Published in final edited form as:

Int J Eat Disord. 2015 July ; 48(5): 522–526. doi:10.1002/eat.22405.

Bone Parameters in Relation to Attitudes and Feelings Associated with Disordered Eating in Oligo-Amenorrheic Athletes, Eumenorrheic Athletes, and Nonathletes

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Abstract

Objectives—Disordered eating may negatively impact bone in athletes. However, it is not known whether this effect is independent of the associated amenorrhea and relative hypercortisolemia. We aimed to compare attitudes, feelings, and cognitions associated with disordered eating using the Three-Factor Eating Questionnaire (TFEQ) and Eating Disorder Inventory-2 (EDI-2) in normal-weight oligomenorrheic athletes (OA), eumenorrheic athletes (EA), and nonathletes, and determine the associations with bone independent of confounders.

Method—109 OA, 39 EA, and 36 nonathletes (14–25 years) completed the TFEQ and EDI-2. Dual-energy X-ray absorptiometry was used to assess spine bone mineral density (BMD), and high-resolution pQCT to assess radius microarchitecture. We measured integrated cortisol (q 20', 11 PM–7 AM), bone formation (procollagen Type 1 N-terminal propeptide, P1NP), and resorption (C-telopeptide, CTX) markers in a subset.

Results—OA had lower spine BMD Z-scores than EA. Cognitive eating restraint (CER), drive for thinness (DT), ineffectiveness, and interoceptive awareness (IA) were higher in OA than EA ($p < 0.05$); CER was higher in OA versus nonathletes ($p = 0.03$). Pulsatile cortisol was positively

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associated with DT, ineffectiveness, and IA ($p < 0.03$). CER was inversely associated with BMD Z-scores and PINP, and ineffectiveness with radius cross-sectional area even after controlling for age, BMI, amenorrhea duration, and cortisol ($p < 0.03$).

Discussion—Higher CER in athletes independently predicts lower BMD.

Keywords

female athlete triad; oligomenorrhea; disordered eating; cognitive eating restraint; bone microarchitecture; bone mineral density

Introduction

The Female Athlete Triad of low energy availability, menstrual irregularity, and low bone mineral density (BMD)¹ is of special concern during adolescence, a time of rapid bone accrual.² Dieting and disordered eating are common among athletes, and range from healthy dieting with modest calorie reduction to restrictive behaviors and eating disorders.¹

Cognitive eating restraint (CER), measured with the Three-Factor Eating Questionnaire (TFEQ), is a conscious attempt to control food intake to maintain a desired weight. CER can be a chronic stressor, causing cortisol elevations and inhibition of the hypothalamic–pituitary–gonadal axis, with detrimental effects on bone.^{3,4} Although some studies report inverse associations of CER with BMD,^{5,6} others are conflicting.^{3,7} Therefore, the associations between CER, cortisol elevations, menstrual dysfunction, and bone remain unclear. Furthermore, the impact of CER on bone structure in athletes has not been studied. The Eating Disorder Inventory-2 (EDI-2) evaluates attitudes and feelings associated with eating along subscales not studied as thoroughly in athletes as TFEQ sub-scales in relation to bone. Female exercisers have inverse associations of drive for thinness (DT) with energy availability,⁸ which may impact bone, whereas runners have inverse associations of ineffectiveness scores with BMD.⁹

We aimed to examine attitudes, feelings, and cognitions associated with disordered eating in 14 to 25-year-old oligomenorrheic athletes (OA) compared with eumenorrheic athletes (EA) and nonathletes (NA), and associations with cortisol and bone. We hypothesized that OA would have higher CER and DT than EA and NA, associated with higher cortisol and impaired bone parameters, even after controlling for BMI, menstrual, and cortisol status.

Method

In total, 184 females (14–25 years) were studied. OA were required to have absent menses for 3 months within 6 months of oligomenorrhea (cycle length, >6 weeks) or the absence of menarche at the age of 15 years. Six OA had primary amenorrhea. As hypothalamic amenorrhea is a diagnosis of exclusion,¹⁰ other causes of amenorrhea were ruled out in OA participants. Eumenorrhea was defined as 9 menses (cycle length, 21–35 days) in the preceding year. Inclusion criteria for athletes included 20 miles of running/week or 4 h of weight-bearing training/week for 6 months in the past year. NA had <2 h/week of weight-bearing activity and did not participate in organized team sports. The initial interview with

potential participants (conducted by the study physician) included targeted questions regarding a history of purging or active purging, the use of laxatives or diuretics, and current or past diagnosis of an eating disorder. If any concern existed regarding behaviors associated with disordered eating, the participants were interviewed by the study psychologist, who used the SCID Eating Disorders module questions to ascertain eating disorder features (including purging behaviors). Participants had a BMI between the 10th and the 90th percentiles. Informed consent was obtained from participants of 18 years and parents of those <18 years, and assent from participants of <18 years. The Institutional Review Board of Partners HealthCare approved the study.

The participants were weighed on a single electronic scale and an average of three height measurements obtained on a wall-mounted stadiometer. BMI was calculated: (weight [kg]/height [m]²). Twelve-month exercise history was obtained to calculate hours/week of activity in the past year. Cortisol was measured by frequent sampling every 20' (11 PM–7 AM) in 55 participants (21 OA, 17 EA, and 17 NA). An access chemiluminescent immunoassay (Beckman Coulter, Fullerton, CA) was used to measure cortisol (limit of detection, 11.0 nM; intra-assay CV, 4.4–6.7%; interassay CV, 6.4–7.9%), an RIA to measure fasting procollagen Type 1 N-terminal propeptide (P1NP, bone formation marker) (Orion Diagnostics, Espoo, Finland; limit of detection, 0.7 µg/L; intra-assay CV, 3.5–5.3%; interassay CV, 3.6–5.4%), and an IRMA for C-telopeptide (CTX, bone resorption marker) (Immunodiagnosics Systems, Fountain Hills, AZ; limit of detection, 0.02 µg/L; intra-assay CV, 5.2–6.8%; interassay CV, 5.6–7.4%) (*n* = 52 for bone markers).

Dual-energy X-ray absorptiometry (Hologic Discovery A, Waltham, MA) was used to measure spine areal BMD. Microarchitecture at the ultradistal radius was assessed by high-resolution peripheral quantitative CT (HR-pQCT) (XtremeCT; Scanco Medical AG, Bassersdorf, Switzerland). The reported parameters include total, cortical, and trabecular cross-sectional area (CSA), cortical perimeter, and volumetric BMD (vBMD).

We measured CER using the TFEQ,¹¹ and DT, ineffectiveness, perfectionism, interpersonal distrust, and interoceptive awareness (IA) using the EDI-2.¹² We excluded maturity fears because of the young age of our participants; bulimia and body dissatisfaction because of their high correlation with DT¹²; social insecurity because of its correlation with DT and interpersonal distrust, and asceticism owing to low internal consistency index.¹³ DT represents body image dissatisfaction from perceived need for a lean figure; IA is the ability to distinguish physiological changes through emotions such as hunger.¹⁴ Ineffectiveness is the feeling of not being in control of one's life.¹⁴

JMP Software (v10) was used for analysis. We report means ± SD. When comparing groups, ANOVA was used followed by the Dunnett's test, with OA as the reference group. For outcomes not normally distributed, the Kruskal–Wallis Test, followed by the Steel–Dwass with control method, was used. Spearman correlations were used to determine the associations with clinical/bone parameters, and multivariate modeling to control for confounders (age, BMI, amenorrhea duration, and pulsatile cortisol). The *p*-value of <0.05 was considered significant.

Results

Clinical Characteristics

For the TFEQ, CER was higher in OA than NA (Table 1). For EDI-2 responses, OA had higher DT, ineffectiveness, and IA scores than EA; and higher perfectionism than NA. Other subscale scores did not differ across groups. Nine OA and one EA reported a present or past history of purging. Of these, only six (all OA) reported a history of purging within 6 months of enrollment.

Associations of Eating Behaviors with Clinical and Bone Parameters

CER scores were positively associated with age and BMI ($r=0.25$ and 0.16 , $p=0.0008$ and 0.04 , respectively). CER and IA scores were associated with amenorrhea duration ($r=0.26$ and 0.17 , $p=0.0007$ and 0.03), and DT scores with hours/week of exercise ($r=0.15$, $p=0.05$).

Higher CER scores were associated with lower lumbar BMD Z-scores ($r=-0.22$, $p=0.006$). At the radius, CER and DT scores correlated positively with cortical vBMD ($r=0.25$ and 0.17 , $p=0.003$ and 0.04). Ineffectiveness scores correlated inversely with total and trabecular CSA ($r=-0.22$ and -0.22 , $p=0.006$ and 0.005) and positively with total and cortical vBMD ($r=0.21$ and 0.16 , $p=0.01$ and 0.05). IA was inversely associated with trabecular CSA ($r=-0.16$, $p=0.05$). CER was inversely associated with P1NP ($r=-0.35$, $p=0.01$), with a trend observed for CTX ($r=-0.26$, $p=0.06$). CTX was also associated with ineffectiveness scores ($r=-0.29$, $p=0.04$). Neither bone marker was related to DT nor to IA scores. In those with overnight cortisol assessment, pulsatile cortisol correlated positively with DT, ineffectiveness, and IA ($r=0.30$; $p=0.03$).

As age, BMI, duration of amenorrhea, and cortisol are known determinants of BMD also associated with CER, we controlled for these in a multivariate model (Table 2). After controlling for covariates, higher CER scores were associated with lower spine BMD Z-scores and lower P1NP; however, the associations of CER with microarchitecture were no longer evident. Ineffectiveness was inversely associated with radius CSA. No other association persisted after controlling for these confounders. We found no associations of exercise activity or purging behavior with BMD measures.

Discussion

We demonstrate higher cognitive restraint in OA than NA associated with lower spine BMD, even after controlling for age, BMI, amenorrhea duration, and cortisol status.

CER was higher in OA versus NA and EA, similar to the data reported by Gibbs et al.,⁸ and DT, ineffectiveness, and IA scores were higher in OA than EA. Studies are conflicting regarding the associations of CER with cortisol secretion, with some,^{4,15,16} but not all^{17,18} reporting positive associations. We found no associations of CER with cortisol although DT, ineffectiveness, and IA were positively associated.

Reports evaluating the relationship between CER and bone parameters in athletes and NA are also conflicting, with some reporting no associations,^{3,5,7,17} and others reporting inverse associations after adjusting for confounders.¹⁹ We found that even after controlling for age, amenorrhea duration, BMI, and cortisol, CER was negatively associated with spine BMD although the associations of CER with HR-pQCT parameters were lost. CER was negatively associated with P1NP, suggesting lower bone formation (and thus lower BMD) in those with higher CER. In contrast to a previous report,¹⁷ we found no association of CER with bone resorption markers.

DT did not correlate with any bone parameter in our study, in contrast to a study in female gymnasts that reported inverse associations between DT and BMD.²⁰ We found associations of ineffectiveness scores with several microarchitecture parameters; inverse associations with radius CSA remained significant after controlling for confounders. Snead et al.⁹ studied the EDI-2 subscales in female runners and found strong unadjusted negative associations between ineffectiveness scores and ward BMD in OA.

The strengths of this study include the large sample of OA, thorough menstrual and training history, and BMD and microarchitecture assessment in participants. The limitations include the cross-sectional design, and self-report of eating behaviors, training, and menstrual status.

Conclusion

OA have greater CER than NA, and greater ineffectiveness, DT, and IA scores than EA. Higher CER is associated with lower spine BMD even after controlling for confounders. Therefore, attitudes, feelings, and cognitions associated with disordered eating may have a negative impact on bone by decreasing nutrient intake and altering energy balance. This study emphasizes the importance of assessing and addressing cognitive restraint in athletes. The recognition of higher cognitive restraint should prompt a closer evaluation of eating behaviors and early management of disordered eating patterns to prevent deleterious effects on bone. Future studies are necessary to determine whether this could have greater repercussions on long-term bone health in athletes.

Acknowledgments

The authors thank their patients and the nurses and bionutritionists in the Massachusetts General Hospital Clinical Research Center.

Supported by [1 UL1 RR025758-01, 1UL1TR001102-01, 1 R01 HD060827-01A1, 1R01MH103402, K24 HD071843] from [National Institutes of Health Grants].

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Clinical, bone, biochemical characteristics, and eating questionnaires in OA, EA, and NA

TABLE 1

Characteristics	OA (n = 109)	EA (n = 39)	Effect Size EA:OA	NA (n = 36)	Effect Size NA:OA	p-Values
Age (years)	19.7 ± 2.6	18.7 ± 2.3	[0.40]	19.7 ± 2.4	[0]	0.09
Bone age (years)	17.4 ± 1.0	17.4 ± 1.1	[0]	17.6 ± 1.0	[0.20]	0.59
Age at menarche (years)	13.7 ± 1.2	12.5 ± 1.4	[0.96]	12.4 ± 1.3	[1.06]	<0.0001 ^{a,b}
Duration of amenorrhea (months)	9.0 ± 12.3					
BMI (kg/m ²)	20.6 ± 2.3	22.1 ± 2.4	[0.64]	21.8 ± 2.4	[0.52]	0.0003 ^{a,b}
Activity (hours/week)	9.9 ± 5.0	10.6 ± 4.2	[0.15]	0.6 ± 0.8	[2.15]	<0.0001 ^b
<i>Body composition</i>						
Total fat (kg)	13.4 ± 4.2	15.4 ± 3.8	[0.49]	17.1 ± 5.2	[0.83]	0.0001 ^{a,b}
Percent body fat (%)	23.3 ± 5.3	24.7 ± 3.7	[0.28]	28.7 ± 6.0	[0.98]	<0.0001 ^b
Total lean mass (kg)	42.5 ± 7.0	44.5 ± 6.9	[0.29]	39.7 ± 4.4	[0.44]	0.03
<i>Areal BMD</i>						
Lumbar BMD Z-scores	-0.75 ± 1.20	0.02 ± 0.90	[0.68]	-0.41 ± 1.01	[0.29]	0.003 ^a
<i>Microarchitecture CT radius (age adjusted values)</i>						
Total density (mgHA/cm ³)	299.7 ± 58.1	312.5 ± 52.5	[0.23]	325.6 ± 60.8	[0.44]	0.07
Total area (mm ²)	261.7 ± 43.7	277.8 ± 45.0	[0.37]	258.2 ± 40.6	[0.08]	0.20
Trabecular area (mm ²)	211.8 ± 46.6	220.5 ± 45.5	[0.19]	203.8 ± 43.0	[0.18]	0.49
Cortical area (mm ²)	47.5 ± 12.5	51.0 ± 10.0	[0.29]	53.0 ± 13.3	[0.43]	0.04
Cortical density (mgHA/cm ³)	816.5 ± 64.9	820.7 ± 55.5	[0.07]	842.6 ± 75.0	[0.39]	0.06
Cortical porosity (%)	1.07 ± 0.66	0.85 ± 0.46	[0.36]	0.68 ± 0.44	[0.64]	0.001 ^{a,b}
<i>Biochemical parameters</i>						
PINP (µg/L) ^c	82.9 ± 30.3	102.7 ± 56.7	[0.51]	84.6 ± 38.1	[0.05]	0.34
CTX (µg/L) ^c	1.04 ± 0.30	1.20 ± 0.39	[0.49]	0.91 ± 0.30	[0.43]	0.04
PINP/CTX ^c	85.0 ± 35.7	85.2 ± 30.9	[0.01]	92.7 ± 25.9	[0.23]	0.70
Cortisol AUC (µg/dL × 8h) ^c	3,609 ± 1,321	2,271 ± 1,083	[1.06]	2,674 ± 1,164	[0.73]	0.006 ^{a,b}
Cortisol pulsatile secretion (µg/dL × 8h) ^c	69.9 ± 95.0	43.6 ± 24.5	[0.32]	46.9 ± 21.4	[0.28]	0.36
<i>TFEQ scores</i>						

Characteristics	OA (<i>n</i> = 109)	EA (<i>n</i> = 39)	Effect Size EA:OA	NA (<i>n</i> = 36)	Effect Size NA:OA	<i>p</i> -Values
Cognitive restraint	47.5 ± 22.9	36.5 ± 20.6	[0.49]	36.9 ± 18.9	[0.48]	0.006^{a,b}
<i>EDI-2 scores</i>						
Drive for Thinness	4.0 ± 5.6	1.5 ± 2.4	[0.50]	2.1 ± 3.7	[0.37]	0.009^a
Ineffectiveness	1.6 ± 2.7	0.5 ± 1.1	[0.46]	1.3 ± 2.2	[0.12]	0.05^a
Perfectionism	6.8 ± 4.2	5.8 ± 4.0	[0.24]	5.0 ± 3.8	[0.44]	0.051 ^b
Interpersonal distrust	1.7 ± 2.3	1.4 ± 2.3	[0.13]	2.3 ± 3.1	[0.24]	0.28
Interceptive Awareness	2.3 ± 3.4	1.4 ± 3.2	[0.27]	1.7 ± 2.9	[0.18]	0.04^{a,c,d}
Impulse regulation	0.9 ± 2.0	0.7 ± 1.2	[0.11]	1.6 ± 3.4	[0.29]	0.19

^a *p* < 0.05 OA versus EA.

^b *p* < 0.05 OA versus NA. Data presented as means ± SD. Significant *p*-values are bolded.

^c Data available for 55 participants: 21 OA, 17 EA, and 17 NA.

^d The values not normally distributed were compared by the Kruskal–Wallis test, followed by the Steel–Dwass test with OA as the comparison group. ANOVA used for three group comparisons followed by Dunnett's test with OA as the comparison group when ANOVA was significant.

Abbreviations: OA, oligomenorrheic athletes; EA, eumenorrheic athletes; NA, nonathletes; PINP, N-terminal propeptide of Type 1 procollagen; CTX, C-telopeptide; AUC, area under the curve.

Associations of CER, and ineffectiveness with BMD and microarchitecture parameters controlling for age, BMI, duration of amenorrhea and pulsatile cortisol

TABLE 2

	Cognitive Restraint			Ineffectiveness		
	Estimate	Standardized Estimate	p-Values	Estimate	Standardized Estimate	p-Values
BMD						
Lumbar BMD Z-score	-0.02	-0.38	0.009	-0.01	-0.02	0.88
<i>Microarchitecture radius (n = 157)</i>						
Total density (mgHA/cm ³)	-0.14	-0.05	0.70	5.01	0.17	0.18
Total area (mm ²)	-0.27	-0.13	0.37	-6.31	-0.28	0.04
Trabecular area (mm ²)	-0.19	-0.10	0.52	-5.16	-0.23	0.09
Cortical area (mm ²)	-0.02	-0.04	0.79	0.24	0.04	0.76
Cortical density (mgHA/cm ³)	0.25	0.09	0.48	4.00	0.13	0.29
Cortical porosity (%)	0.0009	0.04	0.76	0.02	0.09	0.52
<i>Biochemical parameters</i>						
PINP (µg/L)	-0.61	-0.34	0.03	-3.29	-0.16	0.26
CTX (µg/L)	-0.004	-0.27	0.07	-0.04	-0.23	0.10
PINP/CTX	-0.23	-0.18	0.28	-0.90	-0.06	0.68

Abbreviations: PINP, N-terminal propeptide of Type 1 procollagen; CTX, C-telopeptide.