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SHORT COMMUNICATION

High bone mineral density is associated with high body mass index

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Abstract
Summary High BMD is an infrequent finding. In this retrospective cohort study of women 50 years and older, we documented a strong association between high BMD and high BMI.
Introduction High bone mineral density (BMD) has been associated with genetic disorders and a variety of dietary, endocrine, metabolic, infectious and neoplastic diseases that in many cases warrant medical attention. Since body mass index (BMI) is closely correlated with BMD, we sought to explore the relationship between these two parameters in older women.
Methods We conducted a retrospective clinical cohort study of 16,500 women 50 years and older who underwent baseline BMD testing between May 1998 and October 2002. Mean *T*-scores and *Z*-scores, and the proportions of women with high BMD (*T*-score +2.5 or greater, *Z*-score +2.0 or greater), were assessed according to BMI category.
Results Higher BMI category was associated with higher mean *T*-scores and *Z*-scores at all sites ($P<0.001$). The proportion of women with high BMD increased with each BMI category (P for trend <0.05). In women with a lumbar spine *T*-score of +2.5 or more, 43.5% were obese with BMI>30 kg/m^2 (55.6% for the femoral neck and 73.1% for the total hip). For women with a lumbar spine *Z*-score of +2.0 or more, 37.2% were obese (42.0% for the femoral neck and 50.9% for the total hip). There was no evidence of a paradoxical increase in fracture rates in women with high BMD.
Conclusions High BMD is closely associated with elevated BMI in women. This should be taken into consideration prior to initiating extensive investigations for rare pathologies.

Keywords Body mass index · Bone densitometry · Bone mineral density · Dual energy X-ray absorptiometry · Postmenopausal women

Introduction

The World Health Organization defines the presence of osteoporosis in postmenopausal women when bone mineral density (BMD) is 2.5 standard deviations (*T*-score of −2.5) or more below that of a young normal woman, as measured by dual energy X-ray absorptiometry (DXA) at the hip, the spine, or the forearm [1]. In this construct, BMD is considered to be normal when it is greater than a *T*-score of −1.0 without the designation of an upper value above which BMD would be considered to be abnormally high. Osteoarthritis, degenerative changes, vascular calcifications, and compression fractures can cause localized elevations in lumbar BMD and the International Society for Clinical Densitometry reporting guidelines caution on the interpretation of the test in this setting [2]. Generalized high BMD, on the other hand, is associated with genetic disorders and a variety of dietary, endocrine, metabolic,

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infectious and neoplastic diseases that in many cases warrant medical attention [3].

Body weight and body mass index (BMI) have been shown to explain an important proportion of the variance in BMD (8.9–19.8% of total variance) [4, 5]. Indeed, one study has noted that high BMI (BMI over 25 kg/m^2) is a predictor of high BMD in perimenopausal women [6].

The aim of our study was to further explore the relationship between high BMD and high BMI in women 50 years and older.

Materials and methods

The Manitoba Bone Density Program in Canada has managed all clinical DXA testing of this province since 1997 [7]. Criteria for testing are consistent with most published guidelines and, include women age 65 years or older, premature ovarian failure, prior fragility fracture, X-ray evidence of osteopenia, prolonged corticosteroid use, and other clinical risk factors (www.gov.mb.ca/ health/ programs/mbd). The program's database has been shown to be over 99% complete and accurate [7, 8]. The current study was approved by the Research Ethics Board for the University of Manitoba.

We conducted a retrospective historical cohort study of women aged 50 years and older who underwent first clinical BMD testing between May 1998 and October 2002. Height and weight were by self-report prior to 2000 and were measured by a wall-mounted stadiometer and bathroom scale from 2000 onwards. BMI was calculated as weight in kg divided by height squared in meter. DXA scans were performed and analyzed in accordance with manufacturer recommendations. Prior to 2000, DXA measurements were performed with a pencil-beam instrument (Lunar DPX, GE Lunar, Madison WI) and after this date a fan-beam instrument was used (Lunar Prodigy, GE Lunar, Madison WI). Instruments were cross-calibrated using 59 volunteers and anthropomorphic phantoms. No clinically significant differences were identified (*T*- and *Z*-score differences <0.2). Therefore all analyses are based upon the unadjusted numerical results provided by the instruments. *T*-scores (number of standard deviations [SD] above/below young adult mean BMD) and *Z*-scores (number of SDs above/below age-matched mean BMD) were calculated using White female reference data from the manufacturer (lumbar spine) and NHANES (hip). Vertebral levels affected by localized artifact were excluded by experienced physicians using conventional criteria [9]. Women without a valid spine and hip scan were excluded.

BMD was categorized according to *T*-score (≤−2.5, −2.4 to −1.1, −1.0 to −0.1, 0 to +2.4 and ≥+2.5) at the lumbar spine, femoral neck, trochanter, total hip, and maximum hip site. The same sites were also categorized according to *Z*-score (≤−2.0, −1.9 to −0.1, 0 to +1.9 and ≥+2.0). BMI was classified as: ≥30 kg/m^2, 25 to 29 kg/m^2, 20 to 24 kg/m^2 and <20 kg/m^2.

High BMD can be associated with increased skeletal fragility in certain conditions [3]. The presence of an osteoporotic fracture of the spine, hip, humerus or forearm fracture (any ICD-9-CM 805, 812, 813, 820 and 821 code with applicable orthopedic codes for the hip and forearm) between the date of BMD testing and March 31, 2004 (mean time of observation 3.2 years [SD 1.5]) was identified from hospital discharge summary and physician claims using previously documented methods [10]. The Manitoba Bone Density Program database can be linked with these provincial computerized health databases through an anonymous personal identifier [11].

Descriptive statistics were tabulated for the study cohort. Two-sided *T*-tests were used for continuous variables. Mean *T*-scores and *Z*-scores according to BMI category were compared using analysis of variance (ANOVA), and the proportion of women with high BMD (*T*-score +2.5 or greater, *Z*-score +2.0 or greater) was compared with the Cochran–Armitage test for trend. All analyses were performed with Statistica (Version 6.1, StatSoft Inc, Tulsa, OK). A *P*-value of less than 0.05 was considered statistically significant.

Results

A cohort of 16,500 women with valid BMD measurements was considered. The mean age was 65 years [SD 9]. Mean *T*-scores ranged from −1.5 at the lumbar spine to −1.1 at the total hip, while mean *Z*-scores were close to 0 (Table 1). A

Table 1 Baseline characteristics of the study cohort

	N=16,500
Age (years)[a]	65 (9)
Height (cm)	160 (7)
Weight (kg)	68 (14)
Body mass index (kg/m^2)	26 (5)
Lumbar spine *T*-score	−1.5 (1.5)
Femoral neck *T*-score	−1.5 (1.0)
Trochanter *T*-score	−1.3 (1.2)
Total hip *T*-score	−1.1 (1.2)
Lumbar spine *Z*-score	−0.1 (1.5)
Femoral neck *Z*-score	0.0 (1.1)
Trochanter Z-score	−0.1 (1.3)
Total hip *Z*-score	0.0 (1.2)

[a] Mean, (SD)

BMI of 30 kg/m^2 or greater was documented in 21% of women.

Although most women had a *T*-score between −2.5 and −1.0, 17% had a lumbar spine *T*-score of 0 or higher and 0.9% had a *T*-score of +2.5 or higher (Table 2). A similar distribution was documented for the maximum hip measurement. Higher BMI category was associated with higher mean *T*-scores and *Z*-scores at all sites ($P<0.001$). The proportion of women with high BMD (*T*-score +2.5 or greater, *Z*-score +2.0 or greater) increased with higher BMI category at the all sites (P for trend <0.05; Fig. 1). In women with a lumbar spine *T*-score of +2.5 or more, 43.5% were obese with BMI >30 kg/m^2 (55.6% for the femoral neck, 80.0% for the trochanter and 73.1% for the total hip). For women with a lumbar spine *Z*-score of +2.0 or more, 37.2% were obese (42.0% for the femoral neck, 51.5% for the trochanter and 50.9% for the total hip).

The crude fracture incidence in women with maximum *T*-score +2.5 or greater was 5.1 [SD 3.0] per 1,000 person-years compared with 6.6 [SD 0.7] in women with maximum *T*-score between 0 and +2.4 ($P=0.32$). In women with maximum *Z*-score + 2.0 or greater, the fracture incidence was 7.3 [SD 1.0] per 1,000 person-years compared with 10.8 [SD 0.6] in women with maximum *Z*-score between 0 and +1.9 ($P=0.0019$). As expected, fracture rates increased with decreasing maximum *T*-score categories (9.1 [SD 0.8] per 1,000 person-years for *T*-scores between −1.0 and −0.1; 18.4 [SD 0.9] per 1,000 person-years for *T*-scores between −2.4 to −1.1; and 43.3 [SD 3.4] per 1,000 person-years for *T*-scores ≤−2.5; all pairwise $P<0.01$) and *Z*-score categories (−1.9 to −0.1, 21.7 [SD 1.1] per 1,000 person-years; ≤−2, 37.9 [SD 6.7] per 1,000 person-years; all pairwise $P<0.01$).

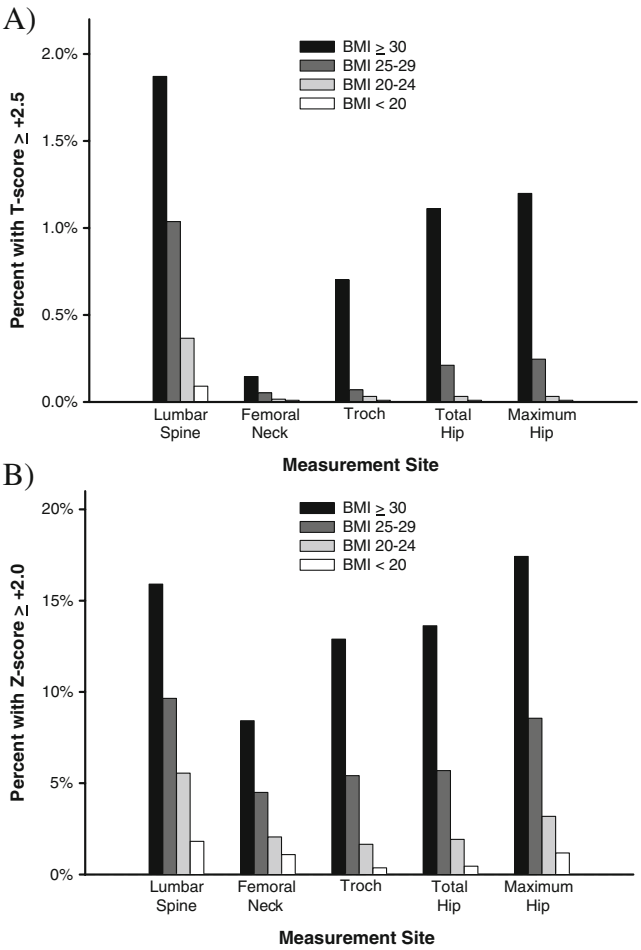

Fig. 1 Proportion of women in each BMI category with **a** *T*-score +2.5 or greater, and **b** *Z*-score +2.0 or greater at different skeletal sites

Table 2 Relationship between BMI and BMD (*T*-scores and *Z*-scores) at different skeletal sites

	Lumbar spine	Femoral neck	Trochanter	Total hip	Maximum hip site
T-scores					
≥+2.5	30±6; (0.9%)[a]	32±7; (0.1%)	37±8; (0.2%)	36±8; (0.3%)	35±7; (0.3%)
0 to +2.4	29±6; (16.3%)	30±6; (6.1%)	30±6; (13.1%)	30±6; (17.2%)	30±6; (18.7%)
−1 to −0.1	27±5; (18.7%)	28±5; (20.9%)	28±5; (25.4%)	27±5; (28.2%)	27±5; (29.9%)
−2.4 to −1.1	26±5; (38.1%)	26± 5; (57.0%)	26±4; (46.0%)	25±4; (43.1%)	25±4; (42.3%)
≤−2.5	25±4; (26.0%)	24±4; (15.9%)	23±4; (15.3%)	23±4; (11.2%)	23±4; (8.7%)
Z-scores					
≥+4	29±6; (0.9%)	32±7; (0.1%)	34±8; (0.2%)	35±7; (0.2%)	33±7; (0.3%)
+2.0 to +3.9	29±6; (7.9%)	29±6; (4.0%)	31±6; (5.0%)	31±6; (5.4%)	30±6; (7.5%)
0 to +1.9	27±5; (35.9%)	28±5; (42.7%)	28±5; (40.0%)	28±5; (43.2%)	27±5; (50.0%)
−1.9 to −0.1	26±5; (47.5%)	25±5; (50.7%)	25±4; (48.8%)	25±4; (47.6%)	25±4; (40.5%)
≤−2	24±4; (7.8%)	22±4; (2.5%)	22±4; (6.0%)	22±4; (3.7%)	21±4; (1.7%)

All $p<0.001$ for difference in means according to BMI category

[a] Values are mean BMI in kg/m^2, ±standard deviation; (proportion of cohort)

Discussion

We found that high BMD was strongly related to high BMI in women over the age of 50 years at all skeletal measurement sites. Although high BMD is uncommon, its frequency was highest in the group of women with the highest BMI values (≥30 kg/m^2). Pesonen et al. have documented a similar relationship in younger women in whom a BMI over 30 kg/m^2 predicted a six-fold increase in the risk of high BMD [6]. In this study, women with high BMD sustained fewer fractures than the control group. We documented similar results in our cohort. In the Study of Osteoporotic fractures, postmenopausal women who gained weight since age 25 years had a lower risk of hip fractures [12]. By contrast, low weight and low BMI are related to increased fracture risk. In a large meta-analysis of 12 prospective population-based cohorts, De Laet et al. documented that the age-adjusted risk of a hip fracture was increased two-fold in older individuals with a BMI of 20 kg/m^2 compared to a BMI of 25 kg/m^2 [13]. Reasons that may contribute to high BMD in the setting of increased body weight are not completely understood but include the surplus estrogen production in the fat tissue, the additional load carried by skeleton and genetic variations [14, 15]. Although the precise mechanism has not yet been identified, adipocytokines, secreted by the adipose tissue, seem to participate in bone mass regulation. Leptin, adiponectin, resistin, and other such molecules have been associated with various, and at times contradictory, effects on bone cells and BMD. Research to better delineate bone and adipose tissue interactions is ongoing [16–18].

Our study has multiple strengths. This is the largest study to evaluate the association between high BMD and high BMI in women over the age of 50 years. BMD measurements were performed and interpreted in a controlled setting [7, 8]. Nonetheless, our results may be limited by the fact that height and weight were self-reported prior to 2000. Self-report of height and weight has been shown to be valid in younger adults but is limited in older adults who tend to underestimate their weight [19, 20]. This would, however, tend to reduce the proportion of women in the high BMI category and diminish the strength of the association we documented. Our database does not capture menopausal status or age of menopause consistently; therefore we were unable to consider this variable in our analyses.

There is no clear definition for high BMD under the WHO formulation. Whyte has elaborated an exhaustive list of pathological conditions that cause high bone density; most of which compromise bone quality and result in increased fracture risk, for example osteopetrosis and systemic fluorosis [3]. The exact incidence of these disorders is not known. Nonetheless, as the incidence of overweight and obesity increases in the general population, high BMD is more likely to be secondary to high BMI [21].

In conclusion, we have documented a strong relationship between high BMD and elevated BMI in this cohort of women. Although guidance as to an upper value for normal BMD is desirable, it is reasonable, based on the results from this study, to take into consideration the value of BMI and the clinical context prior to initiating extensive investigations for rare pathologies.

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Conflicts of interest None.

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