual period was longer in the AN group at the time of the study (Table 1). The mean age at the diagnosis of AN was 16.1 ± 0.1 years. The mean duration since the diagnosis of AN in subjects was 23.4 ± 1.5 months (Table 1).

Lean mass, fat mass, and the ratio of fat mass to lean mass were significantly lower in participants with AN compared to controls. Bone mineral content (BMC), aBMD, and aBMD Z-scores were lower at all sites in the AN group compared to controls. Lumbar BMAD was also lower in the participants with AN (Table 1).

Exercise activity was assessed in a subset of participants, one hundred twenty-six females with AN and fifty-five normal-weight controls. Exercise activity did not differ in females with AN compared to normal-weight controls (17.1 ± 1.1 h versus 15.3 ± 1.3 h, respectively; $p = 0.29$). Height, BMI, and indices of body composition did not differ in this subset of females with AN compared to the other participants with AN.

Fracture History

One hundred forty-seven fractures occurred in ninety-six participants with AN. One hundred twenty-eight events were non-stress fractures, and fourteen were stress fractures. Participants were unable to classify five fractures. Thirty-six fractures occurred in twenty-one normal-weight controls. Thirty-two events were non-stress fractures. Control participants were unable to classify four fractures.

The mean age of participants at time of initial fracture did not differ in controls and participants with AN (10.5 ± 1.0 and 11.6 ± 0.6 years, respectively). The distribution of fracture sites also did not differ in the two groups. The distal upper extremity was the most common location for fracture in both groups (Table 2). Fractures which occurred after the diagnosis of AN were limited to the distal upper and lower extremities.

The prevalence of all prior fractures (stress fractures and non-stress fractures) was significantly higher in participants with AN compared to controls (31.0 % versus 19.4 %, p

= 0.02). The relative risk of prior fracture was 59.8 % greater in the AN group compared to controls (95 % confidence interval [CI], 4.8 – 142.0 % greater relative risk). The prevalence of non-stress fractures was also significantly higher in participants with AN compared to controls (28.4 % versus 17.9 %, $p = 0.04$). A higher prevalence of stress fractures in participants with AN was observed (3.6 % versus 0.0 %), but this difference did not reach statistical significance ($p = 0.07$). Differences in the prevalence of all fractures and also non-stress fractures remained significant after controlling for age ($p = 0.03$ and 0.04 , respectively) (Table 3).

The lifetime incidence rate for all fractures was 109.7 cases per 10,000 person-years (95 % CI, 99.8 – 119.6) in normal-weight controls and 170.0 cases per 10,000 person-years (95 % CI, 163.4 – 176.7) in subjects with AN. The incidence rate for all fractures after the diagnosis of AN was 249.1 cases per 10,000 person-years (95 % CI, 137.3 – 360.9). Prior to their diagnosis, the fracture incidence rate in participants with AN was 133.3 cases per 10,000 person-years (95 % CI, 125.5 – 141.0) (Table 3). Fracture events according to age are depicted in Figure 1. Fracture events peaked at age eleven in normal-weight controls. Fracture events also increased at this age in subjects with AN. Subjects with AN, however, had a second and greater peak in fractures at a significantly later age.

aBMD and Fracture Prevalence

In the AN cohort, participants with prior fracture(s) did not differ from those without a history of fracture for clinical characteristics, including chronological age, sexual maturity, age at menarche, body size and composition, AN disease history, or DXA measures (Table 4).

When participants with AN were stratified according to Z-score cut-offs of < -1.0 , -1.5 , -2.0 , and -2.5 and compared to all normal-weight controls, fracture prevalence was consistently higher in the AN group (Table 5). Compared to normal-weight controls with similar aBMD Z-scores, fracture prevalence was significantly higher in participants with AN when aBMD Z-scores were > -1.0 or -1.5 at subregions of the hip (Figure 2). Importantly, fracture prevalence remained significantly higher in participants with AN even when aBMD Z-scores were > -1.5 at more than one site (OR 1.97 [95 % CI, 1.08 – 3.72] for AN participants with aBMD Z-scores > -1.5 at both the lumbar spine and total hip). Thus, fracture prevalence remained higher in participants with AN even when bone density Z-scores were normal or only modestly reduced. Contrary to expectations, in normal-weight controls with a history of fracture, aBMD was significantly higher at several sites compared to those without prior fractures (data not shown).

When analyzed as continuous variables, lower aBMD at various sites and lower lumbar BMAD were not associated with a higher prevalence of fracture in the females with AN on univariate analyses or multivariate analyses when chronological age, age at menarche, percent IBW, and duration of AN were chosen as additional independent variables. These results were unchanged when exercise activity was added to the multivariate analysis. Increased exercise activity was not associated with a higher prevalence of fracture on univariate analysis or in the multivariate analyses described above.

DISCUSSION

This is the first study to show that the risk of childhood and adolescent fracture is significantly higher in AN compared to a normal-weight population. Prior investigations of fracture incidence in AN have been limited to adults^{17–19}. In our cohort of participants with AN, increased fracture prevalence is observed even without significant reductions of aBMD.

A previous study in adults demonstrated that fracture incidence rises as early as a year after the diagnosis of AN¹⁹. In our cohort the mean duration since the diagnosis of AN was almost two years. The overall incidence of fracture was significantly higher in participants with AN compared to controls, and fracture incidence peaked in participants with AN after the diagnosis of an eating disorder. Interestingly, fracture incidence before diagnosis was also slightly higher in participants with AN compared to controls. Similar findings were reported in adults with AN¹⁹. This may reflect the lag time between the onset of clinical AN and formal diagnosis of the disease. To our knowledge there is no published study that has examined this aspect of AN.

In children, the distal upper extremity is the most common site for fracture^{24–26}. This location was also the most frequent site for fracture in the AN as well as control groups in our study, followed by distal fractures of the lower extremity. Distal extremity fractures are the most common type of fracture in adults with AN^{18,19}. In healthy girls fracture incidence peaks between the ages of ten and fourteen^{24,27–29}. In our cohort of normal-weight controls, fracture events peaked at age eleven. Fracture events also increased at this age in subjects with AN. Subjects with AN, however, had a second and greater peak in fractures at a significantly later age. Although fracture incidence normally decreases in females during late adolescence, the incidence of fracture actually increased after the diagnosis of AN in our cohort. This reversal likely reflects the significant skeletal deterioration that takes place in AN.

Although DXA is a well-recognized instrument to evaluate fracture risk in postmenopausal women²⁰, its predictive capacity in children is less established²¹. aBMD is a two-dimensional measurement, and its assessment is affected by changes in bone size, maturation, and extraosseous body composition. Because the adolescent females with AN in our study had decreased aBMD and increased fracture prevalence compared to controls, we anticipated that reductions in aBMD would be associated with a history of fracture in the AN group. Our results, however, did not demonstrate an aBMD threshold at which fracture prevalence increased in participants with AN. Fracture prevalence was increased in the AN group even in the absence of significant reductions of aBMD. Only six participants with AN met consensus criteria for the definition of osteoporosis in children. These guidelines note that an association between DXA results and fractures “may not apply to children with low bone mass due to chronic disease”²¹. Although our study was retrospective and limited by DXA measurements at a single point in time, the results suggest a cautious approach when extrapolating fracture risk from a single aBMD measurement in adolescent females with AN.

Measurement of bone microarchitecture may have greater value for the prediction of childhood fracture in AN than DXA measures of aBMD. Measures of bone microarchitecture include details such as cross-sectional area and volumetric BMD of cortical and trabecular compartments, trabecular number, thickness and separation, and cortical porosity, and studies suggest that bone microarchitecture contributes to fracture risk independent of DXA measures of aBMD^{30–32}. Microarchitectural deterioration can occur in adolescent females with AN even in the absence of decreased aBMD¹². When adolescent females with AN do have reductions in aBMD, microarchitectural parameters do not correlate with aBMD, and they remain stronger determinants of finite element-derived estimates of stiffness and failure load¹³.

In our study, normal-weight controls with a history of fracture also did not have decreased aBMD. Mean aBMD was actually higher at several sites in controls with a history of fracture compared to those without prior fractures. Fracture prevalence integrates bone strength and the frequency and type of mechanical challenges that the skeleton encounters. We speculate that controls with a history of fracture were more physically active, which may have resulted in a higher frequency of physical trauma. In a study of healthy prepubertal children, a higher level of sports participation was associated with a higher prevalence of fracture, whereas aBMD and BMAD did not differ in those with and without prior fracture³³. Physical activity levels were assessed in a subset of females with AN. In the subset analysis, increased levels of exercise activity were not associated with a higher prevalence of fracture on univariate or multivariate analyses. Even though exercise restrictions were presumably placed on many participants with AN, fracture incidence peaked in this group after the diagnosis of AN.

Our study was retrospective and potentially limited by selection bias. In our study participants with AN were referred from a wide range of treatment settings and practitioners in the United States and Canada. The diversity of our referral group minimizes the bias that might occur if participants had shared a common origin. Our results also argue against the presence of significant selection bias. The prevalence of fracture among normal-weight controls in our study was very similar to the values reported in a large analysis by Cooper et al. (102.9 cases per 10,000 person-years)²⁴. Likewise, the prevalence of fracture in our cohort with AN was comparable to the results reported in a smaller study of female adolescents with AN by Misra et al.¹¹. Additionally, the distribution of fracture sites in controls and participants with AN paralleled the results of previously published studies in healthy children and women with AN^{18,19,24–26}.

Fracture history was obtained by physician interview of the participants. The absence of radiologic confirmation of fractures represents a potential limitation of our analysis. Previously published studies, however, have shown that self-report of fracture occurrence and timing by questionnaire is both sensitive and specific, especially for distal forearm fractures^{34,35}. An important strength of our study is the large number of well characterized participants with AN.

In conclusion, our study demonstrates that the development of AN during adolescence markedly increases the risk of fracture before adulthood. Fracture prevalence is increased in

adolescents with AN independent of reductions in aBMD. Because the clinical course of AN can be variable and marked by periods of recovery and relapse, a single BMD measurement during adolescence likely does not fully reflect long-term fracture risk. Serial measurement of aBMD and the presence of microarchitectural deterioration or additional unspecified risk factors may have greater value for the prediction of fractures in adolescent girls with AN. Prospective studies are needed to determine the relationship of aBMD, bone microarchitecture, and clinical risk factors with the incidence of childhood fracture in this high risk population.

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Figure 1.

Fracture events according to age in adolescent girls with anorexia nervosa and normal-weight controls. (■) denotes normal-weight controls and (■) denotes subjects with anorexia nervosa. Precise age data was not available for seven fractures in controls and forty-eight fractures in subjects with anorexia nervosa. These fractures were not included in the figure.

Figure 2.

Fracture risk in adolescent girls with anorexia nervosa compared to normal-weight controls with similar aBMD Z-scores. (*) denotes statistical significance ($p < 0.05$). (†) denotes $p < 0.1$. Author Disclosure Summary: The authors have nothing to declare.

Table 1

Clinical Characteristics of Normal-Weight Controls and Adolescent Girls with Anorexia Nervosa

	Controls (n=108)	Anorexia Nervosa (n=310)	P value
Age (yr)	17.7±0.2	18.2±0.1	NS
Height (cm)	163.5±0.7	164.5±0.4	NS
Tanner stage (breast)	4.86±0.04	4.80±0.03	NS
BMI (kg/m ²)	21.7±0.2	17.1±0.1	<0.0001
% IBW (BMI)	103.7±1.0	81.2±0.3	<0.0001
Age at menarche (y)	12.3±0.1	13.0±0.1	<0.0001
Duration since last menses (mo)	0.52±0.04	10.85±0.78	<0.0001
Age at AN diagnosis (y)	-	16.1±0.1	-
Duration of disease (mo)	-	23.4±1.5	-
DXA Measures			
Fat mass (kg)	16.6±0.4	8.5±0.2	<0.0001
Lean mass (kg)	40.9±0.5	37.2±0.3	<0.0001
% body fat	27.6±0.5	17.5±0.3	<0.0001
Ratio of fat mass to lean mass	0.41±0.01	0.23±0.01	<0.0001
Femoral neck aBMD (g/cm ²)	0.862±0.011	0.787±0.007	<0.0001
Femoral neck Z-score	-0.19±0.11	-0.91±0.07	<0.0001
Hip trochanter aBMD (g/cm ²)	0.760±0.010	0.656±0.006	<0.0001
Hip trochanter Z-score	0.01±0.11	-1.06±0.06	<0.0001
Intertrochanteric aBMD (g/cm ²)	1.140±0.015	1.016±0.009	<0.0001
Intertrochanteric Z-score	0.11±0.11	-0.83±0.07	<0.0001
Total hip aBMD (g/cm ²)	0.971±0.011	0.861±0.0007	<0.0001
Total hip Z-score	0.00±0.11	-1.04±0.06	<0.0001
Lumbar (PA) aBMD (g/cm ²)	0.990±0.010	0.891±0.006	<0.0001
Lumbar Z-score	0.04±0.10	-0.95±0.06	<0.0001
LBMD (g/cm ³)	0.153±0.002	0.137±0.001	<0.0001
Total body BMC (g)	2036±26	1876±18	<0.0001
Total body aBMD (g/cm ²)	1.055±0.007	1.012±0.005	<0.0001
Total body Z-score	-0.37±0.10	-0.99±0.07	<0.0001
Total body minus head BMC (g)	1574±23	1421±15	<0.0001
Total body minus head aBMD (g/cm ²)	0.922±0.007	0.875±0.005	<0.0001

NS: not significant

Table 2

Fracture Distribution in Normal-Weight Controls and Adolescent Girls with Anorexia Nervosa

	Controls	Anorexia Nervosa	P value
Non-stress Fractures (%)			
Upper extremity	59.4 % (19)	55.5 % (71)	NS
Lower extremity	34.4 % (11)	32.0 % (41)	NS
Non-extremity	6.3 % (2)	12.5 % (16)	NS
Non-stress Fractures (n)			
Upper arm	3	9	
Radius/ulna	0	12	
Wrist	7	27	
Hand/finger	9	23	
Upper leg	0	2	
Knee	0	3	
Tibia/fibula	0	8	
Ankle	3	5	
Foot/toe	8	23	
Nose/jaw	1	7	
Rib	0	2	
Clavicle	1	5	
Pelvis	0	2	
	32	128	
Stress Fractures (n)			
Wrist	0	2	
Fibula/tibia	0	5	
Ankle	0	2	
Foot	0	1	
Vertebral	0	1	
Unknown location	0	3	
	0	14	

NS: not significant

Four fractures in two controls and five fractures in four subjects with anorexia nervosa were unclassified and were not included in this table.

Table 3

Fracture Prevalence and Incidence in Normal-Weight Controls and Adolescent Girls with Anorexia Nervosa

	Controls (n=108)	Anorexia Nervosa (n=310)	P value
Prevalence (n)			
Non-stress fracture or stress fracture	21	96	0.02
Non-stress fracture	19	87	0.04
Stress fracture	0	11	NS
Incidence (fracture/person-yr)			
Lifetime	109.7 (99.8–119.6)	170.0 (163.4–176.7)	<0.001
Prior to diagnosis of AN	-	133.3 (125.5–141.0)	
After diagnosis of AN	-	249.1(137.3–360.9)	

NS: not significant

95 % CI are listed in parentheses.

Four fractures in two controls and five fractures in four subjects with anorexia nervosa were unclassified. Six subjects with anorexia nervosa had a prior stress fracture and non-stress fracture.

Table 4

Clinical Characteristics of Adolescent Girls with Anorexia Nervosa According to Fracture Status

	No Prior Fracture (n=214)	+ Prior Fracture (n=96)	P value
Age (yr)	18.1±0.2	18.4±0.2	NS
Height (cm)	164.4±0.5	164.9±0.6	NS
Tanner stage (breast)	4.77±0.04	4.86±0.05	NS
BMI (kg/m ²)	17.1±0.1	17.2±0.1	NS
% IBW (BMI)	81.2±0.4	81.3±0.6	NS
Age at menarche (y)	13.1±0.1	12.8±0.2	NS
Duration since last menses (mo)	11.3±0.9	9.8±1.4	NS
Age at diagnosis	16.0±0.2	16.5±0.3	NS
Duration of disease (mo)	23.9±1.9	22.3±2.7	NS
DXA Measures			
Fat mass (kg)	8.4±0.2	8.5±0.3	NS
Lean mass (kg)	36.9±0.3	37.9±0.5	NS
% body fat	17.6±0.4	17.3±0.5	NS
Femoral neck aBMD (g/cm ²)	0.789±0.009	0.783±0.011	NS
Femoral neck Z-score	-0.88±0.09	-0.97±0.11	NS
Hip trochanter aBMD (g/cm ²)	0.658±0.008	0.653±0.009	NS
Hip trochanter Z-score	-1.03±0.08	-1.10±0.10	NS
Intertrochanteric aBMD (g/cm ²)	1.018±0.011	1.011±0.015	NS
Intertrochanteric Z-score	-0.79±0.08	-0.91±0.11	NS
Total hip aBMD (g/cm ²)	0.861±0.008	0.861±0.011	NS
Total hip Z-score	-1.03±0.08	-1.05±0.11	NS
Lumbar (PA) aBMD (g/cm ²)	0.889±0.007	0.896±0.010	NS
Lumbar Z-score	-0.95±0.07	-0.94±0.10	NS
LBMD (g/cm ³)	0.137±0.002	0.136±0.002	NS
Total body BMC (g)	1864±24	1899±28	NS
Total body aBMD (g/cm ²)	1.009±0.006	1.019±0.009	NS
Total body Z-score	-0.99±0.08	-0.99±0.12	NS
Total body minus head BMC (g)	1415±19	1434±23	NS
Total body minus head aBMD (g/cm ²)	0.873±0.006	0.878±0.009	NS

NS: not significant

Table 5

Fracture Risk in Adolescent Girls with Anorexia Nervosa, Stratified by Z-score, Compared to All Normal-Weight Controls

Z-score	AN	AN with Fracture	Odds Ratio (95% CI)	P value
Femoral neck				
Below -1.0	146	52	2.29 (1.29–4.18)	0.005
Below -1.5	88	29	2.04 (1.07–3.95)	0.03
Below -2.0	50	14	1.61 (0.73–3.50)	NS
Below -2.5	20	6	1.78 (0.57–5.02)	NS
Hip trochanter				
Below -1.0	142	49	2.18 (1.22–3.99)	0.01
Below -1.5	95	27	1.64 (0.86–3.19)	NS
Below -2.0	53	16	1.79 (0.83–3.81)	NS
Below -2.5	20	6	1.78 (0.57–5.02)	NS
Intertrochanteric				
Below -1.0	101	37	2.39 (1.29–4.53)	0.008
Below -1.5	58	22	2.53 (1.24–5.20)	0.02
Below -2.0	30	14	3.63 (1.53–8.65)	0.004
Below -2.5	13	6	3.55 (1.05–11.81)	0.04
Total Hip				
Below -1.0	141	45	1.94 (1.08–3.57)	0.03
Below -1.5	94	26	1.58 (0.82–3.08)	NS
Below -2.0	51	18	2.26 (1.07–4.78)	0.05
Below -2.5	26	9	2.19 (0.83–5.54)	NS
Lumbar spine (AP)				
Below -1.0	151	50	2.05 (1.16–3.74)	0.02
Below -1.5	93	30	1.97 (1.04–3.80)	0.05
Below -2.0	44	11	1.38 (0.59–3.13)	NS
Below -2.5	18	3	0.83 (0.18–2.80)	NS
Whole Body				
Below -1.0	135	46	2.14 (1.19–3.94)	0.01
Below -1.5	88	29	2.04 (1.07–3.95)	0.03
Below -2.0	53	15	1.64 (0.75–3.50)	NS
Below -2.5	20	4	0.97 (0.26–2.97)	NS