Body Mass and Composition Affect Bone Density in Recently Diagnosed Inflammatory Bowel Disease: The Manitoba IBD Cohort Study

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ABSTRACT

Background. This prospective study was undertaken to clarify the role of body mass and composition as a determinant of BMD in recently diagnosed IBD.

Methods. A nested subgroup of 101 adult subjects of the population-based Manitoba IBD Cohort Study were enrolled. Baseline BMD and body composition were measured and repeated 2.3 ± 0.3 y later.

Results. Greater weight, height and body mass measurements were positively correlated with bone density at all sites ($P<0.01$). Although both fat tissue and lean tissue showed positive relationships with BMD, lean tissue showed a much stronger correlation than fat tissue especially for the total hip (r=0.66, $P<0.001$ vs r=0.23, $P<0.05$) and total body measurements (r=0.59, $P<0.001$ vs r=0.04, *P* NS). Increase (or decrease) in hip bone density was strongly associated with an increase (or decrease) in all body mass variables (r=0.49-0.54, $P<0.001$).

Conclusions. Measures of body mass are important determinants of baseline BMD in recently diagnosed IBD patients. Furthermore, change in body mass is correlated with change in BMD, especially at the total hip. Early optimization and maintenance of nutrition and body weight, particularly toward lean tissue mass, may play an important role in preventing IBD-related bone disease.

Key Words: Bone mineral density; Dual energy x-ray absorptiometry; Inflammatory bowel disease; Nutrition.

INTRODUCTION

A higher incidence of osteoporosis and fractures is a recognized complication of inflammatory bowel disease (IBD) [1]. Population-based studies confirm that IBD patients have a 21-40% increased risk of fractures compared with the general population [2-4]. Multiple factors have been implicated including nutritional deficiencies, systemic inflammation, malabsorption and corticosteroid use.[5]

In adult IBD, body weight [6-8], skin fold thickness [9], and body mass index (BMI) show cross-sectional correlations with BMD in several studies [10-16]. The Manitoba IBD Cohort Study is a research program with the aim of defining multiple health outcomes and their determinants in persons with IBD. Skeletal health in IBD was one of the primary research themes and the current analysis was undertaken to determine the association between BMD, weight and body composition at baseline and follow-up in a population-based cohort of recently diagnosed IBD patients.

METHODS

Patient Population

The study design and patient population have been previously reported in detail[17]. Briefly, individuals within 7 years of IBD diagnosis were identified from the University of Manitoba IBD Research Registry, the largest population-based registry of IBD in North America. The University of Manitoba IBD Epidemiology Database and the University of Manitoba IBD Research Registry were created in 1995 [18]. Patients eligible for inclusion were identified through the population-based administrative health registry of Manitoba Health (the single provincial health insurer that provides comprehensive

coverage to all residents of Manitoba) using an administrative definition of IBD that was validated by random sample chart reviews. Questionnaires were mailed to patients identified in the Manitoba Health registry and those who agreed to be included in a research registry and to be contacted for future IBD related research studies were included in the University of Manitoba Inflammatory Bowel Disease Research Registry. This methodology was repeated in 2000 to enhance the numbers of patients in the Research Registry.

Individuals within seven years of IBD diagnosis and who were 18 years of age or older (N = 606) were identified from the Registry and were invited to participate in the study. A total of 418 (69.0%) individuals initially responded. Following this initial contact, 30 individuals did not respond to the request to complete the baseline survey, another four individuals withdrew, and seven individuals were found to be ineligible, resulting in a final sample of 388 participants for the Manitoba IBD Cohort Study. From the initial study population, a subset was randomly selected for participation in more detailed investigations of bone health. All assessments were performed in non-winter months. The objective was to recruit 100 participants stratified by age (<50 years vs. >50 years) in equal proportion. Exclusion criteria for the bone substudy included current or recent pregnancy (within 6 months), current or recent breast feeding (within 6 months), other disorders known to affect bone metabolism independent of IBD and its treatment (rheumatoid arthritis or other inflammatory joint disease, thyroid disease, parathyroid disease, primary bone disease, severe neurologic disease impairing ambulation, non-cutaneous malignancies, liver disease, eating disorder, or renal dysfunction with serum creatinine greater than 0.150 mmol/L). Individuals that completed the baseline

measurements were invited to return for follow-up BMD measurements 2.3 ± 0.3 years later. The study protocol was approved by the University of Manitoba Research Ethics Board and all participants provided signed informed consent.

Measurements

All subjects underwent measurement of lumbar spine, hip and total body BMD with dual-energy x-ray absorptiometry (DXA) (Hologic QDR-4500, Waltham, MA). Scans were acquired and analyzed using manufacturer specifications and White reference data to provide standard measures of areal BMD including T-scores and Z-scores. T-scores and Z-scores used gender-matched reference data (except for the total body for which male reference data are not available). The total body scan provides a precise measure of body composition as the following three components: bone mineral mass, fat mass and lean mass [19]. Total fat fraction was computed as 100% x total fat / (total fat + total lean).

In accordance with BMD reporting recommendations from the International Society of Clinical Densitometry (ISCD), abnormal BMD was defined as T-score $\leq$ -2.5 in older participants (age 50 years or above), and by a Z-score $\leq$ -2.0 if age was less than 50 years [20, 21]. All results were reviewed by a single study investigator with extensive experience in clinical and research DXA (WDL). Daily quality control of the DXA device gave long-term precision error <0.5% and the in vivo coefficient of variation [CV] was 1.0-1.7% for the measurement sites. Weight and height were measured at the time of BMD assessment using scales that were calibrated annually.

Statistics

Univariate analyses were used to compare groups (Chi square test for categorical data and Student's T-test for continuous data). The association between body mass variables and BMD was assessed separately and in combination using simple and multiple linear regression. Variables were normally distributed and plots of the residuals confirmed a linear relationship between the dependent and independent variables. The slope coefficients for total fat mass and total lean mass were compared using Fisher's Z-test. Continuous data are expressed as mean ± SD unless otherwise stated. All statistical analyses were performed with Statistica version 7.1 (Statsoft, Inc., Tulsa, OK). A *P*-value of less than 0.05 was used to determine statistical significance.

RESULTS

Population

Baseline bone measurements were obtained in 101 subjects as described in Table 1. The median since IBD diagnosis was 4 years. There were slightly more women than men (59 [58%] vs 42 [42%]) which was comparable with the gender distribution in the overall study population. There was a similar number of individuals with Crohn's disease (CD, 56 [55%]) versus ulcerative colitis/proctitis (UC, 45 [45%]) in the bone substudy, and the proportion was similar to the overall study population. By design, one-half of the bone substudy participants was less than age 50 at the time of recruitment and the remainder were over age 50. The mean age (47 ± 15 years) was slightly older than in the overall study population, reflecting the age-stratified recruitment to the bone sub-study. Most of the subjects (61 [60%]) reported a history of prior corticosteroid use. The median age of

first corticosteroid exposure was 40 years (interquartile range 28-51) with median cumulative exposure 4 months (interquartile range 2-9).

Baseline Measurements

Baseline skeletal measurements are summarized in Table 2. Mean Z-scores for the lumbar spine (-0.14 ± 1.25) and total hip (0.08 ± 0.99) indicate BMD close to the age-matched mean. The mean total body Z-scores (1.09 ± 1.37) indicates BMD greater than expected. Even when restricted to women, mean total body Z-score was greater than the expected value of zero (0.63 ± 1.10). CD and UC subjects had similar BMD values for the lumbar spine and total body, but CD subjects had significantly lower total hip BMD ($P<0.05$). CD subjects also had lower weight than UC subjects ($P<0.05$), but the groups did not differ in terms of height, BMI, lean or fat mass. Mean BMD did not differ according to age stratum, but participants younger than age 50 years had lower Z-scores for all sites compared with those age 50 and older (all $P<0.01$). Previous corticosteroid exposure was unrelated to baseline BMD (all $P>0.2$). Nine (9%) of the subjects had at least one abnormal measurement (8 lumbar spine, 2 total hip and 1 total body). No significant difference in the distribution of abnormal bone density measurements was seen according to diagnosis or age stratum.

Greater weight, height and body mass measurements were positively correlated with bone density at all sites (Table 3). No difference was seen in the relationship between weight and BMD for CD versus UC subjects (difference in slopes $P>0.2$) (Figure 1). Although both fat tissue and lean tissue showed positive relationships with BMD, lean tissue showed a much stronger correlation than fat tissue especially for the

total hip (r=0.66, $P<0.001$ vs r=0.23, $P<0.05$) and total body measurements (r=0.59, $P<0.001$ vs r=0.04, P NS).

Body composition strongly affected the effect of weight on bone density measurements for the total hip and total body (Table 4). For each kg of total body soft tissue, lean tissue was associated with a much larger increment in bone density than fat tissue. For total hip bone density, the increment in bone density was almost three times greater for lean tissue than fat tissue, whereas for the total body bone density lean tissue was associated with more than eightfold the effect of fat tissue. When total body lean tissue and fat tissue mass were considered simultaneously, lean tissue mass remained positively associated with total hip and total body bone density (all $P<0.001$) but fat tissue mass did not show a significant positive correlation.

Change in BMD and body composition

Of the original 101 participants undergoing BMD measurements, 94 (53 women and 41 men) returned for repeat measurements 2.3 ± 0.3 years later. There was an increase in mean BMD at all measurement sites between the first and second scans: lumbar spine +0.017 ± 0.049 g/cm^2 (1.7%), total hip +0.003 ± 0.040 g/cm^2 (0.3%), and total body +0.003 ± 0.022 g/cm^2 (0.3%). The change was only statistically significant for the lumbar spine. No gender subgroup differences were seen in the change in bone density (data not shown). Subjects younger than age 50 had a larger increase in total body BMD than older subjects (+0.008 ± 0.021 g/cm^2 versus -0.002 ± 0.021 g/cm^2, $P<0.05$), but age subgroup was unrelated to change at the lumbar spine or total hip.

Although mean body weight showed only a small increase between the first and second assessments (+0.7 ± 6.4 kg), there was considerable individual variation (range from 22.3 kg loss to 17.3 kg gain). Large individual changes were also seen in BMI (mean increase +0.2 ± 2.1 kg/m^2, range -6.5 to +5.5), total fat tissue (0.5 ± 3.9 kg, range -18.8 to +8.1), total lean tissue (+0.2 ± 2.37 kg, range -9.6 to +5.9), and total fat fraction (+0.4% ± 3.62%, range -17.0% to +8.0%). Increase in hip BMD was consistently associated with an increase in all body mass variables and a decrease in hip bone density was strongly associated with a decrease in all body mass variables(r=0.49-0.54, P<0.001) (Table 3, Figure 1). An increase in total body BMD was associated with an increase in weight, BMI and total lean mass while a decrease in total body BMD was associated with a decrease in those variables (r=0.21-0.24, P<0.05). No difference was seen in the relationship between weight change and BMD change for CD versus UC subjects (difference in slopes P>0.2). Greater weight at baseline was also associated with greater bone density loss for the total hip (r=-0.24, P<0.05). This can be explained by greater weight loss in those with higher baseline weight (r=-0.35, P=0.001). Older age was not associated with lower baseline bone density (probably due to the relatively young age of the cohort with only 10 of 101 [10%] over age 65 years), but did show a decreasing trend on follow up (r=-0.15 to -.21) and this was statistically significant for the total hip (P<0.05). Change in spine bone density was unrelated to any demographic or body mass parameter.

Multivariable regression

Multiple linear regression was performed with baseline BMD of the lumbar spine, total hip and total body as the dependent measures. Age group (less than 50 years versus 50 years and older), diagnosis, previous corticosteroid use and height were included in all models. Three approaches to body mass adjustment were then tested: weight alone (Model 1), total fat and total lean (Model 2), and weight with total fat fraction (Model 3). Similar models were constructed for change in BMD predicted by change in except that change in the body mass variables.

Results are summarized in Table 5. Weight consistently associated with baseline BMD at all sites. When total fat and total lean were evaluated, total lean tissue was positively correlated with BMD ($P<0.01$ for all sites) while total fat was negatively correlated with BMD ($P<0.01$ for the total body). A similar effect of fat was seen in Model 3, where weight was positively correlated with BMD ($P<0.01$ for all sites) while total fat fraction was negatively correlated with BMD ($P<0.001$ for the total hip and total body).

The models evaluating change in BMD showed weaker relationships. Weight change was associated total hip BMD ($P<0.011$) and total body BMD ($P<0.05$). Total lean tissue was strongly associated with change in total hip BMD ($P<0.001$) with an independent positive effect from total fat tissue ($P<0.05$).

DISCUSSION

We have found that measures of body mass are important determinants of baseline BMD in recently diagnosed IBD patients. Furthermore, change in body mass, either increase or decrease, is correlated with change in BMD (increase or decrease, respectively),

especially at the total hip which is the site most strongly correlated with fracture risk [22]. Lean mass conferred a greater effect on BMD than an equal amount of fat mass.

One clinical implication from our work relates to the use of simple weight or BMI adjustments for bone mass measurements. Given the complex relationships with body composition, these adjustments may not be reliable when individuals deviate significantly from average. The International Society of Clinical Densitometry (ISCD) has stated that weight adjustments should not be applied to bone density measurements owing to concern over the validity of the corrections [20].

Although weight and body composition exert important effects on BMD throughout life, sex-specific differences have been reported in the elderly. Taaffe et al. [23] studied a cohort of 2,619 older adults (age 70-79 years) of mixed ethnicity (Black and White) and gender in the Health, Aging, and Body Composition study. Lean mass was a positive determinant of BMD in most analyses and fat mass had an independent positive effect on femoral neck and lower body BMD in White and Black women (but not men). The situation becomes more complicated when differential effects of lean tissue versus fat tissue are considered. Although both fat mass and lean tissue mass are positively associated with bone mass, studies in children, adolescents and young women have found that each kg of lean tissue mass has a greater effect on bone density than an equal amount of fat mass [24-26]. More recently, the adverse effects of fat mass on bone density have also been reported in men, premenopausal women, and postmenopausal women [27, 28]. This may also have implications for weight gain during corticosteroid use which is predominantly fat tissue mass [29], and may lead to a false sense of security that this added weight is protective against steroid induced bone loss.

The effect of weight and fracture risk deserves comment. In the meta-analysis of De Laet et al. [30], a BMI of 25 kg/m^2 conferred a twofold reduction in hip fracture compared to an underweight BMI of 20 kg/m^2 but there was only a 17% additional reduction in hip fracture risk with an obese BMI of 30 kg/m^2. The IBD subjects in this study had an average BMI of 27.4 kg/m^2 and a higher proportion were categorized as obese (27%) than underweight (9%). The prevalence of obesity is comparable to the general Manitoba population (BMI$\geq$30 kg/m^2 in 28%) [31], which may reflect lower selection bias in our population-based sample than would be expected in a hospital or clinic based cohort. After adjustment for weight, higher percent fat mass is actually associated with higher rates of osteoporosis and fracture [27].

Fat mass and lean mass probably affect bone mass through multiple mechanisms. It has previously been suggested that bone strength adapts primarily to muscle forces, not to the static loads presented by body weight [32]. Weight contributes to passive skeletal loading but this would not account for differential effects of fat mass and lean mass. The latter is associated with greater muscle mass (a surrogate for greater physical activity) and augments mechanical forces acting directly on bone, thereby favoring mineral acquisition. In contrast, adipose tissue is associated with lower levels of serum 25-hydroxy vitamin D (25OHD) [33]. Since vitamin D is an important factor in skeletal health, the lower serum levels of 25OHD seen in overweight and obese individuals would be expected to blunt any beneficial effect related to loading. In addition, there is evidence that parathyroid hormone (PTH) levels are positively correlated with fat mass and that this relationship is independent of the known inverse relationship between PTH and

25OHD [33]. Other adipocytokines have been suggested to affect bone density, but whether this relationship is independent of the effect of fat mass remains controversial [34].

The advantage of our study was that it was conducted in a population-based sample of IBD patients who had relatively recent onset disease. Several limitations apply to our study. This was an observational study and therefore associations may not reflect causality. We did not assess factors that could affect bone density such as disease severity, previous surgery, diet or non-steroidal medications.

In summary, we found that the relationship between BMD and body mass measurements is complex. The beneficial effect of weight on BMD is modified by the actual soft tissue composition, with lean tissue conferring a much larger positive effect than fat tissue. Weight gain (loss) is associated with total hip BMD gain (loss), and once again the effect of lean tissue dominates the effect of fat tissue. Individuals involved in the nutritional assessment and counseling of IBD patients need to be aware that lean tissue is the skeletally relevant component of soft tissue mass, and that weight in the form of fat tissue has little effect in terms of BMD preservation. Early optimization and maintenance of nutrition and body weight may play an important role in preventing IBD-related bone disease.

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Table 1. Population characteristics compared with all cohort subjects and all eligible registry subjects.

	Bone Substudy Subjects N=101	All Cohort Subjects N=384	Eligible From Registry N=606
Age (years)	47 ± 15	41 ± 15	44 ± 18
Men (%)	42 (42%)	156 (41%)	260 (43%)
Crohn's disease (%)	56 (55%)	188 (49%)	266 (44%)

Mean ± SD

Table 2. Baseline measurements stratified by gender and age subgroups.

Measurement	Combined N=101	Diagnosis subgroups		Age subgroups	
		CD N=56	UC N=45	Age < 50 y N=51	Age ≥ 50 y N=50
Lumbar spine (L1-4):					
BMD	0.987 ± 0.121	0.980 ± 0.124	0.996 ± 0.118	0.985 ± 0.096	0.990 ± 0.144
T-score	-0.71 ± 1.12	-0.76 ± 1.19	-0.65 ± 1.04	-0.69 ± 0.91	-0.73 ± 1.31
Z-score	-0.14 ± 1.25	-0.26 ± 1.32	-0.01 ± 1.15	-0.53 ± 0.94**	0.24 ± 1.40
Abnormal (%) [1]	8 (8%)	4 (7%)	4 (9%)	4 (8%)	4 (8%)
Total hip:					
BMD	0.937 ± 0.132	0.908 ± 0.127*	0.973 ± 0.131	0.921 ± 0.106	0.953 ± 0.154
T-score	-0.33 ± 0.90	-0.51 ± 0.93*	-0.11 ± 0.83	-0.36 ± 0.79	0.29 ± 1.01
Z-score	0.08 ± 0.99	-0.15 ± 0.97**	0.36 ± 0.95	-0.24 ± 0.84**	0.40 ± 1.04
Abnormal (%)	2 (2%)	2 (4%)	0 (0%)	1 (2%)	1 (2%)
Total body:					
BMD	1.132 ± 0.109	1.118 ± 0.098	1.149 ± 0.120	1.128 ± 0.086	1.136 ± 0.13
T-score	0.34 ± 1.26	0.18 ± 1.13	0.55 ± 1.38	0.30 ± 0.98	0.39 ± 1.49
Z-score	1.09 ± 1.37	0.82 ± 1.17*	1.41 ± 1.52	0.61 ± 1.05***	1.57 ± 1.48
Abnormal (%)	1 (1%)	0 (0%)	1 (2%)	0 (0%)	1 (2%)
Body size and mass:					

Height (cm)	169.9 ± 9.0	169.2 ± 8.2	170.8 ± 9.9	169.9 ± 9.0	170.0 ± 9.1
Weight (kg)	79.0 ± 18.8	75.6 ± 18.0*	83.3 ± 19.3	75.0 ± 19.9*	83.1 ± 16.9
BMI (kg/m2)	27.4 ± 6.1	26.5 ± 6.4	28.5 ± 5.7	26.0 ± 6.9*	28.8 ± 5.0
Total fat mass (kg)	21.6 ± 9.8	20.2 ± 10.0	23.5 ± 9.3	19.3 ± 10.9*	24.0 ± 8.1
Total lean mass (kg)	44.8 ± 10.1	43.2 ± 9.1	46.7 ± 11.0	43.3 ± 9.8	46.3 ± 10.3

Mean ± SD
BMD, bone mineral density; CD, Crohn's disease; UC, ulcerative colitis/proctitis
[1] Abnormal defined as T-score $\leq$ -2.5 if age 50 years or older, Z-score $\leq$ -2.0 if age less than 50 years.
P-value * < 0.05, ** < 0.01, *** <0.001 between subgroups

Table 3. Correlation coefficients for baseline and change in bone mineral density (BMD).

	Baseline BMD			Change in BMD		
	Lumbar spine	Total hip	Total body	Lumbar spine	Total hip	Total body
Age (years)	0.05	0.22 *	0.04	-0.17	-0.21 *	-0.20
Height (cm)	0.23 *	0.37 ***	0.45 ***	-0.02	-0.10	0.02
Weight (kg)	0.30 **	0.55 ***	0.41 ***	0.02	-0.24 *	0.02
BMI (kg/m^2)	0.21 *	0.41 ***	0.21 *	0.02	-0.20	0.01
Total fat (kg)	0.19	0.23 *	0.04	-0.02	-0.12	0.03
Total lean tissue (kg)	0.29 **	0.66 ***	0.59 ***	0.06	-0.27 **	0.00
Weight change (kg)	--	--	--	0.07	0.51 ***	0.21 *
BMI change (kg/m^2)	--	--	--	0.10	0.53 ***	0.24 *
Total fat change (kg)	--	--	--	0.04	0.46 ***	0.17
Total lean change (kg)	--	--	--	0.11	0.54 ***	0.24 *

P-value * <0.05, ** <0.01, *** <0.001

Table 4. Relative effects of total body fat and lean soft tissue mass (kg) on bone mineral density (g/cm^2) measurements.

	Univariate			Multivariate	
	Fat mass	Lean mass	*P*-value (fat vs lean)	Fat mass	Lean mass
Lumbar spine	0.194 ± 0.099	0.288 ± 0.096 **	NS	0.123 ± 0.100	0.253 ± 0.100 *
Total hip	0.227 ± 0.098 *	0.662 ± 0.075 ***	<.001	0.043 ± 0.079	0.650 ± 0.079 ***
Total body	0.042 ± 0.100	0.590 ± 0.081 ***	<.001	-0.135 ± 0.084	0.628 ± 0.084 ***

Data are the regression coefficients (± SE) from linear regression models.
P-value * <0.05, ** <0.01, *** <0.001.

Table 5. Multiple linear regression models for prediction of baseline and change in bone mineral density (BMD).

	Lumbar spine	Total hip	Total body
	Baseline BMD		
Model 1:			
Sex	-0.283 ± 0.136*	0.212 ± 0.118	0.094 ± 0.126
Age group	0.013 ± 0.104	-0.046 ± 0.090	-0.056 ± 0.097
Diagnosis	0.022 ± 0.100	-0.144 ± 0.086	-0.046 ± 0.092
Corticosteroid use	-0.125 ± 0.099	0.014 ± 0.085	-0.096 ± 0.092
Height (cm)	0.315 ± 0.138*	0.048 ± 0.119	0.272 ± 0.128*
Weight (kg)	0.282 ± 0.106**	0.453 ± 0.092***	0.287 ± 0.098**
Model 2:			
Sex	-0.568 ± 0.192**	-0.312 ± 0.152*	-0.519 ± 0.160**
Age group	0.061 ± 0.106	0.046 ± 0.084	0.060 ± 0.089
Diagnosis	0.025 ± 0.098	-0.141 ± 0.078	-0.046 ± 0.082
Corticosteroid use	-0.122 ± 0.097	0.021 ± 0.077	-0.086 ± 0.081
Height (cm)	0.168 ± 0.154	-0.221 ± 0.122	-0.048 ± 0.129
Total fat (kg)	-0.087 ± 0.147	-0.210 ± 0.117	-0.411 ± 0.123**
Total lean (kg)	0.607 ± 0.221**	1.072 ± 0.175***	1.105 ± 0.184***
Model 3:			
Sex	-0.499 ± 0.185	-0.228 ± 0.147	-0.432 ± 0.155*
Age group	0.088 ± 0.112	0.106 ± 0.090	0.125 ± 0.094
Diagnosis	0.008 ± 0.099	-0.173 ± 0.079*	-0.080 ± 0.083
Corticosteroid use	-0.104 ± 0.099	0.057 ± 0.079	-0.044 ± 0.082
Height (cm)	0.173 ± 0.160	-0.241 ± 0.127	-0.073 ± 0.134
Weight (kg)	0.528 ± 0.178**	0.953 ± 0.142***	0.885 ± 0.149***
Total fat fraction (%)	-0.381 ± 0.222	-0.774 ± 0.177***	-0.925 ± 0.186***

	Lumbar spine	Total hip	Total body
	Change in BMD		
Model 1:			
Sex	0.099 ± 0.109	-0.025 ± 0.093	0.034 ± 0.105
Age group	-0.091 ± 0.109	-0.102 ± 0.093	-0.235 ± 0.106*
Diagnosis	0.056 ± 0.109	0.092 ± 0.093	-0.001 ± 0.105
Corticosteroid use	0.095 ± 0.109	-0.135 ± 0.093	-0.082 ± 0.105
Weight change (kg)	0.059 ± 0.106	0.515 ± 0.091***	0.205 ± 0.103*
Model 2:			
Sex	0.108 ± 0.109	0.003 ± 0.089	0.046 ± 0.106
Age group	-0.088 ± 0.110	-0.086 ± 0.089	-0.229 ± 0.106*
Diagnosis	0.057 ± 0.109	0.070 ± 0.088	-0.008 ± 0.105
Corticosteroid use	0.088 ± 0.109	-0.145 ± 0.088	-0.088 ± 0.105
Total fat change (kg)	-0.029 ± 0.121	0.245 ± 0.098*	0.060 ± 0.117
Total lean change (kg)	0.123 ± 0.123	0.429 ± 0.100***	0.200 ± 0.118
Model 3:			
Sex	0.104 ± 0.110	-0.020 ± 0.094	0.041 ± 0.107
Age group	-0.094 ± 0.110	-0.105 ± 0.094	-0.239 ± 0.107*
Diagnosis	0.063 ± 0.111	0.098 ± 0.095	0.009 ± 0.108
Corticosteroid use	0.087 ± 0.112	-0.143 ± 0.096	-0.094 ± 0.108
Weight change (kg)	0.095 ± 0.155	0.552 ± 0.132***	0.257 ± 0.149
Total fat fraction change (%)	-0.050 ± 0.154	-0.050 ± 0.131	-0.071 ± 0.149

Data are the beta coefficients (± SE).
P-value * <0.05, ** <0.01, *** <0.001.

Figure 1. Correlation between weight and total hip bone mineral density (BMD). (A) Baseline weight versus baseline BMD. (B) Change in weight versus change in BMD at follow up. Open circle = Crohn's disease, closed circle = ulcerative colitis/proctitis.